PREFACE

Jersey Central Power & Light Company ("JCP&L") submits the following demonstration regarding its Oyster Creek Nuclear Generating Station ("OCNGS") and Forked River Nuclear Generating Station ("FRNGS") to the New Jersey Department of Environmental Protection ("NJDEP") and the U. S. Environmental Protection Agency, Region II ("EPA"), pursuant to Sections 401, 316(a) and 316(b) of the Federal Water Pollution Control Act Amendments of 1972 ("FWPCA"), 33 U.S.C. §§1311, 1326(a) and (b). The OCNGS presently is in operation pursuant to National Pollutant Discharge Elimination System ("NPDES") permit NJ 000 5550; the FRNGS is under construction on an adjacent site and has an NPDES permit application, covering its operation, pending.

The purpose of the demonstration is to support the establishment of effluent limitations and other operating conditions for the two stations which are consistent with current plant operating conditions and designs. In the first instance, this demonstration supports a request to the NJDEP for the designation of a heat dissipation area in the stations' receiving waters, Oyster Creek and Barnegat Bay, as provided for by New Jersey Surface Water Quality Standards (N.J.A.C. 7:9-4.1 _et seq_.). This designation would be included in Section 401 certifications issued by NJDEP, for which application has been made, and, pursuant to FWPCA Section 401(d), in the staions' NPDES permits.

In the alternative, should NJDEP conclude that its guidelines for the establishment of heat dissipation areas are not sufficiently elastic to accommodate continued use of the existing open-cycle cooling system, then the information in the demonstation points out the appropriateness of, and supports, a modification of the thermal water quality criteria for Oyster Creek and Barnegat Bay.

Second, the demonstration supports JCP&L's request for the establishment of alternative effluent limitations pursuant to FWPCA Section 316(a). Although the OCNGS is, because of its age, exempt from any requirement to backfit closed-cycle cooling as "best available technology" under FWPCA Section 301(b)(2)(A), and the FRNGS is designed to use closed-cycle cooling in compliance with FWPCA Section 301(b)(2)(A), some question exists as to whether thermal discharges from either or both will comply with state water quality standards in Oyster Creek. If they are found not to comply,then, in order to meet the resultant standards or limitations, the OCNGS would be required to backfit an alternate cooling system, probably a closed-cycle, natural draft cooling tower; the FRNGS's discharge may have to be rerouted to avoid Oyster Creek or cooled by an auxiliary system. Water quality-based standards or limitations would be adopted by New Jersey as conditions to certifications pursuant to FWPCA Section 401, and incorporated and enforceable in the NPDES permit through FWPCA Sections 401(d) and 301(b)(1)(c). Under FWPCA Section 316(a) and the present delegation of responsibility under FWPCA Section 402, the Regional Administrator of EPA Region II possesses the responsibility to determine alternative standards and limitations. A decision by Region II establishing alternative standards and limitations under Section 316(c) would be binding on New Jersey.

JCP&L believes that application of New Jersey water quality standards to Oyster Creek and Barnegat Bay so as to require alternations in the operating and design characteristics of the Oyster Creek and Forked River Stations would be more stringent than necessary to assure the protection and propagation of a balanced, indigenous community of shellfish, fish and wildlife. Moreover, the benefits which might be achieved by requiring alternative cooling systems for the stations would not be comparable to the capital and operating costs which those systems would entail. As one element of this demonstration JCP&L has included an engineering analysis of alternative cooling systems for both OCNGS and FRNGS and a cost/benefit analysis of alternative cooling systems for OCNGS.

Third, the demonstration is in satisfaction of FWPCA Section 316(b) and a condition of the OCNGS's NPDES permit requiring a study of the environmental effects of cooling water intake structures. Section 316(b) does not provide any specific standards for cooling water intake structures, but requires that case-by-case determination be made of their location, design, capacity and construction so as to minimize adverse environmental effects. The demonstration is designed to support continued use of the OCNGS's intake, and construction and operation of the FRNGS's intake in accordance with the present design. Alternative intake designs and capacities for both stations, and their consequent costs, are considered in the demonstration.

The information contained in the demonstration is drawn from a variety of sources. JCP&L, and its affiliate GPU Service Corporation, have conducted, through various consultants, studies of Oyster Creek and Barnegat Bay since 1964. The effect of thermal discharges on the aquatic communities of Oyster Creek and Barnegat Bay have been studied since OCNGS began operation in 1969. A substantial portion of the data is the product of studies conducted by Icthyological Associates, Inc. over the last 30 months. These studies were an integral part of a plan of study by Region II according to EPA's regulations under FWPCA Section 316(a) (40 C.F.R. §122.7). The studies also were reviewed and approved by the NJDEP. With respect to the FRNGS, modeling has been used to predict the single and incremental effects of the station's cooling tower discharge. All of these data are presented and evaluated in the demonstration.

In terms of the "type" or "form" of the demonstration, EPA regulations under FWPCA Section 316(a) provide for three different types of demonstrations: Absence of prior appreciable harm ("Type I"); protection of representative important species ("Type II"); and biological, engineering and other data ("Type III"). Although the regulations (40 C.F.R. §122.9) require that a permittee complete only one of these demonstrations, this demonstration is a combination of the first two. Type I requirements (40 C.F.R. §122.9(b)(1)) were addressed in terms of the historical data collected by JCP&L both before and after the OCNGS began operation. A Type II demonstration supported the historical data, and provides a basis for evaluating the future effect of the operation of the FRNGS. A complete description of the hydrology and other environmental conditions of Oyster Creek and Barnegat Bay has been included.

No regulations exist to guide studies and reports submitted under FWPCA Section 316(b). However, the information submitted in this demonstration regarding intake structures was collected pursuant to a study plan approved by EPA Region II and NJDEP.

Recently, EPA has published substantially revised drafts of its "Section 316(a) Technical Guidance Manual" and "Section 316(b) Technical Guidance Manual". Because the studies for the present demonstration were well underway by the time these were released, those revised manuals are not applicable to the review in this case.

A request for the establishment, pursuant to Section 316(a), of alternative thermal effluent limitations for the OCNGS was filed initially by JCP&L with EPA Region II on September 23, 1974. This was modified on October 18, 1974, after promulgation of the effluent guidelines and standards for the steam electric generating point source category, to request alternative limitations only in the event that conditions of the OCNGS's NPDES discharge permit required the installation of a closed-cycle cooling system. On December 8, 1974, NJDEP submitted to EPA Region II a letter, purporting to be a certification in accordance with FWPCA Section 401, containing limitations on the size of the heat dissipation area in Oyster Creek assigned to the station. The effect of those limitations, incorporated in the NPDES permit pursuant to Section 401(d), would be to require either rerouting of the discharge away from Oyster Creek, or the installation of a closed-cycle system. Subsequent to issuance of the NDPES permit, NJDEP has agreed to reconsider its certification limitations. A change on those limitations may obviate the need for a decision by the Regional Administrator on JCP&L's 316(a) request.

On August 11, 1975, EPA Region II tendered to JCP&L a list of representative important species to be used in its Section 316(a) demonstration. Shortly thereafter, on October 14, 1975, JCP&L submitted to EPA and NJDEP its proposed plan of study to meet its requirements under Sections 316(a) and (b). After several modifications, the study plan was approved by EPA and NJDEP on January 12-13, 1977 and December 6, 1976, respectively.

A Section 316(a) request for the FRNGS was filed on February 9, 1977 with EPA Region II in conjunction with the application for the station's NPDES permit. Inasmuch as the FRNGS is designed with a closed-cycle cooling system consistent with "best available technology" effluent limitations required under Section 301(b)(2)(a), the request was made conditional on a determination being made that blowdown from the system would not comply with state thermal water quality criteria. To date, no determination of compliance has been made, although a Section 401 certification was issued by NJDEP on June 8, 1973. NJDEP now has indicated its intention to consider the appropriate thermal limitations for the FRNGS in conjunction with its reconsideration of the certification for the OCNGS.

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Chapter 1

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CHAPTER 1: BACKGROUND AND RATIONALE

This chapter presents the master rationale derived from the ecological evaluations contained in subsequent chapters of the demonstration. Section 1.4 provides the analytical approach and rationale pertinent to Sections 316(a) and 316(b). In order to provide some background and context for this analysis, Section 1.1 provides a brief description of the Barnegat Bay area, Section 1.2 a description of the Oyster Creek Nuclear Generating Station (OCNGS), and Section 1.3 a description of the Forked River Nuclear Generating Station (FRNGS). Appendix A contains a detailed description of the stations, their operating characteristics and of the site area.

1.1 Summary Description of the Environment of Barnegat Bay, Oyster Creek and Forked River

Located midway on the eastern New Jersey coast (Figure 1.1-1), Barnegat Bay is a narrow, shallow tidal basin, typical of estuarine embayments found along the Atlantic Coast. The bay receives input from freshwater creeks which border on the western shore as well as form the Atlantic Ocean via Barnegat Inlet, the Point Pleasant Canal and Manahawkin Bay (Figure 1.1-2). Presently, the salinity of the bay varies from 12 parts per thousand (ppt) in the upper reaches to 32 ppt at Barnegat Inlet and lower sections of the bay; average monthly water temperatures range from 2.8°C (37°F) in winter to 26.7°C (80°F) in summer. Due to low flow and velocity from the freshwater creeks and the limited saltwater inflow, the forces governing water circulation in the bay are primarily winds and secondarily tidal action.

Barnegat Bay has undergone significant changes over the years as a consequence of natural processes and human development. Dredging of the Intercoastal Waterway and opening of the bay to the Atlantic Ocean have increased tidal exchange to the bay and changed salinity regimes. Dredging and disposal of dredged spoils have disturbed the benthic community of the bay, but the effects probably were only temporary. Increased commercial and recreational boating may have adversely affected the water quality of the bay.

There has been little industrial development along Barnegat Bay and, other than OCNGS, no heavy industrial facility exists or is planned.

The primary determinant of water quality is inflow from freshwater streams, runoff from adjacent roads and sewage disposal from the numerous residential communities. Pollution of the bay by residential sewage is now being reduced by new sewage treatment capacity under construction for both existing and new housing which has been built along the creeks and artificial lagoons.

Lagoon and bayfront residential developments, which have bulkheaded and drained wetlands, have eliminated important aquatic habitat and provided numerous non-point sources of domestic sewage and road runoff. Although, the loss of wetlands is essentially irreversible, the construction of new lagoons and bulkheads for residential development should be limited since wetlands are now subject to substantial control under NJDEP's Wetlands and Coastal Area Facility Review Acts. Also, the Corps of Engineers has become more concerned for wetlands and other environmental effects in its administration of the Rivers and Harbors Act. Little further wetland loss should occur.

Prior to the construction of OCNGS, Oyster Creek and the South Branch of Forked River were characteristic of other low flow, brackish to freshwater creeks with tidal influence limited to a relatively small reach near Barnegat Bay. Water quality and aquatic life were characteristic of acidic streams in the New Jersey Pine Barrens area and were relatively poor in quality because of low flow, low pH and anaerobic conditions.

The construction of the intake and discharge canals for OCNGS altered Oyster Creek and the South Branch of Forked River by the widening and deepening of the existing stream beds and the creation of new stream channels. The salinity levels in portions of the creeks which had been brackish to freshwater were changed to higher salinities more characteristic of the bay. The South Branch of Forked River, which serves as the intake canal (Figure 1.1-3), no longer has its flow in the lower reach dependent upon tide, but instead flows toward the OCNGS whenever the station is operating. From the discharge canal, water flows away from OCNGS toward the bay. The velocities in both canals were increased by the pumping of water by OCNGS. Water quality is generally improved since OCNGS began operation, with lower total coliform bacteria counts and higher dissolved oxygen measurements. Along with improved water quality, the aquatic community has developed and is more diverse and dense, having a character similar to that found in the bay.

In general, the stresses to aquatic communities from residential development and domestic sewage should be reduced over the operational history of OCNGS and FRNGS. No other significant industrial sources exist along Barnegat Bay or any of its tributaries. Nor are any such facilities known to be planned. As a consequence, the discharge from OCNGS and FRNGS is not likely to interact with that of any other source to adversely affect the aquatic community.

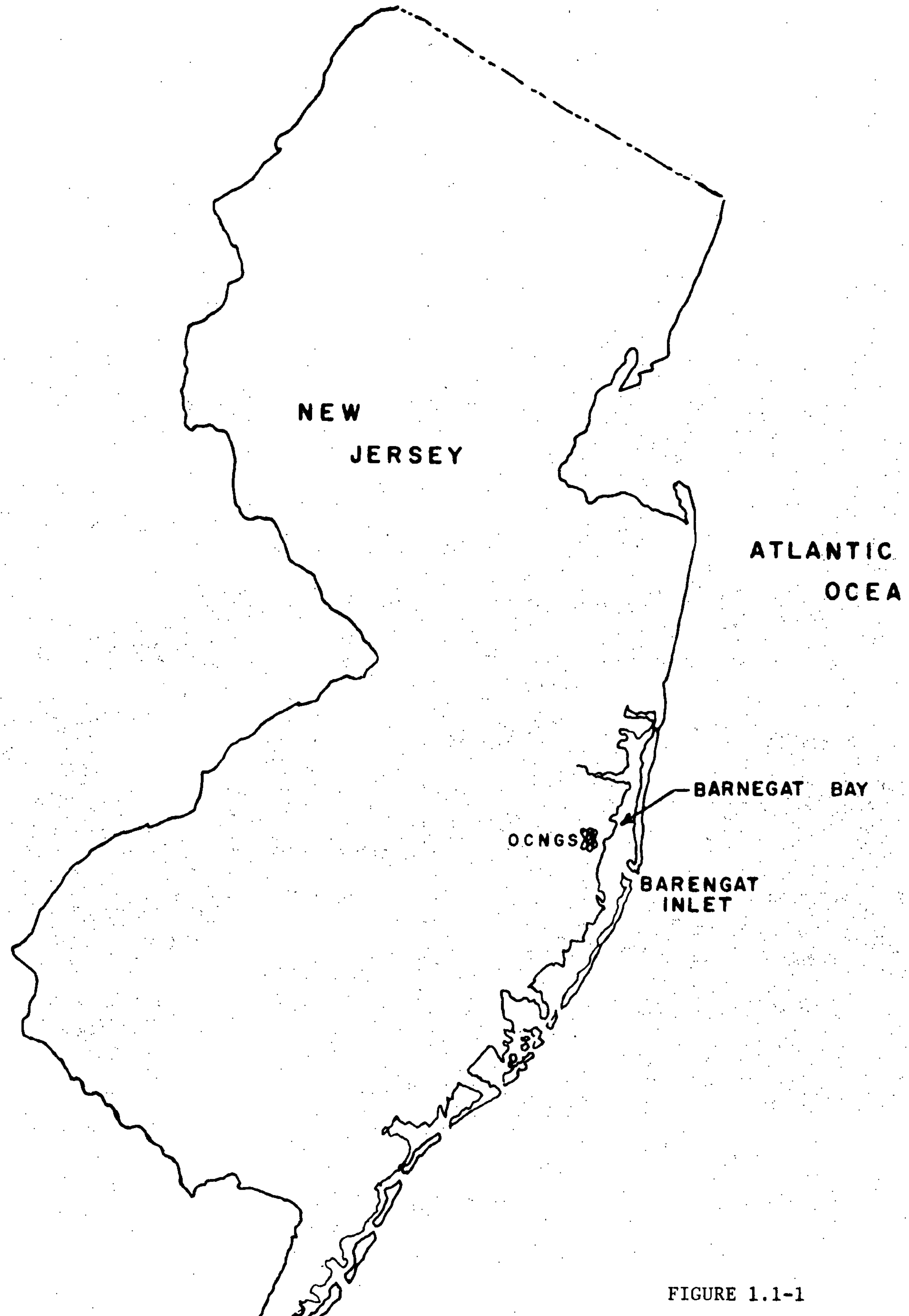

NEW
JERSEY
ATLANTIC
OCEA
BARNEGAT BAY
OCNGS
BARENGAT
INLET

FIGURE 1.1-1

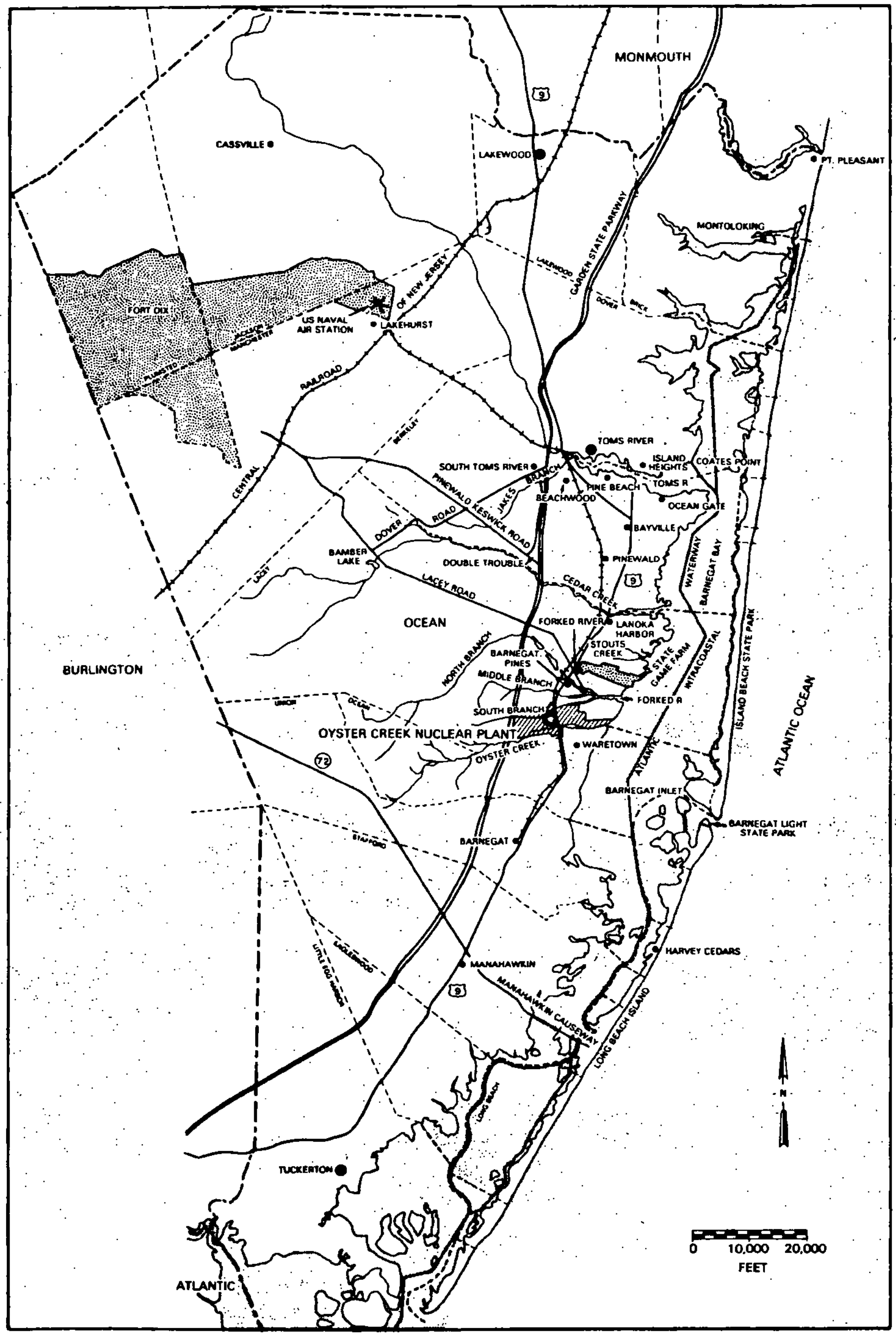

MONMOUTH
CASSVILLE
LAKEWOOD
PT. PLEASANT
MONTOLOKING
GARDEN STATE PARKWAY
FORT DIX
US NAVAL AIR STATION
LAKEHURST
OF NEW JERSEY
RAILROAD
CENTRAL
TOMS RIVER
SOUTH TOMS RIVER
ISLAND HEIGHTS
COATES POINT
PINE BEACH
TOMS R
BEACHWOOD
OCEAN GATE
BAYVILLE
PINEWALD
PINEWALD KESWICK ROAD
JAKES BRANCH
DOVER ROAD
BAMBER LAKE
DOUBLE TROUBLE
CEDAR CREEK
LACEY ROAD
OCEAN
FORKED RIVER
LANOKA HARBOR
STOUTS CREEK
BARNEGAT PINES
NORTH BRANCH
MIDDLE BRANCH
SOUTH BRANCH
FORKED R
STATE GAME FARM
BURLINGTON
OYSTER CREEK NUCLEAR PLANT
OYSTER CREEK
WARETOWN
72
9
BARNEGAT BAY
WATERWAY
INTRACOASTAL
ATLANTIC
ISLAND BEACH STATE PARK
ATLANTIC OCEAN
BARNEGAT INLET
BARNEGAT LIGHT STATE PARK
BARNEGAT
HARVEY CEDARS
MANAHAWKIN
MANAHAWKIN CAUSEWAY
LONG BEACH ISLAND
TUCKERTON
ATLANTIC
N
0
10,000
20,000
FEET

FIGURE 1.1-2

1.2 Summary Description of the Oyster Creek Nuclear Generating Station (OCNGS)

The OCNGS, which is owned and operated solely by Jersey Central Power & Light Company, is located in Lacey and Ocean townships, Ocean County, New Jersey, approximately nine miles south of the town of Toms River. The site is bounded on the north and south by undeveloped land, on the west by the Garden State Parkway and on the east by U.S. Route 9. The station was constructed between December 1964 and September 1969. Operational testing and thermal discharges began in August 1969, with commercial operation commencing in December 1969.

The OCNGS utilizes a single boiling water reactor (BWR) designed to operate at a thermal output of 1930 megawatts and a turbo-generator to produce approximately 640 megawatts of electric power. The unit has an ultimate rating of 670 megawatts of electric power. The OCNGS is a base load station having an annual electrical capacity factor (a ratio of the station's actual annual generation to its design capacity based on its design electrical rating) of 57.0 percent in 1977 to 76.3 percent in 1972, with a cumulative total to the end of 1977 of 64.0 percent.

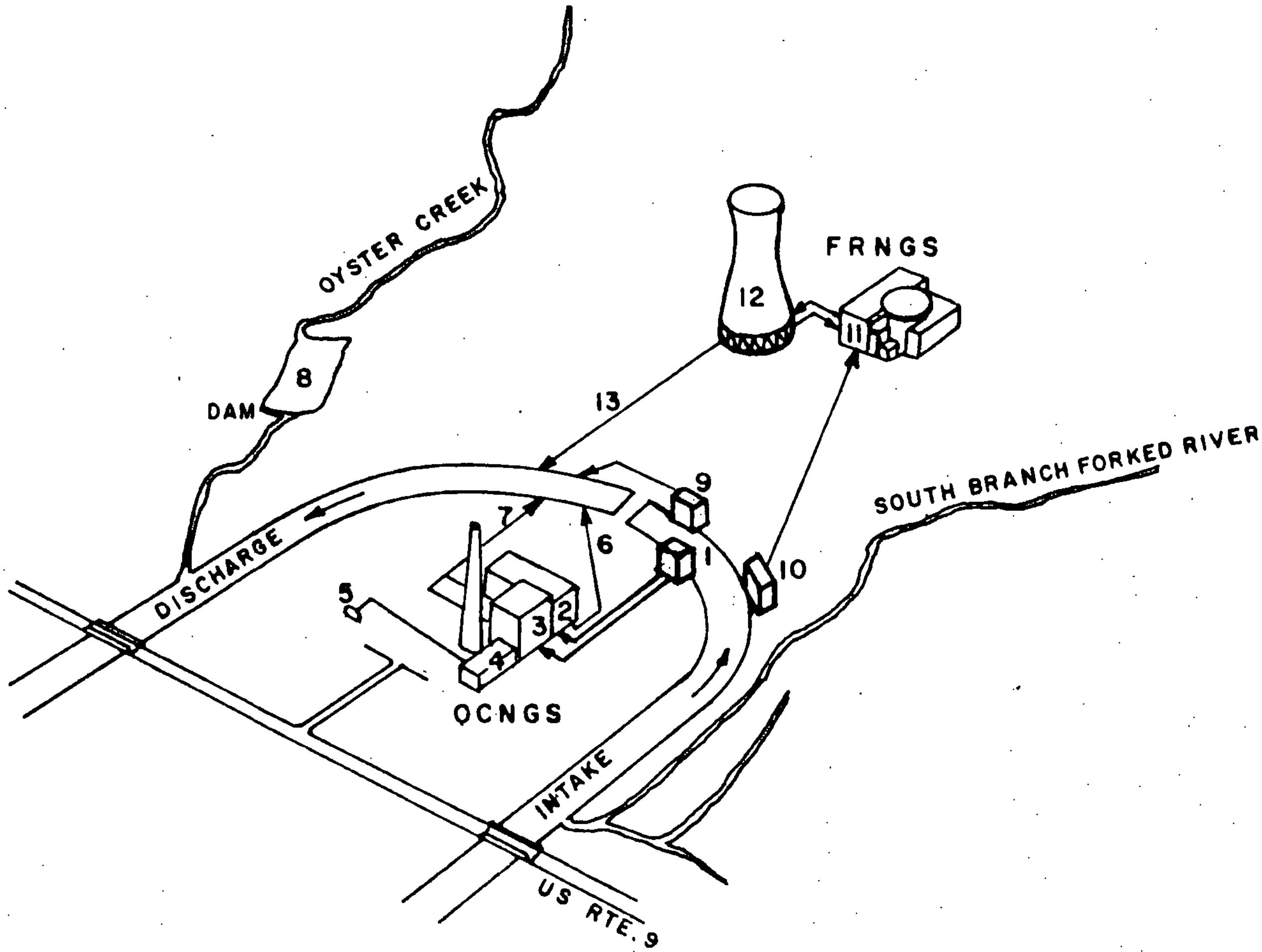
The station has five main water systems: The Circulating Water System, Service Water System, Dilution Water System, Make-up Water System and Domestic Water System. The pumping facilities for the Circulating and Service Water Systems are located at the station's intake pump structure. Under normal operation, approximately 475,800 gpm of water is drawn for these systems from Barnegat Bay via the South Branch of Forked River and the intake canal (Figure 1.2-1). An additional 260,000 to 520,000 gpm of water may be drawn from Barnegat Bay via the South Branch of Forked River and the intake canal for dilution of the station's thermal and radwaste discharges. Water for the Make-up and Domestic Water Systems is drawn from the station's deep well at a variable rate dependent upon systems demand. The flows are only a small percentage of those maintained in the other station systems.

The OCNGS utilizes a once-through cooling system whereby water from the Circulating Water System flows in parallel through each of the six sections of the station's main condenser and is returned to Barnegat Bay via the station's discharge canal and Oyster Creek. The monthly average delta T across the condenser in 1975 to 1977 was less than 10°C (18°F). The design temperature rise across the condenser approaches 12.8°C (23°F) when all circulating pumps are operating. This temperature rise increases to 18.3°C (33°F) during periods when one or more circulating pumps are out of operation due to pump breakdown, pump maintenance or intake screen maintence. Delta Ts above the design of 12.8°C (23°F) have been observed during periods when all circulating pumps are operating. This is attributed to decreased water flow through the condenser as a result of loss of individual pump capacities, decreases in the effective intake area from intake screen blockage or maintenance, and low intake canal water level which occurs under certain meteorological conditions. Average maximum heat rejection from the condenser cooling water is 5.420×10^9 BTU per hour.

Chlorination is conducted to control biofouling on the heat exchanger surfaces and thus maintain the design flow and heat exchanger efficiencies. Chlorine is injected sequentially for 20 minute periods into each of the six condenser section connections and into the station's main service water header six times per 24 hour period. The chlorine injection rate is controlled to maintain an average concentration of free available chlorine at the outlet of each condenser section of less than 0.2 mg/l, in accordance with the station's NPDES permit. Chlorine also is injected into the station's secondary service water header.

In addition to the circulating and main service water, other discharges to the OCNGS discharge canal may include the dilution water, sewage treatment plant effluent, charcoal filter backwashes, make-up demineralizer rinses, heating boiler blowdown and radwaste system effluents.

A more detailed description of the OCNGS and summaries of historical operational data are presented in Appendix A2. The characteristics of the OCNGS thermal plume are presented in Chapter 2.



KEY

1. OCNGS Intake Pump Structure
2. " Turbine Building
3. " Reactor & Office Building
4. " Radwaste Building
5. " Deepwell
6. " Circulating Water Discharge
7. " 30 Inch Discharge
8. " Emergency Water Supply (Fire Pond)
9. " Dilution Pump Structure
10. FRNGS Nuclear Services Pump Structure
11. " Building Complex
12. " Cooling Tower
13. " Blowdown Line

FIGURE 1.2-1

1.3 Summary Description of the Forked River Nuclear Generating Station (FRNGS) 1/

The FRNGS, which is scheduled to enter commercial operation in May, 1983, is being constructed at a location adjacent to and directly west of the site of the OCNGS. The FRNGS received its final construction permit from the Nuclear Regulatory Commission in July 1973 and initial site preparation began at that time.

The FRNGS will utilize a single pressurized water reactor (PWR) designed to operate at a thermal output of 3410 megawatts and a conventional turbine generator to produce approximately 1070 megawatts of electric power. This unit has an ultimate rating of 1120 megawatts of electric power.

The FRNGS has two primary cooling water systems: the Nuclear Services Cooling Water System and the Circulating Water System. The nuclear service cooling water which also provides make-up to the Circulating Water System is withdrawn from the OCNGS intake canal. Additional water for potable, sanitary and other station uses will be drawn from wells located at the site.

The station's Nuclear Services Cooling Water System requires approximately 43,200 gpm of water, which will be drawn from the intake canal. The maximum heat rejection rate to this water system under normal operating conditions will be 190.9×10^6 BTU/hr, which corresponds to a temperature rise of 4.9°C (8.9°F). After being used for cooling at various plant systems, water from this system will provide make-up for the station's natural draft cooling tower.

The Circulating Water System will continuously recirculate 570,000 gpm of water through the station's main condenser and cooling tower. The design temperature rise of the cooling water across the condenser is 14.2°C (25.6°F). The expected average evaporative loss from the tower is 12,000 gpm during summer operation and 10,000 gpm during winter operation. Because the cooling system utilizes saline water for make-up, cooling tower blowdown is necessary to maintain a salt concentration in the circulating water below 45.0 ppt. With the intake water having a salt concentration of 30.0 ppt, this cor-

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1/ FRNGS Circulating Water System presently is undergoing an optimization study by GPU to determine optimum cooling system characteristics, including system flows and cooling tower design, and some changes may be made to the system. While it is not anticipated that these changes will affect the system significantly, a change on the order of 10 percent with respect to the intake and discharge characteristics is possible. When the optimization study is complete, and amendment to this report will be submitted.

responds to a concentration factor of 1.5. During normal operation, the blowdown discharged to the OCNGS discharge canal will exhibit a maximum average seasonal flow rate of 33,200 gpm during the winter and a maximum average seasonal discharge temperature of 28.9°C (84°F) during the summer.

Chlorine will be injected into the FRNGS water systems ahead of the nuclear service water pumps to prevent biofouling of the station's heat exchangers and into the intake of the circulating water pumps to protect the main condenser and cooling tower. Injection time will be 30 minutes every six hours, or 20 minutes every four hours and the injection rate will be adjusted to insure that the concentration of free available chlorine in the discharge does not exceed 0.2 ppm average and 0.5 ppm maximum. Detectable levels of chlorine (free available and total residual) will not be discharged for more than two hours per day.

Other discharges from the FRNGS will include effluents from the laundry drain tank, low activity waste tank, waste condensate tank and building and tank dike rainwater runoff. These effluents will be discharged to the OCNGS discharge canal via the FRNGS cooling tower blowdown line. Plant sanitary and chemical wastes will be discharged to the Lacey Municipal Utilities Authority sewerage system.

A more detailed description of the FRNGS is presented in Appendix A3.

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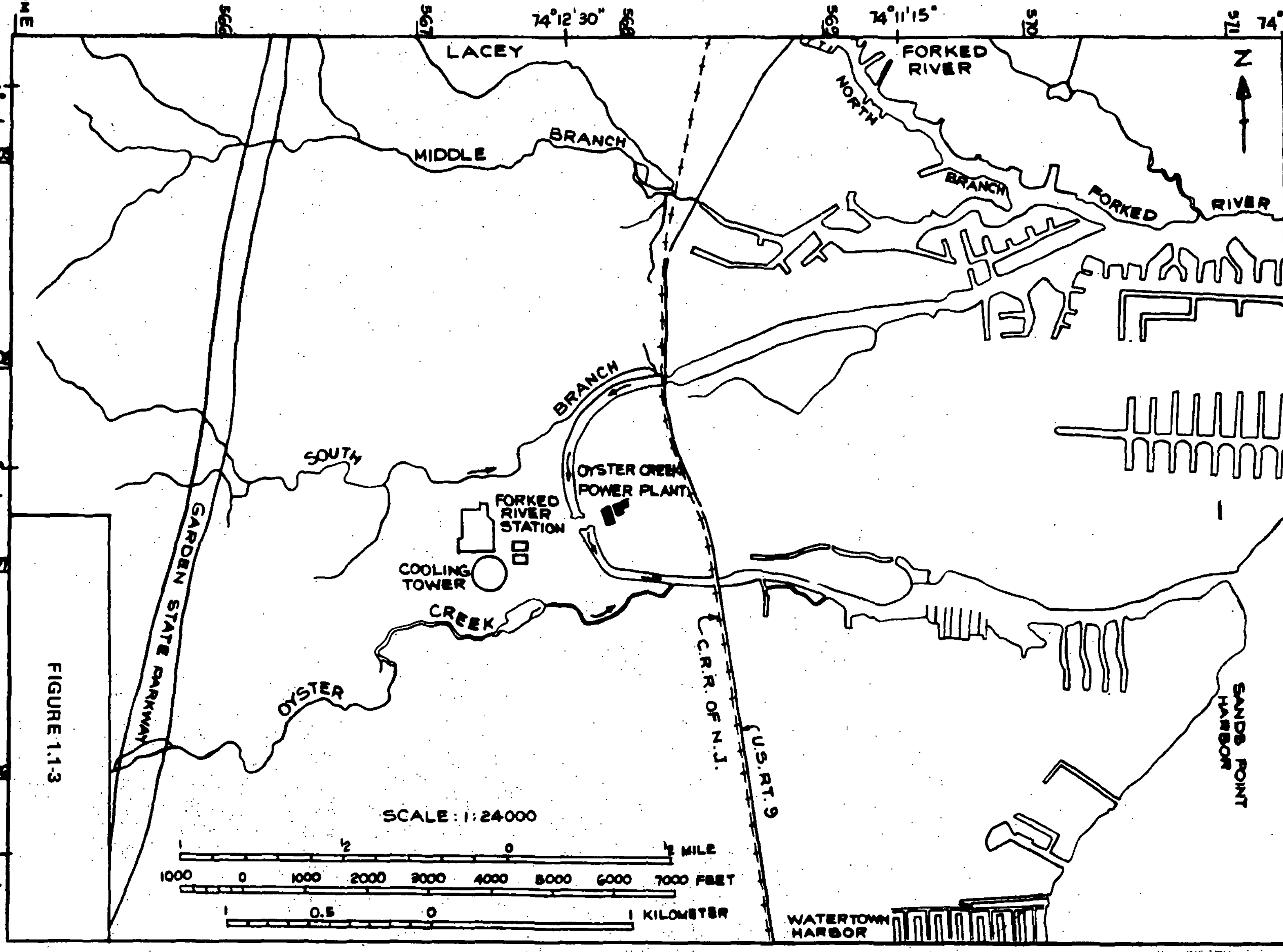

FIGURE 1.1-3

1.4 Biological Summary of the Section 316(a) and (b) Demonstration

The demonstration set forth here is a hybrid. The initial thrust is to show that representative important species ("RIS") designated by the Regional Administrator will not be adversely affected by the thermal discharges from OCNGS and FRNGS. This is supported by data demonstrating the absence of prior appreciable harm caused by OCNGS in the more than eight years of its operation. Pursuant to the principles of Section 316(a), both demonstrations are directed toward the impact of the thermal discharges on the fish, shellfish and wildlife of Oyster Creek and Barneget Bay. Effects on lower trophic levels are important to the demonstrations only to the extent that they may, in turn, affect fish, shellfish or wildlife populations. Section 316(b) is addressed according to the important biotic catagories affected by intake impingement and entrainment, with special emphasis given to the RIS designated for the Section 316(a) demonstration.

Review of the data in both areas of the demonstration should be undertaken with the understanding that the demonstrations under Section 316(a) and (b) are mutually supporting where the prior impact of an existing source is concerned. Assessment of the effect of a thermal discharge on bay populations necessarily includes consideration of intake effects, inasmuch as population effects cannot be distinguished according to the sources of impact.

Both the Section 316(a) and the 316(b) demonstrations begin by addressing the various data requirements proposed by the EPA technical guidance manuals. However, those data requirements are not strictly applicable here. Several editions of the manual were circulated during the period of the demonstration studies, aswellas the period during which the demonstration study program was formulated and reviewed. Because the data requirements of these various manuals were not uniform, it was impossible to construct a study program to fully address them. This was recognised by the EPA Region II technical staff in approving JCP&L's study program. The data requirements for this demonstration were formulated in discussions between JCP&L, NJDEP and EPA Region II concerning the appropriate areas and scope of the demonstrations' studies. For example, a relatively lower level of study was devoted to lower trophic levels of RIS (e.g., <u>Corophium tuberculatum</u>) and biotic catagories (i.e., phytoplankton) because of agreement with the technical staffs of EPA Region II and NJDEP that effects upon them were of interest only indirectly under Section 316(a): effects being important only to the extent that they, in turn, cause an adverse effect on the communities of fish, shellfish and wildlife.

Similarly, the effects of the thermal discharge on the RIS were not always assessed with the temperature-life stage data envisioned by the technical guidance manual. As agreed with the EPA Region II and NJDEP staffs, the effect of the discharge on some RIS species was analyzed by more direct data, such as species distribution in the bay (e.g., Hydroidies dianthus, Mercenaria mercenaria).

For all three aspects of the demonstration (the two approaches under Section 316(a) and the one under Section 316(b)), the area and population studied for most species and biotic categories was that of the central bay, from Good Luck Point to Gulf Point (with an area of 9,816 hectares). In JCP&L's opinion, this was the area of the "coastal waters where human use or enjoyment of the marine resource may be affected" by the OCNGS and FRNGS intakes and discharges. The studies took into account the fact that the study area was only part of the habitat available to estuarine species of Barnegat Bay and the New Jersey coast, and that it is interconnected with other estuaries and the Atlantic Ocean. Thus, the populations of the study area may be supplemented by recruitment from elsewhere in the bay and from offshore areas.

The demonstration takes into account the irreversible changes which have been made to Oyster Creek and Forked River as a consequence of construction of the OCNGS intake and discharge canals, and the circulating water flow which would be maintained there whatever the thermal discharges might be. Prior changes in Barnegat Bay, which may have affected bay populations, also were recognized.

It is JCP&L position that the OCNGS discharge has not adversely affected the indigenous populations of fish, shellfish or wildlife in Barnegat Bay. Some impacts of the discharge have been observed in the immediate area of the thermal discharge in Oyster Creek during peak temperatures in summer, but these are not significant to the maintenance and functioning of the bay's communities.

To the extent relevant, particularly with respect to the RIS demonstration, JCP&L submits that the thermal mixing zone, or heat dissipation area, be defined as bounded by the 2.2°C (4.0°F) isotherm. This generally is the outer limit of potential exclusion (due to temperature avoidance) of the designated RIS, and represents approximately 4.4 percent of the area of the central bay (exclusive of the many creek areas having characteristics similar to Oyster Creek and Forked River). It should be recognised that the concept of either exclusion or a thermal mixing zone is relevant only to peak summer conditions, June through August. During most of the year, the area of the thermal discharge within the 2.2°C (4.0°F) isotherm is a preferred habitat for many species. Only the very few species preferring colder temperatures in winter (e.g., winter flounder, sand shrimp) will avoid the elevated temperatures within the 2.2°C (4.0°F) isotherm during non-summer months.

The proposed thermal mixing zone clearly would occupy all of Oyster Creek from the point of discharge to Barnegat Bay during all months of the year. This is potentially objectionable since the discharge could block the stream (not leaving open a "zone of passage") for migrant species. The demonstration studies indicate, however, that the thermal discharge does not constitute a blockage and reservation of a zone of passage is not necessary. Migration is not likely along Oyster Creek and, to the extent that some individuals may use Oyster Creek, the discharge does not impair movement for those species during their migration or spawning season.

The proposed thermal mixing zone occupies only 25 percent of the surface width and cross-sectional area of Barnegat Bay measured at its narrowest extent, between the mouth of Oyster Creek and Sedge Island. In Barnegat Bay, the discharge does not constitute an impediment to seasonal movements.

The thermal mixing zone does not impinge on any critical nursery or spawning areas. Outside of the thermal mixing zone, a normal distribution of fish and shellfish, of all life stages, is found, except for the young winter flounder which may be excluded from up to 7.8 percent of the bay during summer.

Considering the minimal effects of the OCNGS discharge, and the absence of prior appreciable harm to the bay community of fish and shellfish, a limitation on the thermal discharge more stringent than that which obtains under present operating modes is not required. A more stringent limitation is particularily inappropriate in view of the high costs of alternative cooling systems -- $61 million for a natural draft cooling tower -- and the relatively slight benefits which such systems would provide.

The FRNGS discharge will not alter this result. Instead, the FRNGS will moderate the OCNGS discharge, cooling it slightly in summer and warming it slightly in winter. During winter, the FRNGS discharge also may help to reduce the potential for cold-shock mortalities, by moderating temperatures in Oyster Creek in the event of an OCNGS shutdown.

The data provided with respect to Section 316(b) supports the conclusion that the operation of OCNGS -- both its intake and discharge -- has not adversely affected the populations of the bay. The effect of the intake on individual organisms appears to be numerically large, but does not translate into population effects. Populations vary in the bay within the range of natural variation observed in Barnegat Bay and other mid-Atlantic estuaries and embayments. The effects of the intake on individuals may be subject to mitigation, although cost-effective modifications to reduce entrainment mortalities have not been identified. A possible modification to the intake's vertical travelling screens to reduce impingement mortality is under study by JCP&L at OCNGS, and will be adopted if it proves effective and feasible.

1.4.1 Section 316(a) - Thermal Discharge Effects - Representative Important Species Demonstration

The representative important species were selected by a variety of criteria on the premise that if they are not appreciably harmed by the thermal discharge, the remainder of the aquatic community will be protected. Two tests are involved in the RIS demonstration. First, the thermal mixing zone must not be so large as to interfere with maintenance and functioning of the indigenous community of shellfish and fish (e.g., by blockage of migration, exclusion from spawning or nursery areas, etc.). Outside the thermal mixing zone, the excess temperatures from the discharge should not interefere with growth, reproduction or survival of the RIS.

Population studies were conducted on several of the RIS to determine their distribution and relative abundance in the bay. Variations in population size in Barnegat Bay over the period of OCNGS operation and the relevant study periods were compared to variations of these populations in other estuaries to determine if they were due to wide ranging environmental and biotic factors rather than station induced. Changes in species abundance in the mixing zone also were examined with respect to a potential impact on the bay populations.

In addition to the population data, thermal data were gathered on the fish RIS through laboratory behavioral testing. These data were useful in predicting the potential combined effects of OCNGS and FRNGS. Thermal data were not developed for the non-fish RIS because of the impracticality of and lack of standard procedures for, such laboratory work. As agreed with EPA Region II and NJDEP, only distributional data has been provided for these species.

Data collected on the RIS demonstrate that these organisms will not be adversely affected by thermal discharges from OCGNS and FRNGS. In no case will the extent and stress of the mixing zone be such as to interfere with the normal functioning of the bay's populations. No critical functions will be eliminated, nor will important migratory routes be blocked by the mixing zone. The abundance of fouling organisms will not increase so as to interfere with the balanced, indigenous populations.

A potential exists with some species for cold shock and heat shock inside the thermal mixing zone, and has been experienced during OCNGS operation. However, under present operating modes for OCNGS, cold shock potential is relatively small. Since cold-shock mortalities were experienced, operating procedures have been changed to reduce overwintering by some species, especially Atlantic menhaden. Dilution pump operation has been altered to provide some temperature stability in Oyster Creek after OCNGS shutdown. The FRNGS discharge also will help stabilize the temperature after an OCNGS shutdown, and will reduce this potential further.

The populations of three of the RIS species, Menticirrhus saxatilis (northern kingfish); Sphaeroides maculatus (northern puffer) and Morone saxatilis (striped bass) are important to the recreational and commercial fisheries, and have experienced large declines during the 1970's. Few individuals were collected in Barnegat Bay during JCP&L's field studies. These declines were observed elsewhere in New Jersey and along the Atlantic Coast, however, and reflect natural fluctuations in population density rather than any effect of OCNGS operation.

Brevoortia tyrannus (Atlantic menhaden) was the most important species in New Jersey's commercial fishery, both by weight and dollar value, from 1972 through 1974. This species does not reproduce in Barnegat Bay, utilizing the bay primarily as a nursery area. Although the Atlantic menhaden may be excluded from approximately 2.1 percent of the bay from Cedar Beach to Gulf Point during July and August, this area of exclusion is well within the thermal mixing zone. It is unlikely that the loss of this small area will affect the population since schools of this fish occur throughout Barnegat Bay from April through October and no portion of the bay is a critical area.

The losses of Atlantic menhaden that have occurred as a result of cold-shock mortality following winter shutdowns have had no significant effect on the large Atlantic Coast population of this species. Changes in the mode of operation of the OCNGS have reduced the frequency and extent of cold-shock mortality, and further reductions in the incidence of these mortalities should be realized with the onset of thermal discharge from the FRNGS.

The most abundant sport fish landed in New Jersey during 1975 and in Barnegat Bay from 1975 to 1977 was Pomatomus *saltatrix* (bluefish). The bluefish spawns offshore and the juveniles move into Barnegat Bay during their first summer, utilizing the estuary as a nursery. Young bluefish may be excluded from most of the discharge canal during July and August, but the area of exclusion constitutes less than 1 percent of the central bay and is within the thermal mixing zone. Mortality from heat shock has not occurred and cold-shock mortality was limited to the few individuals which overwinter in the discharge canal. As mentioned above, the frequency and extent of cold-shock mortalities have been reduced since the implementation of modified shutdown procedures and the problem will be mitigated further with the addition of the FRNGS thermal discharge.

Cynoscion regalis (weakfish) is another species important to the recreational fishery of Barnegat Bay. Weakfish spawning is confined to the ocean, and eggs and larvae were not found in the bay. The migratory habits of the weakfish are similar to those of the bluefish as the adults and juveniles enter the bay in the spring and leave in the fall. The effect of the thermal discharge on the weakfish also is very similar to that on the bluefish. Both species avoid stressful temperatures in the thermal discharge during summer, and have a few individuals that overwinter in the discharge canal. The weakfish may be excluded from 4.4 percent of the central bay during the summer, but the area of exclusion is within the thermal mixing zone. The few individuals overwintering in the discharge canal may be killed following a station shutdown but even this effect, combined with the summer exclusion from a small part of the bay, will have no significant effect on the population of weakfish in Barnegat Bay or along the New Jersey coast.

Pseudopleuronectes americanus (winter flounder) utilizes Barnegat Bay as a spawning and nursery area and is important to the recreational and commercial fisheries of the area. Adults of this species reproduce from January through March, and the thermal discharge will not exclude them from any portion of the bay during that period. Young winter flounder are found primarily in the shore zone from June through September, and the thermal discharge may exclude them from a small area of the shoreline within the thermal mixing zone. As the young move to the deeper areas of the bay during July and August, up to 7.8 percent of the area of the central bay may be unavailable to them due to excessively high temperatures. This is probably an overestimate, since the thermal plume generally occupies only the top five feet of the bay, leaving large areas of the bottom in the deeper portions of the bay unaffected by the thermal discharge and available to the winter flounder.

Heat-shock and cold-shock mortalities of adults and young have not been observed and, based upon the temperature tolerance of this species, are not expected to occur in the future.

Paralichthys dentatus (summer flounder) accounted for 13 percent of the sport catch of finfish in Barnegat Bay from December 1971 through November 1972. This species ranked first (by weight) in commercial landings for Ocean County from September 1975 through August 1977.

The summer flounder is a seasonal migrant in Barnegat Bay, with adults and juveniles being found in the bay from March through December. The thermal discharge from the OCNGS and FRNGS will have no effect upon the reproductive process in this species since spawning occurs in the ocean. Heat-shock and cold-shock mortality will not occur because the summer flounder avoids the warmest areas of the discharge during summer and is not attracted to the thermal discharge during its fall emigration from the bay.

During July and August, the thermal discharge may exclude the summer flounder from approximately 1.9 percent of the area of the central Barnegat Bay. This area of exclusion is well within the thermal mixing zone, however, and should have no significant effects upon the populations of this species in Barnegat Bay or the Atlantic Coast.

Mercenaria mercenaria (hard clam) is the only invertebrate among the representative important species identified by the Regional Administrator that is of commercial or recreational importance. Barnegat Bay has always supported a hard clam fishery with annual yields ranging from 90,718 to 402,233 kg (200,000 to 900,000 lbs) of meat. A report on shellfish surveys in the bay in the 1960's described Barnegat Bay's hard clam fishery as suitable for sport and limited commercial harvesting. The low level of recruitment into the fishery has been a chronic problem. In spite of this, however, the 1976 hard clam catch from Barnegat Bay was larger than any other since 1959.

The OCNGS thermal discharge has had no apparent adverse effect on the planktonic egg and larval stages of the hard clam. This species has successfully settled near the mouth of Oyster Creek during the early 1970's and recruitment has recently (1975-1976) been observed in Oyster Creek as well as in Barnegat Bay, both inside and outside of the thermal mixing zone. The survival of juvenile and adult clams in Barnegat Bay is unaffected by the thermal discharge, but there is some evidence indicating that clams near the mouth of Oyster Creek grow at a reduced rate during the summer months when compared to clams that are unaffected by the discharge. This reduction in growth, however, amounts to the loss of approximately 1 mm of shell per year and is not significant over the lifespan of the animal.

JCP&L's biological studies indicate, therefore, that Mercenaria mercenaria is not excluded from any area in which it would normally settle and is not subjected to any stresses which will interfere with its preservation and propagation.

Four of the representative important species (Crangon septemspinosa, Neomysis americana, Corophium tuberculatum, and Anchoa mitchilli) are forage for organisms at higher trophic levels, including commercially and recreationally important species of fish.

Crangon septemspinosa (sand shrimp) is an epibenthic decapod that is abundant in Barnegat Bay, Oyster Creek, Forked River, and the intake and discharge canals of the OCNGS during much of the year. Most of the Barnegat Bay population emigrates to the ocean during the summer months, and, thus, is not subject to potential for heat shock mortality or exclusion from portions of the bay affected by the thermal discharge.

A small portion of the bay (approximately 0.5 percent) may be unavailable to Crangon during the cooler months, but this area of exclusion is well within the thermal mixing zone. Since most reproduction occurs from October through June, most secondarily entrained zoeae will not experience lethal temperatures. Cold shock mortality has not been observed and is not expected to occur in the future.

Neomysis americana is a mysid crustacean common to the coastal waters of eastern North America from the Gulf of St. Lawrence to northeastern Florida. It is important as forage for many commercially and recreationally important species including flounders, shad, herring, mackerel, bay anchovy and weakfish.

High water temperatures will exclude N. americana from Oyster Creek from June through September and from approximately 4 percent of the central bay during July and August. The areas of exclusion are within the thermal mixing zone. Heat shock mortality could affect approximately 1.2 percent of the population in the bay in July and August; cold shock mortality is not a problem since only a small population resides in Oyster Creek during winter.

Anchoa mitchilli (bay anchovy) was the most abundant fish in Barnegat Bay during 1975 through 1977 and represents an important source of food for many fishes of commercial and recreational importance. This species should not be excluded from more than 2.6 percent of the volume of the central bay during the summer months, and this area is not critical to its protection and propagation. Heat shock mortality is not a problem because the bay anchovy avoids temperatures greater than 31°C (87.8°F). Although the bay anchovy is attracted to the thermal discharge in the fall, making it susceptible to cold shock mortality, no large kills have ever been observed.

Corophium tuberculatum is a gammaridean amphipod common to the entire Atlantic Coast and represents a minor source of forage for both fish and birds. *C. tuberculatum* may be excluded from the discharge canal during the summer months, but the presence of a breeding population of this species in the intake canal during most of the year, including the summer, indicates that it has not been appreciably harmed by the thermal discharge outside the area of the mixing zone.

Gasterosteus aculeatus (threespine stickleback), which is neither commerically or recreationally important not significant forage for other fish in Barnegat Bay, is a cold water species that spawns in the estuary. The distribution of this species in Barnegat Bay appears to be determined primarily by the presence of vegetation, which is most abundant on the eastern side of the bay. Few individuals were found on the western side of the bay. Heat shock and cold shock mortality have not been observed and are not expected to occur in the future.

Hydroides dianthus is a tube dwelling polychaete worm which is a fouling organism. The density of this species in the discharge canal has been found to be lower than that in surrounding regions of the bay. However, *Hydroides* appears to be evenly distributed outside of the discharge canal.

Teredo spp. cause damage to unprotected submerged wooden structures by boring into wood. Barnegat Bay harbors four known species of teredinid borers. *Teredo navalis* is the dominant species on the eastern side of the bay, and its distribution reflects its sensitivity to humic material in marshland runoff rather than any effect of the thermal discharge.

Teredo furcifera is a subtropical species which apparently has been introduced into Barnegat Bay, possibly by a transient wooden boat. At its peak observed abundance, this species has occurred in extremely low densities and does not appear to be truly established in Barnegat Bay. No correlation has been observed between the distribution and abundance of this species and the thermal discharge from the OCNGS.

Teredo bartschi, another subtropical species purportedly introduced into Barnegat Bay, has been found only in Oyster Creek. This limited distribution suggests a positive effect of the thermal discharge on its population. The absence of T. bartschi from other parts of Barnegat Bay, however, indicates that the thermal discharge has not caused the proliferation of this species outside of Oyster Creek.

Bankia gouldi is the most widely distributed teredine borer in Barnegat Bay and the most abundant borer along the bay's western shore. Bankia gouldi is common in areas of the bay influenced by the thermal discharge, but the major concentrations of this species occur in areas to the north of Oyster Creek outside of the influence of any heated water.

Histological studies of gonadal development in B. gouldi have indicated that due to the thermal discharge, the gonads mature slightly earlier in Oyster Creek when compared with specimens from surrounding areas. There is no evidence, however, of any increase in the abundance of B. gouldi in Barne-Bay as a result of this phenemenon.

Thus, the distribution and abundance of three of the four species of teredine borers in Barnegat Bay are unaffected by the thermal discharge. The fourth species, Teredo bartschi, is found only in the discharge canal indicating a positive correlation between the thermal discharge and its distribution. This effect, however, has only been observed within the thermal mixing zone. Whatever impact the thermal discharge may have had on any of these species has not been at all consequential to the fish or shellfish populations of the bay.

1.4.2 Section 316(a) - Thermal Discharge Effects - Absence of Prior Appreciable Harm Demonstrations

The results of the RIS demonstration are confirmed by the absence of prior appreciable harm caused by OCNGS. Studies on the various biotic catagories of the Barnegat Bay community have been conducted since 1965 and were analyzed for this demonstration. Analysis was concentrated on four biotic catagories: (1) phytoplankton, (2) zooplankton and meroplankton; (3) benthic macroinvertebrates; and (4) fish. A specific study of the effect of the discharge on wildlife was not undertaken since prior ecological studies, for permits from NRC for both OCNGS and FRNGS, had shown the area to be of low potential impact.

The results of the surveys and studies undertaken show that the impacts of OCNGS operation have been minimal and have not adversely affected the protection and propagation of the bay's balanced indigenous community of fish and shellfish. The community structure of the bay is typical of other estuaries and embayments of the mid-Atlantic coast in terms of composition, distribution, relative abundance, productivity and seasonal succession. Observed changes in community structure have been within the range of natural variation.

Some changes in community structure have been observed in the immediate area of the discharge in Oyster Creek. Phytoplankton, for example, experiences lower diversity in Oyster Creek during the summer. Lower density of some zoo- and meroplankton also have been observed in the discharge canal and Oyster Creek. However, the effects of these changes have been confined to Oyster Creek and have not resulted in changes in the fish and shellfish communities. These changes also have not resulted in a shift in structure favoring nuisance or pollutant tolerant species, such as by inducing noxious phytoplankton blooms. Species resident to Barnegat Bay have evidenced normal survival, reproduction and growth; and migrant species have shown successful movement throughout the bay, except in the thermal mixing zone during peak summer temperatures.

Phytoplankton

Data have been compiled on the phytoplankton species composition, abundance, seasonal succession, primary productivity, and biomass in Oyster Creek, Forked River, and Barnegat Bay. The analyses of these data show that the phytoplankton community in the bay consists of a diverse assemblage of species typical of unpolluted estuaries along the mid-Atlantic coast. More than 180 phytoplankton species have been identified in the bay, with the community reflecting large seasonal fluctuations in species composition, abundance, and primary productivity. These fluctuations are not related to thermal discharge from the OCNGS; however, they demonstrate a natural response to seasonal changes in water temperature, photoperiod, and nutrient supply.

The abundance of phytoplankton in Barnegat Bay reaches a maximum in the summer and a minimum in the winter. Ultraplankton dominate the phytoplankton community in the summer; the density of phytoplankton may exceed 10^6 cells/l at this time. Nanoplankton (microflagellates and dinoflagellates) are common constituents of the phytoplankton community in the summer, and their density may surpass 10^6 cells/l.

The composition of the phytoplankton community in the fall is mainly an extension of summer populations, but by midwinter diatoms dominate the phytoplankton. A diatom bloom occurs in the estuary by mid to late winter, being mainly comprised of *Thallassiosira nordenskioldi*, *Detonula confervacea*, and *D. cystifera*. Grazing of zooplankton, particularly the copepod *Acartia*, terminates the bloom. By spring, *Skeletonema costatum* becomes the dominant phytoplankton.

Biomass estimates in the form of chlorophyll *a* measurements are highest in the bay during the winter-spring diatom blooms, and secondary maxima occur in the summer in connection with peak phytoplankton cell numbers. The biomass of phytoplankton is characterized by large seasonal variations. For example, chlorophyll *a* measurements range from one to 30 mg/l over an annual phytoplankton cycle. Spatial variations in biomass also are substantial, but this is commonly observed in natural, balanced ecosystems.

Primary productivity peaks in the summer and is lowest in the winter. Gross productivity rates in the bay vary from zero to 500 mg $O_2/m^3/hr$ over an annual phytoplankton cycle. The spatial variations in primary productivity that occur in the bay also occur in Oyster Creek and Forked River.

Although the composition, abundance, primary productivity, and biomass of phytoplankton in Barnegat Bay are variable, they were within the natural range observed in most mid-Atlantic estuaries. Since the OCNGS went into operation in 1969, the thermal discharge has not caused any substantial change in the phytoplankton composition, abundance, primary productivity, and biomass in the bay. A balanced community of phytoplankton exists in the bay, and this community seems to be unaffected by the thermal discharge.

Effects of the thermal discharge on phytoplankton in the Barnegat Bay estuary appear to be restricted to Oyster Creek. Data from 1971 indicate a maximum decrease in gross productivity of 30.3 percent, a maximum decrease in net productivity of 20.1 percent, and a maximum decrease in chlorophyll *a* of 17.7 percent at the mouth of Oyster Creek when compared to the mouth of Forked River. Data from 1972 show a decline in gross productivity of 11.9 percent and a drop in net productivity of 35.0 percent at the mouth of Oyster Creek when compared to Forked River. None of these reductions, however, is statistically significant ($P \quad 0.05$).

Lower phytoplankton diversity also occurs in Oyster Creek when compared to Forked River and may be attributable to thermal discharge from the OCNGS. The lower diversity in Oyster Creek, however, has not adversely affected organisms located at other trophic levels and is considered to be inconsequential.

Although some adverse effects of thermal discharge from the OCNGS on the phytoplankton community are documented in Oyster Creek, these effects have not caused a shift in the phytoplankton community in Oyster Creek or the bay to one which is dominated by nuisance species. No phytoplankton blooms result from thermal discharge from the OCNGS, and changes in the phytoplankton variables in the discharge canal have not affected the balanced, indigenous community of shellfish, fish, and wildlife in the Barnegat Bay estuary.

It should be recognised that at the time that some effects on phytoplankton were observed in Oyster Creek, 1969 to 1970, OCNGS operated only one dilution pump in the summer and none in the winter. And operation of the one pump was not uniform. Thus, at times, phytoplankton in Oyster Creek were subjected to temperatures nearly as high as the condenser discharge temperature (a maximum of 41.1°C, 106°F). Since 1975, OCNGS has operated two dilution pumps throughout the summer, which results in a 50 percent reduction in the condenser discharge temperature after mixing. Thus, in the present operational mode, effects on phytoplankton are likely to be less than those observed in the studies discussed.

Thermal discharge from the FRNGS is not anticipated to adversely affect the phytoplankton community in Oyster Creek or the bay.

<u>Zooplankton and Meroplankton (Ichthyoplankton)</u>

Thermal discharge from the OCNGS does not appear to affect the zoo- and ichthyoplankton communities in Barnegat Bay. Fluctuations in the species composition, distribution, and seasonal succession within these communities are comparable to those of other estuaries and embayments in the northeastern United States. These fluctuations result from the natural population dynamics of the organisms and not from stress of the thermal discharge.

Holoplankton, primarily copepods (62 percent) and rotifers (24 percent), were the most abundant microzooplankton sampled between 1975 and 1977, comprising 86 percent of all microzooplankton (planktonic invertebrates 500 microns in length) taken. Copepods were the most common microzooplankton collected, with <u>Acartia</u> being the most abundant genus. Microzooplankton densities reached maximum levels between March and July and minimum levels between September and November.

Meroplankton (forms which spend only part of their life or daily activity in the water column) comprised only 14 percent of the microzooplankton because they were present only seasonally. Polychaete larvae (38 percent of all meroplankton), bivalve larvae (17 percent), barnacle larvae (14 percent), gastropod larvae (7 percent), and unidentified trochophores composed most of the microzooplankton sampled.

The most abundant macrozooplankton (planktonic invertebrates 500 microns in length) were <u>Neomysis americana</u>, zoeae of

Crangon septemspinosa, Sarsia spp., Rathkea octopunctata, xanthid zoeae, and amphipods. The macrozooplankton community apparently was separated into one assemblage of forms at temperatures above 18°C (64.4°F), and another assemblage below that temperature. Below 18°C (64.4°F) the dominant macrozooplankton were Neomysis americana, Sarsia spp., Rathkea octopunctata, zoeae of Crangon septemspinosa, and amphipods. Above 18°C (64.4°F) the dominant forms were zoeae of xanthids, amphipods, N. Americana, and zoeae of C. septemspinosa.

The species composition and abundance of ichthyoplankton was seasonally dependent. During the cold season (December through April), larvae of the winter flounder (59 percent of the larvae during December through April) and sand lance (41 percent) dominated the collections. During the warm season, eggs (98 percent of all eggs) and larvae (70 percent of all larvae) of the bay anchovy and larvae of gobies (24 percent) were most common.

The species composition, relative abundance, distribution, and seasonal occurrence of zoo- and ichthyoplankton in Barnegat Bay do not appear to be adversely affected by thermal discharge from the OCNGS. Effects of the thermal discharge seem to be confined to the discharge canal and Oyster Creek. Some differences were found in the absolute abundances of zoo- and ichthyoplankton between the mouth of Oyster Creek, the OCNGS discharge, and Forked River. Microzooplankton which were less abundant at the mouth of the Oyster Creek than at the OCNGS discharge included: barnacle larvae (72 percent less abundant at the mouth of the discharge canal); polychaete larvae (42 percent); copepod nauglii (19 percent); unidentified bivalve larvae (25 percent); Acartia tonsa (57 percent); and Acartia spp. (61 percent). Other microzooplankton were more numerous at the mouth of Oyster Creek than at the OCNGS discharge: rotifers (103 percent more numerous at the mouth of the discharge canal), cyphonate larvae (3,547 percent), gastropod larvae (70 percent), and Mulinia lateralis larvae (155 percent).

Differences in macrozooplankton also were noticeable between Forked River and Oyster Creek. The mean density of Crangon septemspinosa zoeae; the mud crabs Neopanope texana, Panopeus herbstii, and Rhithropanopeus harrisii; Hippolyte spp.; the mud shrimp Upogebia affinis; hermit crabs Pagurus spp.; and spider crabs Libinia spp. consistently were greater in Forked River than in Oyster Creek. Zoeae of Palaemonetes spp., however, consistently were greater in Oyster Creek than in Forked River.

In some cases, reductions in the density of ichthyoplankton in Oyster Creek were apparent. The density of larvae and juveniles of the bay anchovy and northern pipefish was less in Oyster Creek than in Forked River. The density of bay anchovy eggs and goby larvae also were lower in Oyster Creek.

Changes in zoo- and ichthyoplankton in Oyster Creek, although correlated with thermal discharge from the OCNGS, cannot be attributed solely to the thermal discharge. Because of the location of the sampling stations, these studies measured the total impact of station operation on zoo- and meroplankton. Some of the changes of these forms undoubtedly were caused by primary entrainment effects, and some result from secondary entrainment into the discharge canal. Reproduction also may take place in the discharge canal, producing the greater abundance of some forms in the discharge canal and masking some primary entrainment effects. Differences between Oyster Creek and Forked River due to natural fluctuations, are difficult to segregate from the above factors.

Although the number of zoo- and ichthyoplankton generally were lower in Oyster Creek than in the intake canal, these reductions have not affected the balanced, indigenous community of shellfish, fish, and wildlife in the Barnegat Bay estuary. The species composition, relative abundance, distribution, and seasonal occurrence of zoo- and ichthyoplankton in Barnegat Bay are similar to those of other estuaries, and changes of these groups in the bay do not appear to be related to thermal discharge from the OCNGS. These conditions are not expected to be altered by thermal discharge from the FRNGS.

Benthic Macroinvertebrates

Six hundred and ninety four samples of benthic invertebrates were collected in Barnegat Bay between 1965 and 1974 to evaluate any biotic changes associated with thermal discharge from the OCNGS. Qualitative sampling predominated between 1965 and 1968 and quantitative sampling between 1969 and 1974. The quantitative variables investigated were the number of individuals per square meter, the number of species, the diversity index, the dry weight of sample, the number of *Mulinia lateralis*/m^2, the number of *Pectinaria gouldii*/m^2, the number of *Ampelisca* sp./m^2, the number of *Retusa canaliculata*/m^2, the temperature at bottom, and the salinity at bottom.

Between 1965 and 1968 the community of benthic invertebrates in western Barnegat Bay was dominated by two species, the polychaete, *Pectinaria gouldii*, and the lamellibranch, *Mulinia lateralis*. The community tended to be uniform in structure during this interval. In the fall of 1969, however, large increases in the abundance of *P. gouldii* and *M. lateralis* occurred at the three sites sampled in the bay -- the mouths of Stouts Creek (an area outside the influence of the thermal discharge), Forked River, and Oyster Creek. The increases in the abundance of these two benthic species at this time were unrelated to thermal discharge from the OCNGS because the thermal discharge affected only a minor portion of the bay, and increases in the abundance of these species were noted in areas unaffected by the thermal plume.

From 1969 to 1970, the abundance of benthic invertebrates declined significantly at the mouths of Stouts Creek, Forked River, and Oyster Creek, to levels approximating those observed during the 1965 to 1968 sampling period. The decline at the mouths of Oyster Creek and Stouts Creek involved the benthic dominants, *Mulinia lateralis*, *Pectinaria gouldii*, and *Retusa canaliculata*, but the decline at the mouth of Forked River involved only *M. lateralis* and *R. canaliculata*. A net increase in benthic species other than the dominants occurred at the mouth of Forked River. The decrease in the density of benthic populations was greater at the mouth of Oyster Creek than at the mouths of Stouts Creek or Forked River, but was within the range of natural variability established by the other two stations. Accordingly, it is attributed to natural fluctuations in the populations rather than to thermal discharge from the OCNGS.

The density of benthic invertebrates continued to fall at the mouths of Oyster Creek, Stouts Creek, and Forked River from 1970 to 1973. The diversity of the communities and the dry weight of samples, however, increased at these localities. Changes in diversity and sample dry weight were generated directly by changes in density.

During the summer to fall period of any one year, the density of populations was greater at the mouths of Stouts Creek and Forked River than at the mouth of Oyster Creek. The density during the winter to spring period of any one year was greater at the mouth of Oyster Creek than at the mouths of Forked River and Stouts Creek. No significant differences in the density of benthic populations were found between the three bay sampling sites, however, when averaged over the entire year. The species composition also remained remarkably consistent at each site from year to year.

In essence, the thermal discharge does not affect the yearly standing crop, species composition, and diversity of benthic organisms in the bay. A possible seasonal effect of the thermal discharge on the abundance of benthic invertebrates exists in Oyster Creek and the region of the bay immediately around the mouth of Oyster Creek. This seasonal effect, however, does not influence the protection and propagation of the balanced, indigenous community of shellfish, fish, and wildlife in the Barnegat Bay estuary.

Fish

The fish populations sampled in the Barnegat Bay estuary were characterized by large natural variations in abundance from year to year. The abundance of many populations fluctuated as much as 50 to 100 percent in the bay from 1966 to 1970. Fluctuations of this magnitude are not unusual, however, and similar fluctuations occurred during this period in nearby New Jersey estuaries and estuaries located along the mid-Atlantic coast.

Most changes in the fish populations in Barnegat Bay during the operational years of the OCNGS from 1969 to 1970 and 1975 to 1977 appear to be unrelated to the thermal discharge. The thermal discharge from the OCNGS has caused some minor changes in the distribution of fish populations in the bay and mortality of some individuals in Oyster Creek by heat and cold shock. But these effects have not been large relative to the fish populations' size and extent of habitat and, therefore, have not been significant to the maintenance and functioning of the fish populations in the bay.

Fish sampling conducted from 1966 to 1970 and 1975 to 1977 indicate that some fish populations have declined in the bay. These include the Atlantic silverside (*Menidia menidia*), the tidewater silverside (*Menidia beryllina*), the fourspine stickleback (*Apeltes quadracus*), the northern pipefish (*Syngnathus fuscus*), the northern puffer (*Sphaeroides maculatus*), the silver perch (*Bairdiella chrysura*), and the winter flounder (*Pseudopleuronectes americanus*). The number of spot (*Leiostomus xanthurus*), however, has substantially increased from the late 1960s to the mid-1970s, and the catches of the bay anchovy (*Anchoa mitchilli*) and the mummichog (*Fundulus heteroclitus*) in the mid 1970s were similar or greater than those in the late 1960s.

These changes largely reflect the effect of environmental factors other than the OCNGS discharge, as well as natural variability in the populations. Recent development of the surrounding areas in the form of the installation of bulkheads, elimination of wetlands, increased domestic discharges, and increased recreational use of the bay undoubtedly contributed to the fluctuations in some populations (particularily those favoring aquatic vegetation for a habitat). Changes in habitat caused by construction are essentially irreversible and have caused changes in population distribution which also are irreversible. Fortunately such changes are not likely to continue under present regulatory controls. However, the impact of these stresses is difficult to determine and quantify.

Effects of thermal discharge from the OCNGS on fish populations are confined primarily to Oyster Creek. The distribution of some species have been affected because they may prefer, or may avoid, Oyster Creek at various times of the year in response to the heated water. Some species also are susceptible to heat and cold shock mortality due to sudden temperature changes in the discharge canal generated by shutdowns of the OCNGS.

From June through September, for example, Atlantic menhaden, bluefish, and weakfish avoid some part of Oyster Creek, and young winter flounder avoid most of the canal because of excess temperatures. This loss of habitat, however, is within the thermal mixing zone and is inconsequential to the success of the populations in the bay or along the Atlantic coast (since Oyster Creek constitutes a net addition to the bay's habitat, consequent to construction of the intake and discharge canals, denial of this area to these fishes for part of the year could not adversely affect the indigenous populations of the bay).

From fall through early winter, Atlantic menhaden, bluefish, spot, bay anchovy and weakfish are attracted to the discharge canal. Some Atlantic menhaden, bluefish, weakfish, spot and bay anchovy overwinter in the canal, but these fish do not show abnormally high rates of parasitism or disease, retarded growth, or aberrant reproductive characteristics.

The greatest effect of thermal discharge from the OCNGS on fish populations has been mortality from heat and cold shock. Heat shock mortality has not been a problem of any significance, as only two incidents of heat-shock mortality have been documented, and these developed under unusual operating or natural conditions. The magnitude of these fish kills was small and did not harm the local populations.

Fish kills of overwintering populations, particularly Atlantic menhaden, have been more numerous. These events, however, have been of little consequence to the large populations from which these species were derived along the Atlantic coast. The number of bay anchovy, bluefish, and weakfish killed during winter shutdowns has been small. Although one loss of the Atlantic menhaden was relatively large (up to one million individuals), they represented less than one percent of the average annual commercial catch of the species in New Jersey and are small in relation to the catch of a single commerical fishing vessel. These losses, therefore, were probably of no consequence, and they did not affect the fish community in the bay.

Changes in the operating mode of the OCNGS have reduced substantially the potential for a cold-shock incident, and the number of mortalities which might result from one. In recent years two dilution pumps have been operated during the fall and winter to reduce temperatures in the discharge canal and Oyster Creek and, thereby, discourage fish from overwintering. In the event of a shutdown, dilution water pumping is stopped immediately, delaying the cooling of heated water in the discharge canal. Heated discharge from the FRNGS in the winter should further mitigate cold-shock mortality of overwintering populations.

Barnegat Bay is a spawning and nursery area for many fish and these activities occur throughout the central bay. The exclusion of some fish species from Oyster Creek during the summer months has not adversely affected maintenance of the fish communities. The area of the thermal discharge from which exclusion is possible will not impinge on any critical spawning and nursery areas in the estuary.

The thermal plume will not preclude the dispersal of fish populations throughout the estuary (exclusive of the mixing zone during summer) or access to the ocean via Barnegat Inlet. Some fish which are attracted to Oyster Creek, especially in the fall, may have their migration to the ocean delayed or stopped. These individuals, however, only represent a small part of the large coastal populations from which they are derived, and no adverse impact should occur on the overall populations along the coast.

The small increase in temperature during winter (0.25°C, 0.45°F), a slight temperature decrease during the summer, and slightly increased salinity (1 ppt) associated with the FRNGS discharge should not affect the distribution or increase the mortality of organisms in Oyster Creek during any season of the year.

1.4.3 Section 316(b) - Impingement and Entrainment Effects

Section 316(b) of the Federal Water Pollution Control Act 33 U.S.C. Section 1326(b) authorizes establishment of requirements for the location, design, capacity, and construction of cooling water intake structures as part of standards set under sections 301 and 306 for permitted point sources. It requires that intake structure requirements be established so as to "minimize adverse environmental effects" through application of "best technology available."

In the context of 316(b) an adverse environmental impact, or effect, refers to the impingement or entrainment of aquatic organisms. In this case, it may be defined as one causing a reduction in the diversity, composition, or abundance of constituent populations in the aquatic community that is greater than naturally occurring variations.

Changes in an existing intake structure may be required only where an adverse environmental effect is demonstrated. The concept of "minimizing" adverse effect suggests two levels of inquiry. First, the impact of the intake structure on the population should be assessed. If no gross population effects are shown, then the effect of the impact on individuals should be considered. Changes may be required to an intake under Section 316(b) only to the extent that they are practical and are cost effective, in relation to the impact demonstrated and the benefits to be obtained by a change.

It is JCP&L position that the intake structure for OCNGS has not had an adverse effect on the aquatic community of Barnegat Bay. Mortalities to individual organisms have occurred in relatively large number, both as a consequence of impingement and entrainment, but have not been consequential to the bay's populations. The operation of FRNGS will cause some additional mortalities, but these are not expected to add to the impact of OCNGS such that any adverse effect on the populations is observed. Alternative intake systems to mitigate intake impacts on individual organisms have been, and are now being investigated by JCP&L. At the present time, no cost-effective modifications have been demonstrated to reduce entrainment mortalities. A modification of the travelling screens--the so-called "Ristroph" system of fish handling--is under testing at OCNGS and shows promise of reducing impingement mortalities. If it proves effective and operationally feasible, it will be adopted. The present FRNGS design already includes the Ristroph system. No other alternatives have been demonstrated as available and cost effective.

Biological data collected between 1975 and 1977 indicate that the composition, diversity, and seasonal succession of the indigenous aquatic community in the bay are not significantly affected by impingement and entrainment at the OCNGS. Changes in constituent populations of the bay are within the range of natural variations of estuarine populations. Fluctuations of populations in the estuary approximate those of comparable, relatively unstressed estuaries having a balanced, indigenous aquatic community.

Some organisms are more greatly affected by impingement than entrainment, whereas others are more susceptible to entrainment. Fish which seasonally migrate into the bay and do not utilize it for spawning, for example, are more susceptible to impingement than entrainment. Fish populations in Barnegat

Bay which fall into this category include the Atlantic menhaden, striped bass, bluefish, weakfish, spot, northern kingfish, striped searobin, smallmouth flounder, and summer flounder. The alewife and the blueback herring spawn in tributary streams and, therefore, their early life stages are not susceptible to entrainment. In regard to zooplankton and most macroinvertebrate populations, however, the greatest impact of the OCNGS, and potentially the greatest effect of the FRNGS, is through entrainment of one or more life stages of an organism through the cooling water system. Other fishes such as the Atlantic silverside, threespine stickleback, northern puffer, and the winter flounder undergo both intake effects at different life stages: juveniles and adults are impinged on intake screens, and early life stages are entrained through the cooling water system. The relative significance of either effect is species specific: for example, for the northern pipefish and the winter flounder, entrainment appears to have the greater effect, whereas, for the Atlantic silverside, impingement seems to cause the larger impact.

Impingement

The most abundant fish and macroinvertebrates impinged from September 1975 through August 1977 were (in numerical order) the blue crab, the sand shrimp, the bay anchovy, the grass shrimp, the Atlantic menhaden, spot, the Atlantic silverside, the smallmouth flounder, the striped searobin, and the blueback herring. Approximately 13 million individuals were impinged, with invertebrates comprising 79 percent and fish 21 percent of all impinged organisms. Most impingement (83 percent) occurred at night, and the impingement of most fishes occurred during seasonal migrations rather than when they were most abundant in the bay. Most fish were impinged, therefore, when water temperatures were seasonally increasing (spring) or decreasing (fall) because the movement of fish into and out of the estuary was correlated with changing water temperature.

For seven comparable months of 1976 and 1977, the estimated number of impinged organisms for 13 of 16 species studied was significantly different. Some of the larger differences were recorded for the grass shrimp (373,288 specimens impinged in the seven months in 1976; 29,885 in 1977), the sand shrimp (3.3 million; 600,278), the blue crab (5.6 million; 230,691), the Atlantic menhaden (17,788; 94,960), the bay anchovy (1.8 million; 147,202), the bluefish (14,086; 3,935), the smallmouth flounder (8,022; 57,713), and the winter flounder (3,908; 18,618). Some of these differences may be due to variables in OCNGS operation, but most were attributable to natural fluctuations in the abundance of the populations.

Population surveys were made in the central bay to determine the percent of the standing crop lost through impingement at the OCNGS during a month. These ranged from 2 percent to 10 percent for the bay anchovy, from 0.6 percent to 3.6 percent for the blue crab, and less than 1.5 percent for the northern pipefish, winter flounder, and sand shrimp. These values are very low, and reflect the minimal impact of impingement on bay populations.

Although the effect of impingement losses has not been discernible on the fish populations, the number of individuals lost through impingement at OCNGS has been relatively large. If Ristroph screens were installed at OCNGS, the immediate survival of impinged organisms should be from 1.5 to 13.2 times greater than with the present vertical travelling screens. Estimates of survivability are based on data for similar species of fish impinged on a similar fish handling system at VEPCO's Surry Station. Blueback herring, for example, experienced 65 percent immediate mortality with existing screens, but only 9.6 percent immediate mortality is projected with Ristroph screens. For other species the reductions in mortality should be of a similar magnitude: Atlantic menhaden (88 percent immediate mortality on existing screens, 5.1 percent projected for Ristroph screens); bay anchovy (96 percent, 18 percent); Atlantic silverside (55 percent, 6 percent), bluefish (54 percent, 14.7 percent); weakfish (61 percent, 41 percent); and spot (59 percent, 3.3 percent).

FRNGS already is designed to use Ristroph screens on its intake. Since the FRNGS intake with two Ristroph screens will circulate only approximately 40,000 gpm, the number of organisms impinged at the FRNGS will be substantially less than that impinged at the OCNGS (six screens; 460,000 gpm). With Ristroph screens in operation at FRNGS and the present screen system at OCNGS, impingement losses for both stations would not be greater than 1.09 times the impingement mortality rate of the present OCNGS intake. With Ristroph screens in operation at both the FRNGS and the OCNGS, the losses at both generating stations should be below the losses observed at the OCNGS from September 1975 through August 1977. Because the losses at the OCNGS from 1975 to 1977 did not have a demonstrated effect on the balanced, indigenous community, impingement losses with both stations in operation should not adversely affect the community.

Entrainment

Zoo- and ichthyoplankton samples were collected from September 1975 through August 1977 at the intake and discharge of the OCNGS Cooling Water System to estimate the species composition, abundance, and mortality of organisms passed through the circulating water system (four pumps; 460,000 gpm). A total of 5.16 x 10^{13} microzooplankton (zooplankton 500 microns in length) were entrained through the OCNGS during the ten months that the OCNGS circulated water during 1975-76, and 4.03 x 10^{13} were entrained during the eight months sampled in 1976-77. Most (78 percent) of the microzooplankton entrained were holoplankton (organisms that are planktonic for their entire life cycle). Copepods represented 89 percent of the holoplankton entrained, with *Acartia clausi*, *A. tonsa*, and *Oithona colcarva* (*brevicornis*) the predominant species. Meroplankton (organisms that spend only a portion of their life cycle or daily activity in the water column) accounted for 22 percent of the entrained microzooplankton; larvae of barnacles (33 percent of all meroplankton), polychaetes (27 percent), gastropods (13 percent), and bivalves (12 percent) were the dominant meroplankton.

Meroplankton stages (egg, cleavage, trochophore, straight hinge, and umbo stage larvae) of the economically important bivalve *Mercenaria mercenaria* were entrained at the OCNGS. Because the species spawns predominantly in the summer months, most eggs and larvae of the clam are entrained during this season. In 1976, 1.14 x 10^{11} straight-hinge and umbo stage larvae were entrained, and in 1977, 1.86 x 10^{9}. The difference in the number entrained in the two years was due to shutdown of OCNGS from May through mid-July 1977. The number of eggs and trochophore larvae entrained could not be determined because of the inability to identify these stages to the species level.

One hundred and eighty five macrozooplankton forms were entrained at the OCNGS from September 1975 through August 1977. An estimated total of 4.25 x 10^{11} macrozooplankton (zooplankton 500 microns in length) were entrained during the ten months sampled during 1975-76 and 9.98 x 10^{10} during the eight months sampled during 1976-77. Only the number of *Oxyurostylis smithi*, *Ampelisca* spp., gravid *Mysidopsis bigelowi*, mud crab zoeae, grass shrimp and sand shrimp entrained were not significantly different between the two years. Differences in the number entrained between years probably reflects real differences in abundance each year or the large range of variability found when sampling similar plankton populations.

A total of 28 species of ichthyoplankton was entrained at the OCNGS from September 1975 through August 1977. During the first year of sampling in 1975-76, eggs of the bay anchovy (96.1 percent of all entrained eggs) and cunner (1.4 percent) were the dominant eggs entrained. The most commonly entrained larvae and juveniles at this time were the American eel (2.4 percent of entrained larvae and juveniles), the bay anchovy (48.4 percent), the northern pipefish (2.0 percent), the sand lance (13.1 percent), gobies (22.8 percent), and winter flounder (8.9 percent). During the second year of sampling in 1976-77, eggs of the bay anchovy (89.7 percent), were again dominant and tautog (3.0 percent), and cunner (4.8 percent) eggs also were common. Larvae and juveniles of the bay anchovy (54.9 percent), the northern pipefish (1.4 percent), the sand lance (3.4 percent), gobies (8.4 percent), and the winter flounder (29.2 percent) were the most common larvae and juveniles entrained.

Although losses of zoo- and ichthyoplankton occurred as a consequence of entrainment through the OCNGS, the species composition, distribution, and seasonal succession of invertebrate and fish communities in Barnegat Bay apparently has not been affected. The microzooplankton populations in the bay are similar to those in other estuaries in the northeastern United States. As in most zooplankton populations, the holoplankton, the dominant microzooplankton, are resilient and losses from a point source do not usually reduce these populations in estuaries.

In the case of the economically important species, Mercenaria mercenaria, entrainment of eggs and larvae at the OCNGS should not affect adult populations in the bay. Based on the comparison of heat-shock experiments conducted in the laboratory with operating conditions at the OCNGS, most cleavage-stage eggs and about 50 percent of the trochophore larvae of M. mercenaria entrained during the summer of 1976 probably died. Mortality of straight-hinge and umbo larvae probably was less than 10 percent, and at least 1.03×10^{11} straight hinge and umbo larvae survived passage through the OCNGS. With such a high survival, successful recruitment of this species in the bay should not be adversely affected by OCNGS operation.

Although some losses of entrained macrozooplankton have occurred, no major changes were apparent in this community due to operation of the OCNGS. The number of a form entrained during a 12-hour period was compared to the estimated number of the form in the bay. For most (70 percent) comparisons, the number entrained was less than 5 percent of the estimated number in the bay, and, for about half the comparisons, it was less than 2 percent. Zoeae of Hyppolyte spp., Upagebia affinis, Panopeus herbstii, Neopanope texana, Pagurus spp., Libinia spp., the sand shrimp, the blue crab, and adults and juveniles of the mysid Mysidopsis bigelowi had more than 5 percent of the number in the bay entrained during a 12-hour period on some days and less than 5 percent on others. This variation in percentage was attributed to the variable distribution of these forms in the bay. It is concluded that these losses have not caused any observable variations in the bay populations in as much as the bay's populations have remained similar in structure to those in Great Bay.

Similarly, the fish community in the bay has not experienced any variation in species composition or abundance that may be attributable to entrainment losses at the OCNGS. Changes in the relative abundance of some fish that reproduce in the bay also were noted for other southern New Jersey and mid-Atlantic estuaries. These changes in Barnegat Bay were attributed to natural population fluctuations and environmental factors that affect those populations throughout the mid-Atlantic area rather than to OCNGS entrainment losses.

Operation of the FRNGS should not alter existing conditions for macrozooplankton. Based on 1977 survey data, the additional percentage of forms that would be entrained at the FRNGS during a 12-hour period range from 0.1 percent to 3.2 percent of the forms in the central bay. Megalopae of the blue crab may experience greater losses at the FRNGS than at the OCNGS because most zoeae survive entrainment at the OCNGS. Macrozooplankton losses, however, will be small (0.1 percent of those in the bay) and should be inconsequential.

The number of eggs and larvae (ichthyoplankton) lost in the FRNGS cooling tower should be about 8.7 percent of those entrained at the OCNGS, and these losses ranged from 0.1 percent to 1.9 percent of the number in the central bay. These incremental losses from operation of FRNGS will not adversely affect the populations of zoo- and ichthyoplankton in the bay.

Chapter 2

CHAPTER 2: HYDROTHERMAL CONSIDERATIONS

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The biological, physical, hydrological, and meteorological characteristics of Barnegat Bay, Oyster Creek, and the Forked River are described in Appendix A and summarized in Chapter 1. Appendix B portrays the thermal plume survey data, and reports on the circulation studies and thermal modeling efforts. This chapter summarizes the studies and data presented in Appendix B in the following manner: describes the water temperature regime in Barnegat Bay and the extent of the thermal plume discharged from OCNGS, discusses the plume structure and configuration from the operation of OCNGS and FRNGS, and compares the observed and predicted plumes with the currently applicable New Jersey Surface Water Quality Standards for temperature (N.J.A.C. 7:9-4.6(d)(2)((vi)).

2.1 Temperature Distribution in Oyster Creek and Barnegat Bay

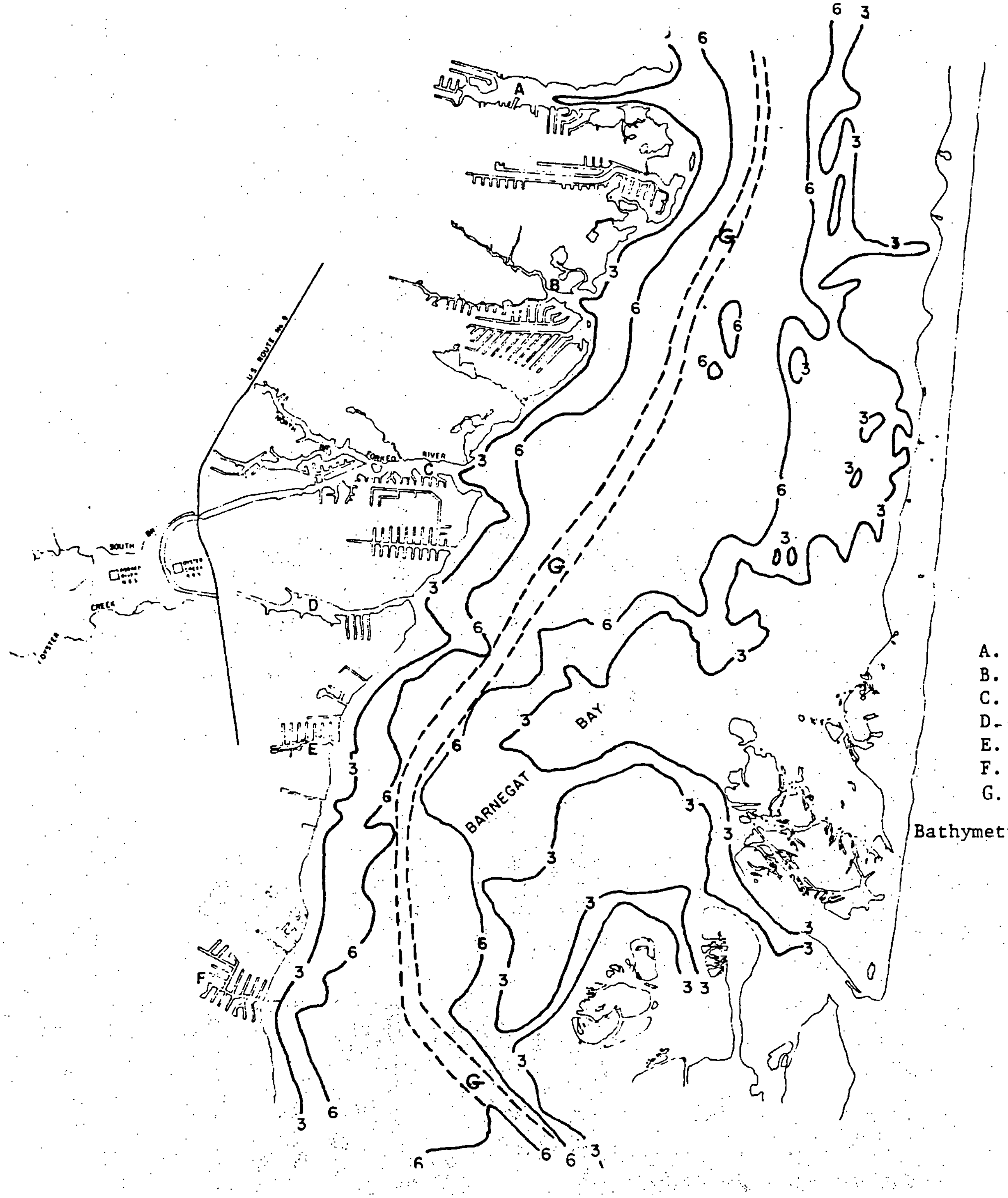
Barnegat Bay dissipates heat to the atmosphere by back radiation, evaporation, and conduction, and receives heat primarily through short wave solar radiation and long wave atmospheric radiation. Aquatic heat fluxes occur in Barnegat Bay due to wind induced circulation exchanges with surrounding water bodies as well as tidal induced circulation exchanges with the ocean, primarily through Barnegat Inlet and secondarily through the Point Pleasant canal and Manahawkin Bay. The components of Barnegat Bay's heat budget depend on the temperature of the ocean water entering from Barnegat Inlet and the Point Pleasant canal, the temperature of the water entering Barnegat Bay through Manahawkin Bay, the temperature of the freshwater entering from the many streams along the western boundary of the bay, and the surface heat exchange and heat rejection by OCNGS.

Barnegat Bay is a long and relatively narrow estuarine embayment with shallow areas on the eastern and extreme western boundaries and a relatively deep dredged waterway along the western shore (Figure 2.1-1). Navigation channels connect the deeper portion of the bay with Barnegat Inlet, and results in strong tidal velocities in the narrow inlet and channel. Because of the general shallowness of Barnegat Bay, the circulation of the bay is largely dependent upon meteorological processes. Tidal forces are of relatively minor importance. The exchange of ocean and bay water, coupled with low velocity southeasterly winds, produces density stratification in Barnegat Bay during summer months. Periods of high winds produce a vertically homogeneous water body. The circulation pattern in the bay was analyzed by Pritchard-Carpenter (1963) using dye distribution studies (Addendum B1).

Horizontal salinity gradients are marked during summer months. Differences of 15-20 ppt exist on the surface between the Toms River, the northern portion of the bay and Barnegat Inlet.

Because of the interplay of hydrology and meteorology, the distribution of ambient temperatures in the bay is complex. Shallow areas of the bay respond rapidly to ambient air temperature and wind conditions. Rapid heating and cooling of the shallow areas substantially contribute to the heat budget in the bay. Natural temperature variations within the bay have magnitudes similar to that of the excess temperature magnitudes from the operation of OCNGS. Temperature changes of 5-10°C (9-19°F) can occur in periods of less than a week in the spring and fall months (Appendix A1).

Significant temperature gradients are geographically observable on a daily basis. Temperatures increase from the ocean to the bay during periods of increasing ambient air temperature but decrease during periods of decreasing air temperature. Spatial gradients of 5°C (9°F) have been observed in areas of the bay unaffected by OCNGS (Appendix B3 and Addendum B3). Relatively deep and narrow lagoon complexes located on the shores of the bay undoubtedly contribute to the heat budget when they exchange with the bay.



KEY

A. Cedar Creek
B. Stouts Creek
C. Forked River
D. Oyster Creek
E. Waretown Creek
F. Lochiel Creek
G. Intracoastal Waterway

Bathymetry of Barnegat Bay

FIGURE 2.1-1

2.2 Thermal Plume Distributions

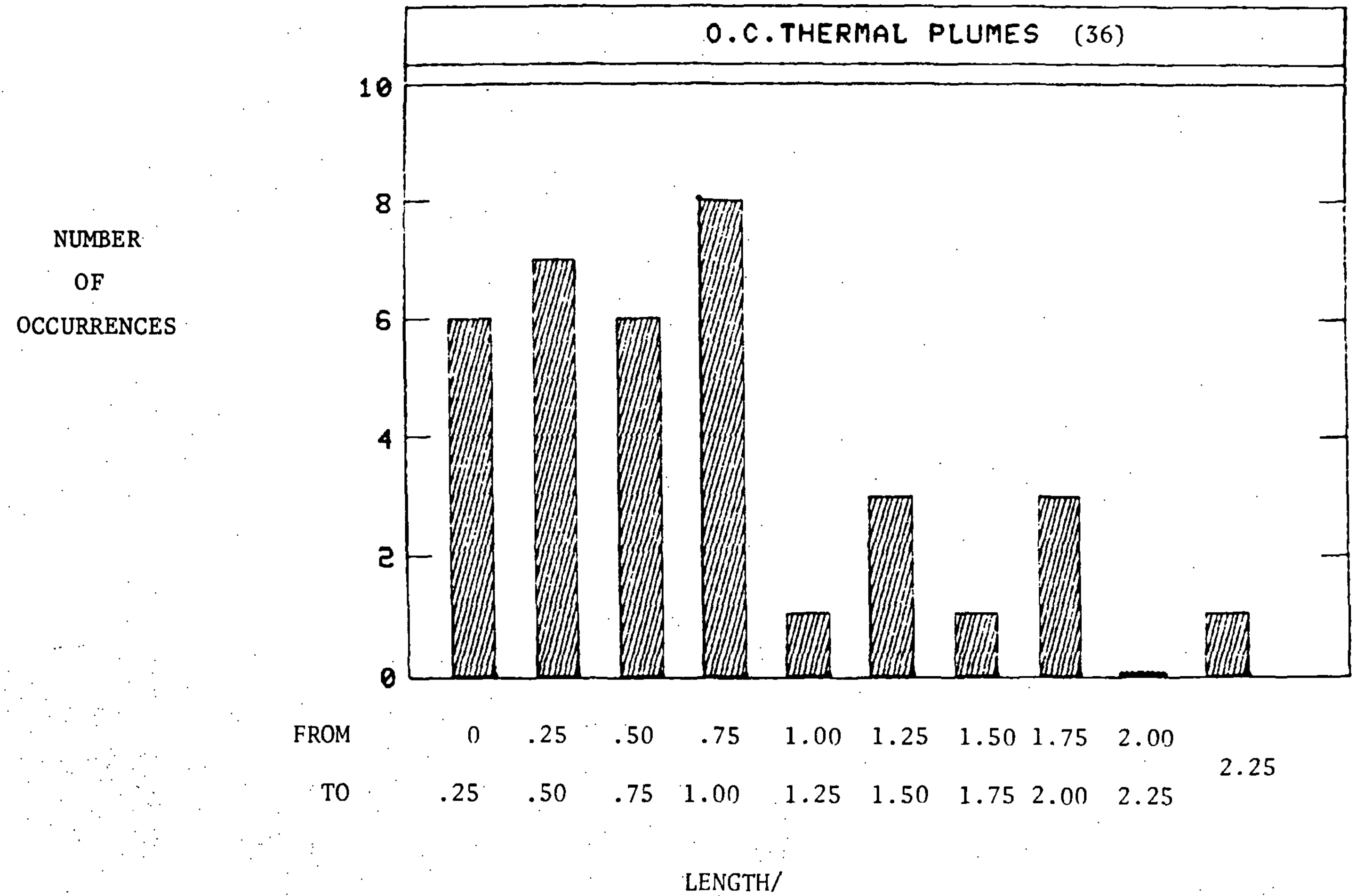
Because of the complexity of factors affecting heat distribution and dissipation in the bay, a variety of different techniques have been necessary to determine the extent of contribution by OCNGS to elevated bay temperature. Dye studies conducted by Pritchard-Carpenter (Appendix B2, Addendum B1) prior to OCNGS operation provided the first look at the bay's complex circulation and a prediction of the configuration and behavior of the OCNGS' thermal plume. Since 1969, 59 direct measurements of the thermal plume have been made by several investigators. Sandy Hook Marine Laboratory conducted 26 thermal surveys in 1969, 1970 and 1971 (Appendix B, Addendum B2). In 1973, U.S. EPA conducted an aerial infrared survey of surface temperatures. Woodward-Clyde Consultants reported on 15 thermal plume surveys performed in 1974 and 1975 (Appendix B, Addendum B3). JCP&L conducted 17 surveys in 1975 and 1976 (Appendix B, Addendum B4 and B5).

From the surveys conducted, three rather different thermal regimes can be observed in Oyster Creek and Barnegat Bay. In Oyster Creek, initial mixing of the condenser discharge with dilution water routed around OCNGS produces a reduction in discharge temperature of between 2.8 to 6.1°C (5 to 11°F) depending upon whether one or two dilution pumps is operating; little temperature decay is observable east of U.S. Route 9 until the discharge reaches Barnegat Bay. Little horizontal or vertical temperature difference is found in Oyster Creek between U.S. Route 9 and the bay because of the relatively short residence time and the lack of turbulence and additional dilution. In Barnegat Bay, temperatures are rapidly reduced as substantial mixing with ambient temperature bay water and heat rejection to the atmosphere occurs. In the bay, the plume spreads on the surface, thereby abetting atmospheric heat rejection. Thus, there is a very small area near the OCNGS condenser discharge of relatively high excess temperature in which turbulent dilution mixing produces rapid temperature reductions; a somewhat larger area in Oyster Creek between OCNGS and Barnegat Bay in which little further temperature reduction occurs; and a still larger area in the bay in which the plume spreads on the surface.

About 150 m (164 yds) in the bay east of Oyster Creek the water depth decreases from approximately 3.4 m to 1.5 m (11 ft to five ft), causing turbulence and mixing and directing the plume toward the surface. In general, excess temperatures do not impinge on the bottom on the bay except in the area immediately adjacent to the mouth of Oyster Creek. Shoreline plumes extend from the surface to the bottom since the water depths are usually less than 1.5 m (five ft). In Barnegat Bay, the plume occupies a relatively large surface area with low excess temperatures where the balance of the heat discharged by OCNGS is dissipated to the atmosphere or diluted by entrained bay water. The surface excess temperature isotherm of 2.2°C (4°F) under all operating conditions is contained in a rectangle approximately 1.6 km (one mi) along the east-west axis and 5.6 km (3.5 mi) along the north-south axis bounding the mouth of Oyster Creek. For the 0.8°C (1.5° F) isotherm, the rectangle is 2.4 km (1.5 mi) by 7.2 km (4.5 mi). With the exception of the USEPA infrared over flight discussed in Appendix B, no plume depicted the 0.8°C (1.5°F) isotherm beyond one-half the width of Barnegat Bay. All plumes exhibited a plume length of approximately two to three times their width (Figure 2.2-1).

FIGURE

LENGTH/WIDTH RATIO OF THERMAL PLUMES



2.3 Thermal Plume Modeling Results

Because of the difficulty encountered in separating excess temperature produced by OCNGS from natural temperature variations, an excess temperature model was produced for OCNGS and FRNGS for separate and combined operations. Employing a two-dimensional, vertically averaged, steady state model, plume configurations were simulated for west, south, north, and no wind conditions with varying pumping from OCNGS and FRNGS. The model overestimates excess temperature due to simulation of mean low water levels in the bay and low atmospheric heat transfer rates. Excess temperature plume configurations were depicted horizontally for the surface and vertically along a cross-section from the Oyster Creek mouth to Sedge Island (the narrowest extent of the bay measured from the mouth of Oyster Creek). All simulations were done under full OCNGS and FRNGS loads, when either or both stations were in operation.

In general, the results of the model were consistent with those obtained in thermal plume surveys regarding plume orientation. All plumes simulated were relatively similar, but the areal distributions portrayed had much larger areas of excess temperature than all but one of the plume survey measurements, indicative of the very conservative nature of the model.

Near field heat dissipation in the OCNGS discharge canal and Oyster Creek was predicted to negligible: less than 7 percent. When OCNGS is in operation the predicted far field excess temperature region varies slightly with the number of dilution pumps in operation (one or two), but not at all with the addition of FRNGS. The maximum predicted extent of the plume to the 2.2°C (4°F) isotherm is less than 25 percent of the cross-sectional area and surface width measured at the narrowest extent of Barnegat Bay from the mouth of Oyster Creek.

The model results depict a relatively constant surface area covered by the excess temperature field from the OCNGS and FRNGS thermal plume. Since the model was a steady state model, temporal variations in wind speed and direction were not incorporated, although steady wind conditions were simulated. The plume configurations are clearly dependent upon the circulation pattern in Barnegat Bay and the circulation is due in large part to the force of the wind stress. The effect of the atmospheric heat transfer on the distribution of excess temperature was found to be minimal due to the relatively shallow nature of the bay. Lower atmospheric heat transfer did result in larger areas for the thermal plume, particularly greater extents in the north-south axis of the plume.

2.4 Recirculation Analysis

Under certain wind conditions the thermal plume will be oriented from the mouth of Oyster Creek in a northeasterly direction and allow excess temperatures to enter the mouth of the Forked River and be transported to the intake of OCNGS and FRNGS. Based upon observed thermal plume behavior relative to wind speed and direction, this configuration which is necessary for recirculation to occur, would have a frequency of less than 4 percent on an annual average basis. Of approximately 59 thermal plume measurements conducted, only eight of the surveys (14 percent) had detectable recirculation, i.e., greater than 0.8°C (1.5°F).

Thermal model simulations which were conducted under four different wind conditions indicated recirculation of some excess temperature greater than 0.8°C (1.5°F) would occur. The highest observed recirculation at the intake was approximately 1.7°C (3.0°F), the lowest was 0.9°C (1.6°F). The highest value would reoccur approximately 3 percent of the time on an annual basis. The results of the modeling indicate that thermal recirculation of 0.6 to 1.1°C (1 to 2°F) would recur as much as 70 to 80 percent of the time on an annual average basis. Because of the conservative nature of the model the latter percentages are considered to be high. The effects of recirculation were considered in predicting the thermal plume.

Radiological studies of the distribution of reactor product nuclides in the sediment in the discharge and intake canal have been conducted by the USEPA and the NJDEP. Based upon the distribution of Mn_{54} and Co_{60} these investigators have concluded that on an average annual basis, recirculation of discharge waters into the intake canal occurs on the order of 18 to 22 percent. The concentration of the nuclides in the water or sediment is indicative of the recirculation of water only and not of the recirculation of heat, but these data provide an upper limit on the amount of heat which could be recirculated.

Considering the above information and recognizing that recirculation of the 0.8°C (1.5°F) isotherm into the mouth of the Forked River is dependent primarily on wind direction, it is concluded that thermal recirculation occurs between 4 and 22 percent of the time, on an annual basis.

2.5 Plume Configuration versus New Jersey Water Quality Standards

The New Jersey surface water quality standards applicable to Oyster Creek and Barnegat Bay set forth two types of limitations to be met by any thermal discharge. First, temperatures in the receiving water outside of a designated heat dissipation area or mixing zone may not exceed 2.2°C (4°F) above ambient temperatures during September through May, or 0.8°C (1.5°F) during June through August. Nor should temperatures exceed 25.4°C (85°F). Second, "as a guideline", a heat dissipation area should not exceed 25 percent of the cross-sectional area of the receiving water or 67 percent of the surface width (N.J.A.C. 7:9-4.6(d)(2)(vi)).

As indicated in N.J.A.C. 7:9-4.6(d)(2)(vi)(C), the guideline limitation for heat dissipation areas is premised upon two assumptions: that a zone of passage is required for free swimming and drifting organisms so that "negligible or no effects are produced on their populations", and that the requisite margin of safety for passage requires 75 percent of the cross-sectional area. In the case of Oyster Creek, however, the assumptions are not borne out and other bases to support the guideline limitation are not apparent. As discussed in Chapter 3, there is no direct evidence of migration up Oyster Creek by anadromous species (i.e., alewife and blueback herring) before or after OCNGS construction and operation. The species which might use Oyster Creek for spawning migrate during spring and would not be blocked except at the very latter stages. However, if Oyster Creek has been used by some individuals for spawning, and were a blockage to occur, the loss of freshwater habitat available for spawning (the area west of the discharge canal and east of the dam for the firepond) would be inconsequential to the habitat available in the bay.

Substantial movement of organisms through the plume in Oyster Creek and Barnegat Bay also has been well documented, with substantial numbers of many species at times preferring the habitat within the plume. Thus, the only species which may require a zone of passage are those washed from traveling screens or secondarily entrained in the plume after being passed through the dilution pumps. Examination of those organisms, however, does not indicate stress or mortality which will have more than negligible impact on populations in the Barnegat Bay area. Accordingly, a special zone of passage need not be maintained in Oyster Creek and the heat dissipation area may extend shore-to-shore.

Biological studies indicate that the plume does not constitute a barrier to migration of either free swimming or drifting organisms in the bay. The movement of organisms occurs during all times of the year, in all but a very small area of the plume having relatively higher temperatures near the mouth of Oyster Creek. At average bay temperatures, the area avoided by free swimming species (when avoidance does occur), and in drifting organisms are subject to stress, is within the 2.2°C (4°F) excess temperature isotherm for all but the young of winter flounder. Exclusion, of this form from the 2.2°C (4°F) excess temperature area may not occur because the plume doesn't impinge on the bottom at depths greater than 1.5 m (5 ft) - the habitat of the young winter flounder. As a consequence, the heat dissipation area may be established in Barnegat Bay to the 2.2°C (4.0°F) isotherm even during the summer months, June through September.

Under average monthly bay temperatures, OCNGS and FRNGS should not produce temperatures in excess of 29.4°C (85°F) in the bay outside the heat dissipation area. However, surface ambient temperatures in excess of 29.4°C (85°F) have been observed occasionally in the bay during summer. At these times the exclusion area may be somewhat greater than that reported previously. However, it should be noted that many fishes naturally avoid warmer areas of the bay during summer (i.e., young winter flounder move out of the shore zone in July and August) and that a somewhat larger exclusion area due to the heated discharge will not affect the propagation and protection of the balanced indigenous community.

Based upon the observed correlation between meteorological conditions and the circulation patterns in the bay, JCP&L reviewed the occurrence of various plume configurations with respect to wind direction, persistence and speed. This confirmed Pritchard-Carpenter's analysis of bay circulation and established that similar plumes do occur under similar wind conditions, principally wind direction. This relationship permits a prediction of the frequency of occurrence of each configuration.

		Expected Occurrence	
Wind Direction	Plume Orientation	Percent Annual	Percent Summer
N to NE	Southwesterly	14	13
WNW to NNW	Southerly	23	13
W, ENE to SE	Easterly	26	25
SSW to WSW	Northeasterly	25	32
SSE to S	Northerly	12	14

From the conservative plume predictions of the model, and the above frequency of occurrence data, it may be concluded that the plume to the 2.2°C (4°F) isotherm will conform with the heat dissipation area guideline under all operation conditions at all times of the year (Figures 2.5-1 to 2.5-5). During June through August, the plume to the 0.8°C (1.5°F) isotherm will exceed the guideline under at least some operating conditions. The maximum plume, that measured southeasterly at the narrowest portion of the bay on a transect from Oyster Creek to Sedge Island, will occur approximately 13 percent of the time during that period, covering less than 50 percent of the surface width and 50 percent of the cross-sectional area as measured at ebb tide. Considering the survey data collected to date, this plume may actually be somewat less in size than predicted, and the 0.8°C (1.5°F) boundary of the plume may be difficult to observe because of naturally occurring temperature gradients in the bay.

FIGURE 2.5-1

FAR-FIELD THERMAL PLUME
RUN # 1 (LMST Ø5)
BARNEGAT BAY

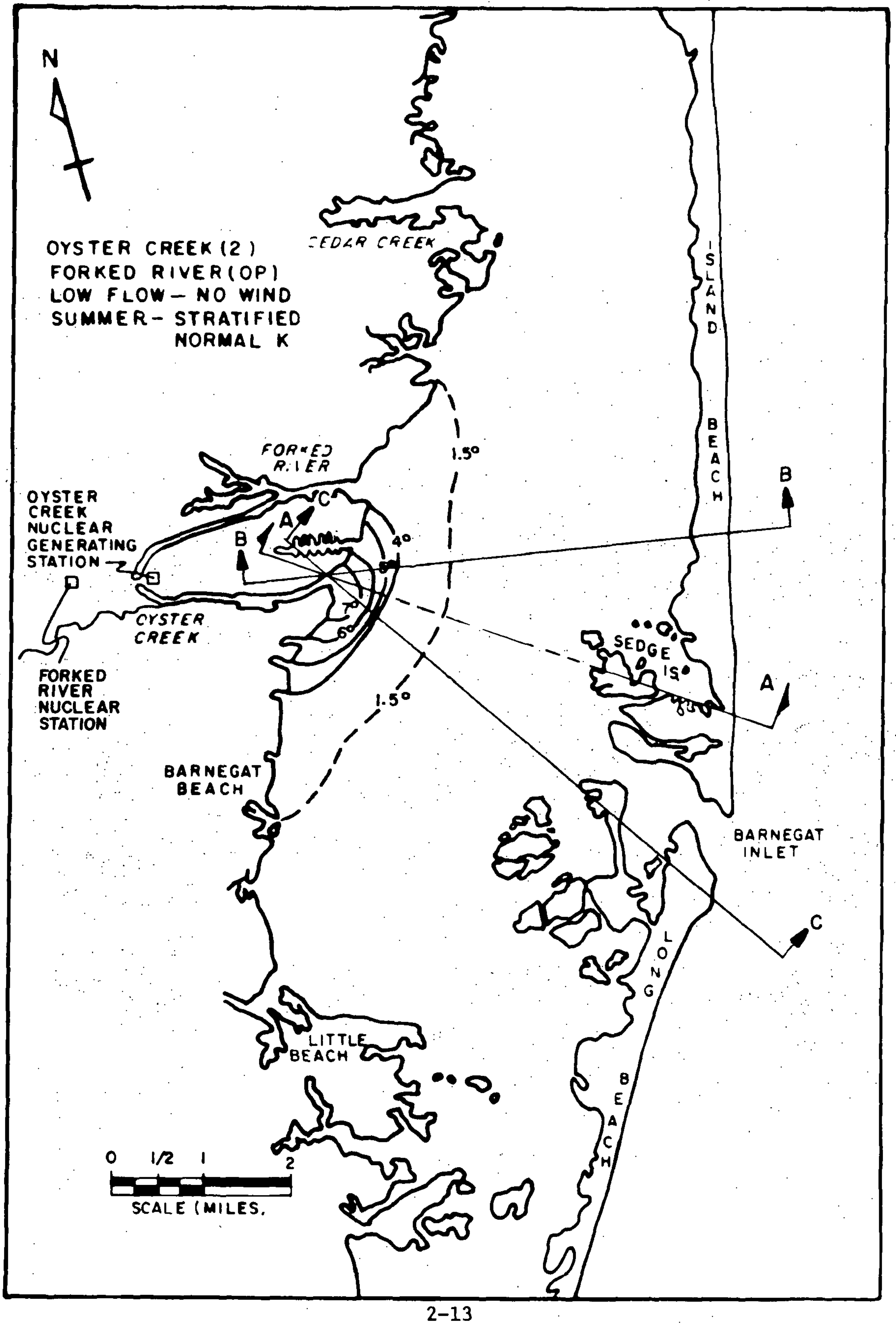


FIGURE 2.5-2

FAR-FIELD THERMAL PLUME
RUN # 3 (LMST 12)
BARNEGAT BAY

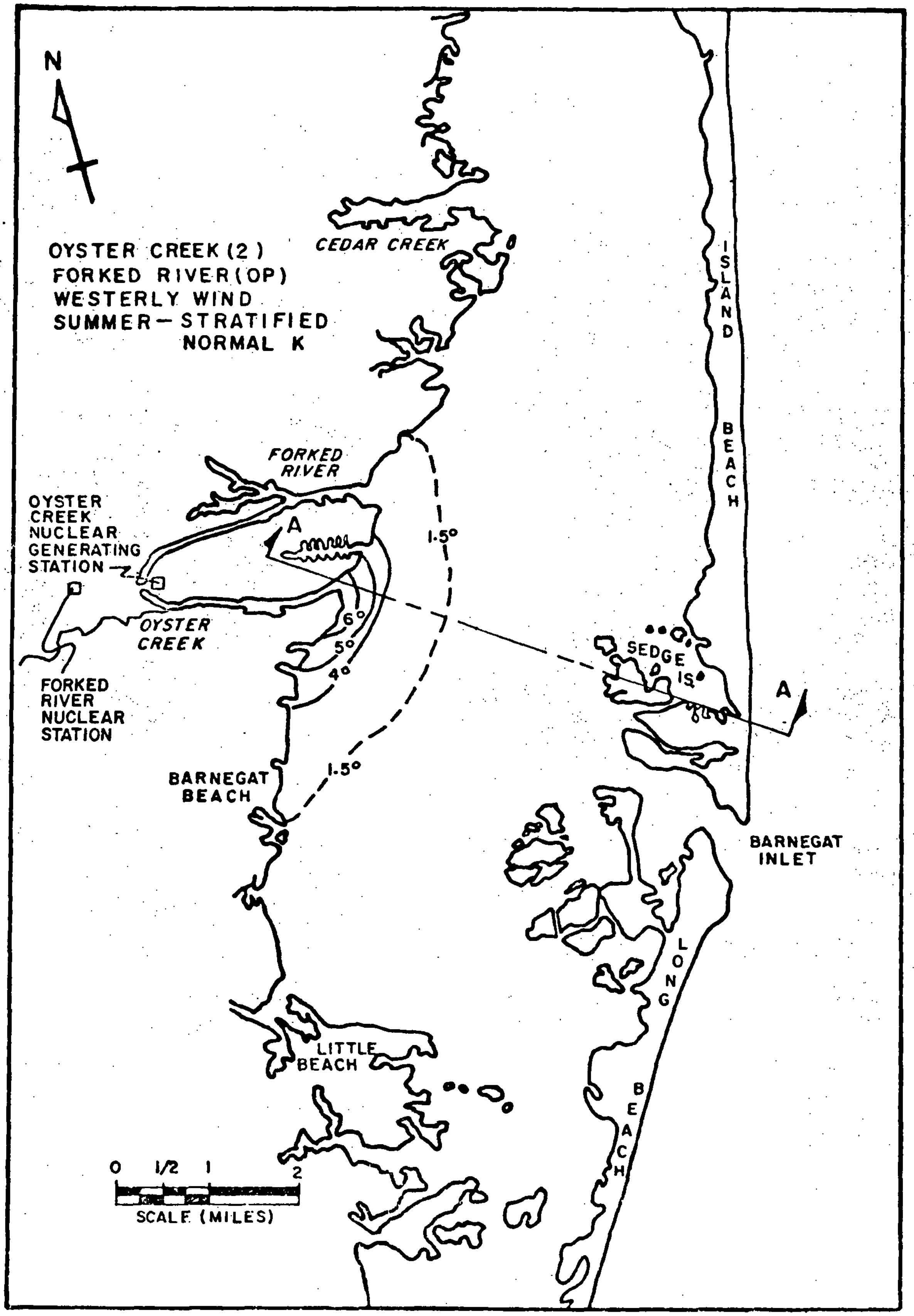


FIGURE 2.5-3

FAR-FIELD THERMAL PLUME
RUN # 5 (LMST Ø8)
BARNEGAT BAY

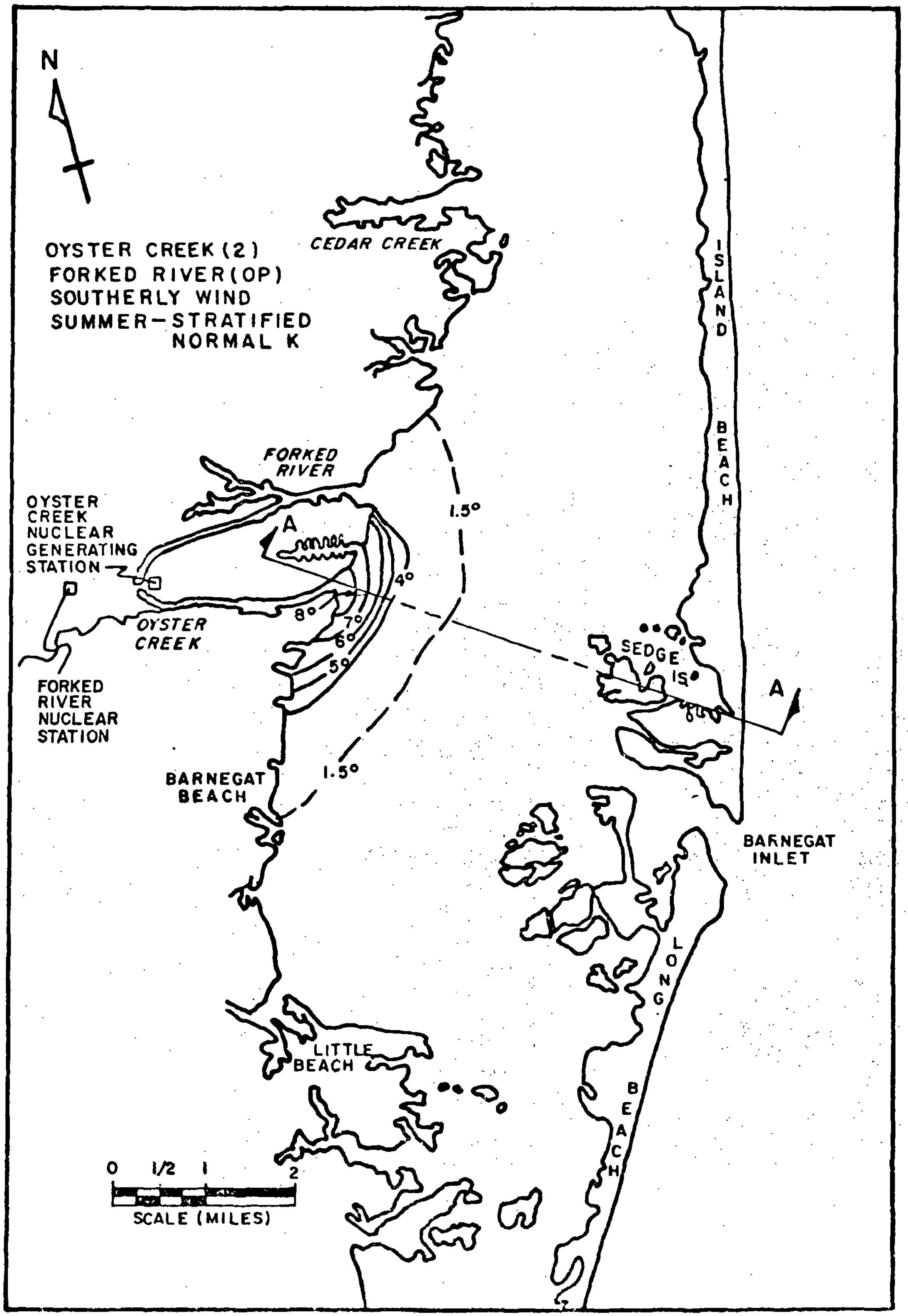


FIGURE 2.5-4

FAR-FIELD THERMAL PLUME
RUN # 6 (LMST II)
BARNEGAT BAY

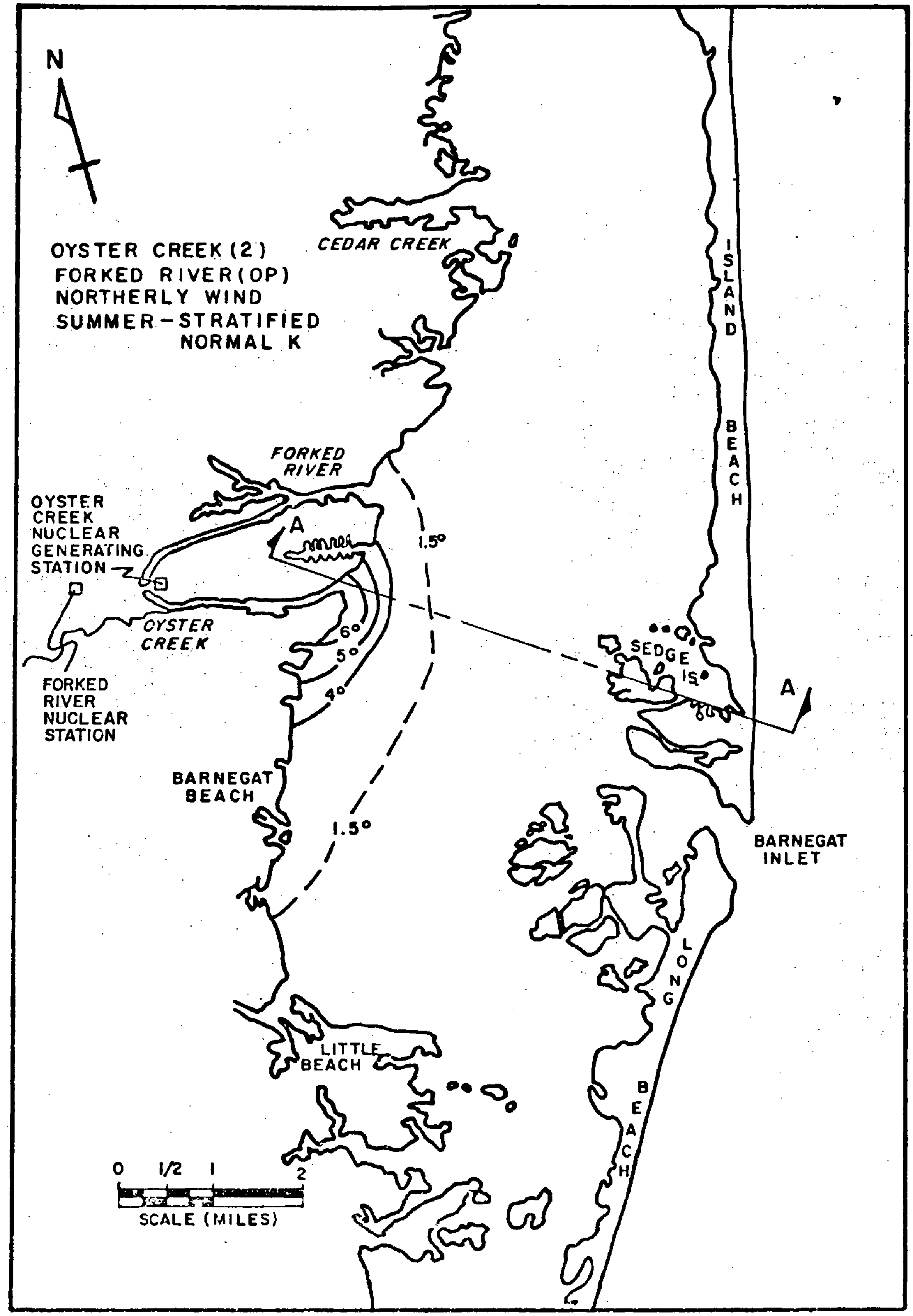
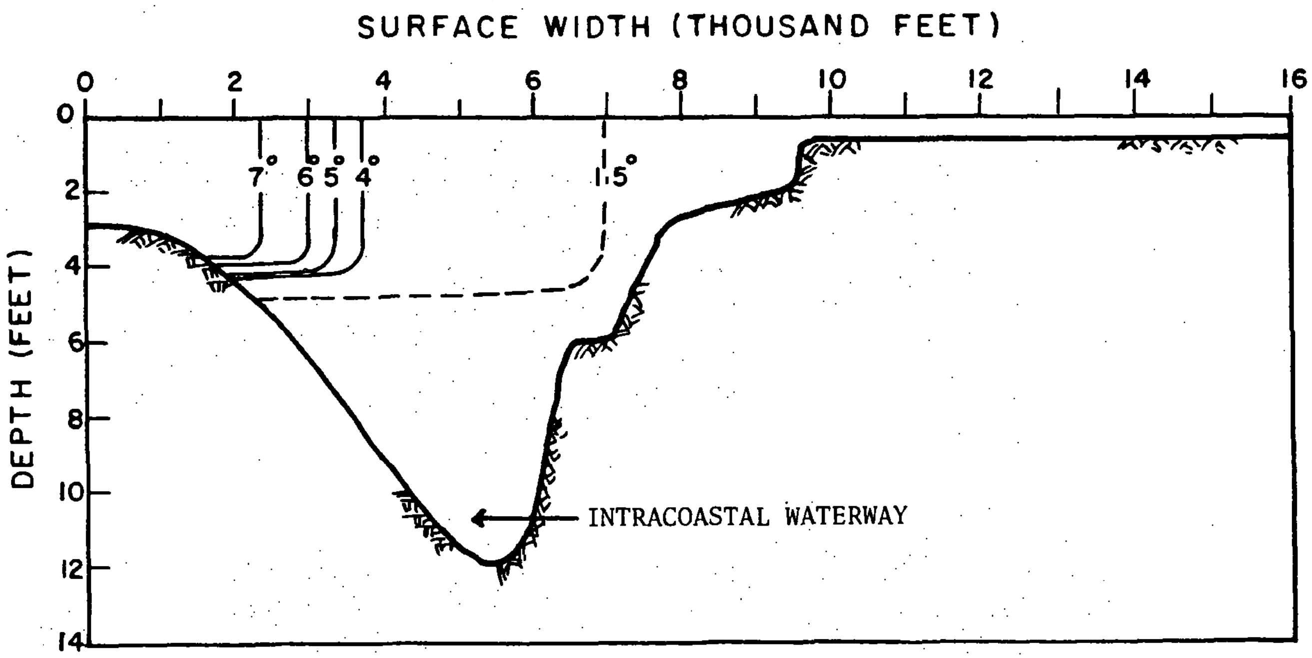


FIGURE 2.5-5

SUBSURFACE THERMAL PLUME AT CROSS SECTION A-A
RUN #1 (LMST05)



Temperatures in °F

Chapter 3

CHAPTER 3: ENVIRONMENTAL EFFECTS OF STATIONS' DISCHARGES Page

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Chapter 3: ENVIRONMENTAL EFFECTS OF THE STATIONS' DISCHARGES

EPA's regulations under Section 316(a) provide two principal tests for determining the effects of a thermal discharge on a balanced indigenous community of fish, shellfish and wildlife: the first, the absence of prior appreciable harm test, is directed towards those stations which already are in operation and for which both pre-operational and operational data on a broad range of aquatic species are available. The second, the representative important species "RIS" test, is an alternative to the first test and is a predictive tool by which to assess the effect of a station not yet placed in operation. The following chapter looks at the aquatic community of Oyster Creek and Barnegat Bay from both test perspectives. Historical, laboratory and literature data on identified representative important species are presented here first to provide a prediction of the continued effect of the OCNGS and the future effect of the FRNGS. Historical data from before and after operation of the OCNGS, the results of recent studies and data on communites in other middle Atlantic estuaries and closed embayments are then melded with the RIS analysis to show that station operation has not caused any significant change in the aquatic community of Oyster Creek and Barnegat Bay.

At the outset, it is important to note that the inquiry mandated in this case by Section 316(a), 303(c) and (g) is relatively limited. In the first instance, the Section 316(a) statutory test focuses only on the maintenance of shellfish, fish and wildlife in the receiving water body. Other trophic levels are significant to a 316(a) determination only to the extent that an effect on species in these levels may result in appreciable harm on the community of shellfish, fish and wildlife. Section 303, including 303(g), limits the state determination and application of water quality standards to the same extent.

Second, Section 316(a)'s reference to a "balance, indigenous" aquatic community simply means a "reasonable maintenance of aquatic biology...." And, it commands reference to the aquatic community as it exists, taking into account such changes in the native or original community as were caused by substantial, irreversible environmental modifications. In the case of OCNGS and FRNGS, these modifications would include the changes to Oyster Creek and the South Branch of Forked River resulting from construction of the intake and discharge canals, and the blockage to movement along the remaining freshwater reach of Oyster Creek by the fire pond dam.

* Senate Committee on Public Works, A Legislative History of the Water Pollution Control Act Amendments of 1972, 93rd Congress, 1st Session (1973), p. 267. Accord, _Id_. at 264.

Apart from its purely predictive aspects, the approach of this demonstration has been to determine whether the community has been functioning within the range of normal variability (i.e., without appreciable adverse effect) of mid-Atlantic estuaries and closed embayments since OCNGS began operation. Three standards of comparison have been used in this analysis. First, recent study results have been compared against those available for studies performed prior to the commencement of OCNGS' thermal discharge. Differences have been analyzed to determine whether they are attributable to the thermal discharge and, if so, their significance to the population of fish and shellfish. This has been difficult to accomplish. A number of different investigators performed studies, in different areas, and with different equipment and methods. To the extent possible, the potential sources of error in the analysis have been taken into account. More importantly, however, not all of the types of study now commonly undertaken were either available or recognized as important prior to 1969. Thus, for some species or biotic catagories data are not available to provide a basis for comparison.

Comparisons also are made between data from sampling inside and outside the influence of the thermal plume. Stations outside the plume, either in streams similar to Oyster Creek or in Barnegat Bay, provide reliable control points for this demonstration. Although Barnegat Bay historically has undergone significant, irreversible changes which have altered its physical and biological characteristics (as discussed in Section 1.1 and Appendix A.1), and may be subject to further changes (such as possible enlargement of Barnegat Inlet) in the future, it is not subject to other significant industrial discharges which would adversely affect its indigenous aquatic community. Some ongoing stresses are apparent in the bay: boating, which may disturb shore vegetation; sewage plant discharges or non-point discharges from septic systems, which may reduce dissolved oxygen levels. There is no evidence that these will have, in conjunction with the OCNGS discharge, any adverse effect on bay populations. Accordingly, no allocation of load between OCNGS and other discharges is required.

Finally, where possible, results from the several studies in Barnegat Bay have been compared to data from other mid-Atlantic estuaries and closed embayments. Several areas have been studied and are used in this respect, including Great Bay and Little Egg Harbor in New Jersey, and the Chesapeake Bay. These data provide a measure of the natural variability of species composition, and relative abundance. They also have been examined to establish population trends of natural variability, which may explain the cause and extent of variations in populations in Barnegat Bay.

The areas of Oyster Creek and Barnegat Bay which have been studied are, of course, material to the conclusions reached in the demonstration. In Oyster Creek and Forked River, studies have been largely confined to the areas east of the points at which the OCNGS intake and discharge canals intersect the South Branch of Forked River and Oyster Creek, respectively. As discussed in Chapter 1 and Appendix A.1, both streams were changed substantially by construction of the OCNGS -- by being deepened and widened and made more open to Barnegat Bay -- such that they are now essentially hydrological and biological extensions of Barnegat Bay. Neither stream in its reconstructed area is now capable of sustaining the type of community which previously was found there and this change is irreversible. In the case of Oyster Creek, however, this change is not a significant loss, since the stream was relatively unproductive and the community was typical of New Jersey's pine barrens streams. West of the intake and discharge canals, both streams continue to support freshwater populations that are typical of streams found in New Jersey's pine barrens.

The construction of the canals has created, in fact, a new habitat for the indigenous populations of Barnegat Bay. The indigenous community of the bay can be maintained and protected through maintenance of its habitat in the bay regardless of what use it can make of these new areas.

Since the population at issue is that found naturally in Barnegat Bay, it is the bay which has been the principal focus of the demonstration study. For various elements of the study, three different areas of the bay have been identified according to the effect which the OCNGS and FRNGS discharges may have. According to the Administrations' decision in <u>In the Matter of Public Service Company of New Hampshire</u>, Case No. 76-7 (1977), the areas which are of importance to a Section 316(a) decision are those "of the coastal waters where human use or enjoyment of the marine resource may be affected". <u>Id</u> at 23. As discussed below the study areas selected by JCP&L are consistent with this criterion.

The area of primary investigation, with respect to the populations of fish and shellfish, has been the central bay, extending from Good Luck Point, approximately nine miles north of OCNGS, to Gulf Point, approximately five miles to the south. Exclusive of the many creek areas having characteristics similar to Oyster Creek and the bay and harboring estuarine populations like the bay's, the central bay has a surface area of 9,816 hectares. Studies here took into account the fact that it is but part of the large area available to estuarine species of Barnegat Bay and central New Jersey, and is interconnected with the Atlantic Ocean. Thus the populations of the study area may be supplemented by recruitment from elsewhere in the bay and from offshore areas (See the Administrator's Seabrook decision at p. 23).

In studying the Teredo spp., the investigators considered their presence throughout Barnegat Bay. A larger study area was required here because not all species of Teredo are found in the immediate area of Oyster Creek, and because of the great variations in abundance and distribution encountered with some species. Additionally, because of the destructive potential of the Teredo spp., JCP&L wished to establish with finality the effect which OCNGS operations has had on bay populations.

The third area is somewhat smaller, extending from Stout's Creek on the north to Waretown on the south, and was the focus of the phytoplankton and benthic studies conducted by Rutgers University. Because the horizontal extent of the thermal plume does not encompass this area, the impact of the thermal discharge on these communities can be described without reference to the larger areas of the bay.

The following chapter is broken down according to the two component parts of the demonstration. Section 3.1 contains the data of the RIS demonstration. Species are discussed individually (Sections 3.1.4 - 3.1.19). In addition to the RIS species, Section 3.1 also contains a discussion of the impact of the discharge on the blue crab (Callinectes sapidus), because of its abundance in the bay and its commercial and recreational importance (Section 3.1.20). An overall rationale for the RIS species is provided in Section 3.1.2. Section 3.2 supports the RIS demonstration by discussion of the observed impact of OCNGS operations on the species of the several biotic categories: Section 3.2.1, Phytoplankton; Section 3.2.2, Zoo- and Meroplankton (Ichthyoplankton), Section 3.2.3, Benthic Macroinvertebrates; and Section 3.2.4, Fish. Rationales for each category are provided. An overall evaluation of both components of the demonstration is provided in Section 1.4. Section 3.3 contains a summary of data documenting the substantial recreational fishery available in Oyster Creek since OCNGS began operation, and Section 3.4 provides a brief description of the populations supported by Forked River and Oyster Creek before and after construction of the intake and discharge canals.

This demonstration does not contain a specific discussion of the effect of the discharges on wildlife. The area of Barnegat Bay near Oyster Creek is not a habitat of or critical significance to aquatic wildlife, and does not support any rare, threatened or endangered aquatic species. The area is part of the Atlantic "flyway" and, migratory waterfowl often are found there during spring and fall. Oyster Creek provides a particularly rich forage area for wildlife at those times. The only other effect of the discharge, also a positive one, is to provide a refuge for non-migrating waterfowl during particularily cold winters, as experienced in 1976-77 and 1977-78 when most of the bay was covered by ice. For these reasons, the area is believed by JCP&L to be one of low potential impact, for which further studies and demonstration are not required.

3.1 Representative Important Species (RIS) Demonstration

The thesis underlying the RIS test is that selected species of the community may be used to represent and predict the discharge effects on the entire aquatic community. Particular attention should be directed toward ensuring the protection of species that are important to human use and enjoyment. Generally, then, RIS designations fall into one of three types: species that are of commercial or recreational importance; threatened or endangered species, or species sensitive to changes in temperature of the receiving waters because they are at the extreme of their range; or species which may be sensitive to thermal discharges, such that if they are protected then there is a reasonable assurance of protection for other species in the study area.

The representative important species (RIS) identified by the Regional Administrator in response to JCP&L's request include six species of macroinvertebrates and ten species of fish. The macroinvertebrates include:

Crangon septemspinosa (sand shrimp)
Neomysis americana (mysid shrimp)
Mercenaria mercenaria (hard clam)
Corophium tuberculatum (amphipod)
Hydroides dianthus (tubicolous Polychaete worm)
Teredo spp. (shipworms)

The fish species are:

Brevoortia tyrannus (Atlantic menhaden)
Anchoa mitchilli (bay anchovy)
Gasterosteus aculeatus (threespine stickleback)
Morone saxatilis (striped bass)
Pomatomus saltatrix (bluefish)
Cynoscion regalis (weakfish)
Menticirrhus saxatilis (northern kingfish)
Paralichthys dentatus (summer flounder)
Pseudopleuronectes americanus (winter flounder)
Sphoeroides maculatus (northern puffer)

The macroinvertebrates, including shellfish, serve a variety of functions in an estuarine system such as exists in the Oyster Creek and Barnegat Bay area. Such species as *Crangon septemspinosa* (sand shrimp), *Neomysis americana* (mysid shrimp) and *Corophium tuberculatum* may be elements of the aquatic food web, providing forage for species of higher trophic levels.

Of the designated RIS macroinvertebrates, Mercenaria mercenaria (northern quahog or hard shell clam) is the only species of direct recreational and commerical importance. However, because of its importance and abundance in the bay, this section also will address the effect of thermal discharges on Callinectes sapidus (blue crab).

Two of the macroinvertebrates, Hydroides dianthus (a tubicolous polychatete worm) and Teredo spp. are fouling organisms that are not of direct importance to the "shellfish, fish and wildlife" test of Section 316(a). The species may be of significance only if a change in their populations may affect indirectly the population of fish and shellfish in the bay.

Eight of the ten fish comprising the representative important species list are of commerical or recreational importance along some areas of the New Jersey coast. Included among these eight Brevoortia tyrannus (Atlantic menhaden), Morone saxatilis (striped bass), Pomatomus saltatrix (bluefish), Cynoscion regalis (weakfish), Menticirrhus saxatilis (northern kingfish), Paralichthys dentatus (summer flounder), Pseudopleuronectes americanus (winter flounder) and Sphoeroides maculatus (northern puffer). Anchoa mitchilli, (bay anchovy) represents important forage for commercial and sport fishes, and it is the most abundant fish in the bay. Gasterosteus aculeatus (threespine stickleback), is an estuarine spawning species which is not recreationally or commercially important.

3.1.1 Decision Criteria

To determine the effect of the thermal discharge on the community, the response of the RIS to the thermal discharge was evaluated by two methods. The first method is predictive and discusses the thermal tolerances of the life stages of each RIS in relation to the projected thermal plume. The time and extent that these species will be excluded from the thermal plume and the stress of secondary entrainment into the plume were determined. These thermal responses were either established from the literature, or measured in the laboratory (Sections 3.1.4, 3.1.5, and 3.1.10 through 3.1.20).

A second, more direct method was to determine the distribution of the RIS within and outside of the thermal discharge. These data are a direct index of the extent to which the species may be excluded by the discharge, and an indirect measure of its tolerance to the discharge. Distribution of Mercenaria mercenaria, Corophium tuberculatum, Hydroides dianthus, Teredo spp. and all RIS fishes in the bay were either inferred from the literature or determined from collections in the bay, the intake canal, and the discharge canal (Sections 3.2.2, 3.2.4). If the thermal discharge has an appreciable impact, it will be observable in a spatial or temporal change in the distribution, abundance or seasonal succession of the species within the plume. An important portion of both analyses is the extent to which the thermal plume will impinge upon important spawning or nursery areas for shellfish, macroinvertebrates, and fishes, and whether any such impingement will interfere with the functions of the resident species. Areas of projected exclusion for each species, based on LMS plume models and temperature avoidance data, are discussed below. The impact of the plume on critical habitats is discussed more fully in Sections 3.2.1 through 3.2.4.

The distribution and abundance of <u>Teredo</u> spp. were analyzed somewhat differently and were the subject of a separate study (Section 3.1.9).

Under 40 C.F.R. Section 122.9(b)(2)(iii)(A), the thermal discharge must meet the temperature requirements of a species for survival, growth and reproduction. However, this condition must be met, under Section 122.9(b)(2)(iii)(b), only outside of the limits of an appropriately sized mixing zone. In this case, JCP&L has proposed that the thermal mixing zone be defined as bounded by the 2.2°C (4.0°F) isotherm (see Chapter 2 and Appendix B). Under all operating conditions for OCNGS, or OCNGS and FRNGS combined, the 2.2°C isotherm will encompass all of Oyster Creek and a part of Barnegat Bay.

In summary, the requirements of Section 316(a) will be satisfied if the following criteria are met:

1. The thermal discharge will not substantially interfere with the survival, growth and reproduction outside of the 2.2°C (4.0°F) isotherm of representative important species of fish and shellfish. Outside that isotherm, a species abundance, distribution and seasonal succession should be within the range of that considered normal for Mid-Atlantic estuaries and closed embayments.

2. Inside the mixing zone, stress on a fish or shellfish species should not be so severe as to interfere with its maintenace within the range of normal, self-sustaining populations in the central Barnegat Bay area. The mixing zone ordinarily should not impinge upon areas of critical importance to a species; the thermal plume should not interfere with successful reproduction and

growth of species which use the central bay for spawning, or a nursery. Neither should fish or shellfish populations suffer appreciable harm as a consequence of heat or cold shock.

3. The population of species other than fish and shell fish should be maintained so as not to interfere with the survival, growth and reproduction of a population of shellfish, fish and wildlife which is, within the range of normal variation, characteristic of Mid-Atlantic estuaries and closed embayments.

4. The populations of fouling organisms should not be increased by the thermal discharge, inside or outside of the mixing zone, such as to interfere with the survival, growth and reproduction of a population of shellfish, fish and wildlife which is within the range of normal variation, characteristic of Mid-Atlantic estuaries and closed embayments.

5. Migration of species to or from spawning or nursery areas should not be blocked by the thermal discharge.

If these criteria are met, where applicable, then it must be concluded that the OCNGS and FRNGS thermal discharges will not interfere with the existence and functioning of a balanced indigenous community of fish, shellfish, and wildlife, and the demonstration held successful. If one or more of the criteria cannot be met, then the data should be examined to determine the cause and significance of the variant condition. If it is not caused by the stations' discharges, or is not significant to maintenance and protection of fish, shellfish and wildlife popuations in Barnegat Bay, then the demonstration also may be considered successful.

3.1.2 RIS Rationale

Data collected on the ten species of fish and five species and one genera of macroinvertebrates composing the representative important species for this demonstration show that the organisms will not be adversely affected by thermal discharges from the OCNGS and FRNGS. Survival, growth and reproduction will not be adversely affected outside of the 2.2°C (4.0°F) isotherm. During most of the year, October through May, the thermal plume provides an attractive habitat for the RIS species. Generally,they are excluded from the area of the mixing zone, or only from some parts of it for several species, only from June through September.

In no case will the stress of the mixing zone be such as to interefer with normal functioning of a population. Cold shock and heat shock are the most important stresses which may be enountered, and these will not be significant for any species. Most species that would be susceptible to heat shock in summer also would avoid the area of the plume during that season. Heat shock for those species resident in the discharge canal and Oyster Creek is unlikely with the present mode of operation for OCNGS. Operation of FRNGS may reduce this possibility further, as blowdown from FRNGS actually will reduce somewhat the temperature of the OCNGS discharge. With the exception of the relatively few individuals secondarily entrained in the plume during high bay temperatures, after either passing through the dilution pumps or being impinged on the intake screens, little heat shock mortality ever has been observed or should occur. Cold shock mortalities are possible, but unlikely with revised operating procedures at OCNGS. Operation of FRNGS will reduce this risk further, since the FRNGS discharge will be able, to some extent, to stabilize temperatures in the discharge canal in the event of an OCNGS shutdown.

Several species use the bay for either a spawning or nursery area For those species which use the bay as a nursery area, the thermal plume will not interfere with seasonal use of the bay. For none of those species would loss of the small area of the bay to the 2.2°C (4.4°F) isotherm be significant to those critical functions.

Some early life stages of the RIS species would be subject to stress by the peak temperatures which may be encountered in the mixing zone. For several species, these early life stages may not be present when peak temperatures occur. For others, peak temperatures may coincide with their presence and mortalities result. Considering the overall population of the bay, however, the level of these mortalities should not be significant.

The thermal plume and mixing zone occupy all of Oyster Creek and a portion of Barnegat Bay. Because none of the RIS use Oyster Creek for spawning or other critical functions, the concept of thermal blockage was not material to this aspect of the demonstration. However, a few oral reports have indicated the potential use of Oyster Creek by anadromous alewife and blueback herring. Although these reports are unconfirmed, and no additional evidence exists indicating potential use of the available freshwater areas of Oyster Creek for spawning, the potential for blockage of these species to migration was considered. As discussed more fully in Section 3.2.4, the discharge should not constitute a barrier to successful migration to the few individuals that may use Oyster Creek, except in the very late portion of the spawning season. In Barnegat Bay, because at least 75 percent of the width and cross-sectional area of the bay is available for migration, the discharge will not constitute a barrier to the migration, dispersal or other biotic functions of migrant species.

Of the two fouling organisms, Hydroides dianthus has experienced some reduction in abundance in Oyster Creek.

The abundance of the second fouling taxa, shipworms, include Teredo bartschi, which appears related to the thermal discharge from OCNGS and Bankia gouldi, which seems to undergo an earlier maturation of gonads in Oyster Creek than in other parts of the bay. This is of no apparent significance to the population of fish and shellfish, however. Historically observed increases in the species around Oyster Creek have not been of a magnitude to make them dominant in the area, or to interfere with the existence or functioning of shellfish or fish populations. Additionally, a program of removing untreated wood from Oyster Creek has eliminated the habitat for a resident breeding population of Teredo spp. and provided a successful control on any increased productivity which might be attributed to the thermal discharges.

3.1.2.1. Macroinvertebrates

3.1.2.1.1 Crangon septemspinosa (sand shrimp)

Crangon septemspinosa, an epibenthic decapod that is common in the intake and discharge canals and Barnegat Bay during the fall, winter, and spring provides important forage for some organisms located at higher trophic levels. The species emigrates from the canals and bay to the ocean in the summer, and this eliminates the possibility of exclusion of a substantial portion of the population from areas subjected to the thermal discharge, and reduces the probability of heat shock mortality.

During the cooler months of the year the sand shrimp may be excluded from a small portion of the bay (approximately 0.5 percent or less) because of the thermal discharge, but this area of exclusion is within the thermal mixing zone. Cold shock mortality has not occurred in the past and should not occur in the future. Because reproduction of the decapod takes place from October through June, secondary entrainment mortality of zoeae is not a problem.

In effect, the thermal discharge does not adversely effect the reproductive processes of C. septemspinosa.

3.1.2.1.2. Neomysis americana (mysid shrimp)

Neomysis americana is a mysid crustacean residing in Barnegat Bay during all months of the year although most individuals migrate to the ocean during the winter. Many important fish species such as winter and summer flounder, bay anchovy, weakfish, herring, and mackerel utilize the mysid as a food source.

The mysid shrimp possesses an upper lethal temperature of 31°C (87.8°F), and it is found in the bay at temperatures up to 28°C (84.2°F). N. americana will avoid high water temperatures and will be excluded from the discharge canal from June through September. It will be excluded from the discharge canal and a small part of the bay in July and August, an area amounting to approximately 4 percent of the bay. This area of exclusion, however, lies within the thermal mixing zone.

Approximately 1.2 percent of the mysid shrimp population in Barnegat Bay is susceptible to heat shock mortality in July and August. Secondarily entrained mysids may experience heat shock mortality in the discharge canal in the summer when water temperatures exceed 31°C (87.8°F). Cold shock mortality is not a problem with this species because most individuals in the intake and discharge canals and bay emigrate to the ocean when water temperatures fall below 3°C (37.4°F).

3.1.2.1.3 Mercenaria mercenaria (northern quahog, hard clam)

Commercially and recreationally, Mercenaria mercenaria is the most important bivalve in Barnegat Bay. Although an adult population of the pelecypod does not exist in the intake and discharge canals, the bay supports a population with annual yields from 200,000 to 900,000 pounds of meats.

The meroplanktonic stages (eggs and larvae) of M. mercenaria are more susceptible to thermal discharge than post-set benthic stages. No evidence exists, however, that thermal discharge from the OCNGS adversely affects meroplanktonic stages of the clam. For example, the species successfully set at the discharge canal, at the mouth of Oyster Creek, and in areas outside of the thermal mixing zone during the 1970's when the OCNGS was operating.

In regard to post-set stages of the northern quahog, thermal discharge from the OCNGS in the summer results in a ten to 25 percent reduction in the growth of adults within a 1.6 km (1 mm) radius of Oyster Creek. These affected clams, however, represent only a minor part of the total population in the bay, and the reduction in growth (approximately one mm of shell per year in the worst case) is inconsequential when the entire lifespan of the animal is examined. Although the thermal discharge affects the growth of some individuals in the bay, it does not affect their mortality patterns. Thus, the thermal discharge does not adversely affect the protection and propagation of this species.

3.1.2.1.4 Corophium tuberculatum

Corophium tuberculatum is a gammaridean amphipod which may provide forage for some fish in the near and far field regions. The density of this species substantially fluctuates from year to year in Barnegat Bay, but this is unrelated to the thermal discharge. In the 1970's it occurred in greater abundance, over a longer period of time in the intake canal compared to the discharge canal, but the closely related forage species, C. ascherusicum, resided in the discharge canal in large numbers throughout the year. No effect on the population has been observed outside of the area of the mixing zone.

The net effect of thermal discharge on C. tuberculatum is to exclude the species from the discharge canal during the summer months. This disappearance of C. tuberculatum from the discharge canal should not effect predacious fishes which might feed on it because these fishes also may be excluded from the thermal discharge during the summer months. If consumers are present in the canal during this period of exclusion, the abundance of C. ascherusicum in the discharge canal in the summer season may mitigate the effect of the low abundance of C. tuberculatum because C. ascherusicum may provide forage for fish and birds within the thermal mixing zone.

3.1.2.1.5. Hydroides dianthus

The serpulid polychaete worm, Hydroides dianthus, secretes a calcareous tube which is responsible for serious damage to shellfish crops and for fouling of boats. The species is abundant and evenly distributed in central Barnegat Bay. It is less abundant in the discharge canal and Oyster Creek. The relative scarcity of the serpulid worm in the discharge canal has not been adequately explained but may be caused by the inhibition of settlement in the summer months due to the thermal discharge.

Any reduction in the abundance of this species does not seem to affect organisms located on other trophic levels. The low abundance of H. dianthus in the discharge canal should not harm the balanced, indigenous community of shellfish, fish, and wildlife in the near and far field regions.

3.1.2.1.6. *Teredo spp.* (shipworms)

The four species of teredinids identified in the Barnegat Bay System are capable of destroying unprotected wooden structures by boring into them. *Bankia gouldi*, the most abundant teredinid is dominant on the western side of the bay, whereas *Teredo navalis* is dominant on the eastern side of the bay. *Teredo bartschi*, a subtropical teredinid, occurs only in Oyster Creek, and *Teredo furcifera*, another subtropical species, has been found in low densities throughout the bay.

Of the four teredinids in the Barnegat Bay System, *Bankia gouldi* has the most extensive distribution. Its distribution, however, is not related to thermal discharge from the OCNGS and large concentrations of the species occur outside of the thermal plume. *B. gouldi* also is common in areas affected by thermal discharge from the OCNGS, but the greatest densities of this species are in areas north of Oyster Creek outside of the influence of the thermal plume. The impact of the discharge on this marine borer appears to be a slightly earlier than normal maturation of the gonads of individuals in Oyster Creek. No evidence exists, however, that this early gonad development results in increased abundance of *B. gouldi* in the bay.

The abundance and distribution of *Teredo navalis* is unaffected by thermal discharge from the OCNGS. The species distribution reflects its sensitivity to humic material in marshland runoff rather than a response to the thermal discharge.

Teredo furcifera occurs in very low concentrations throughout the bay, and data indicate no correlation between thermal discharge from the OCNGS and the abundance or distribution of this species.

The distribution of *Teredo bartschi* suggests a direct association with the thermal discharge. The species distribution is confined to Oyster Creek, and this may indicate a positive influence of the heated water on the species. The absence of *T. bartschi* from other parts of the Barnegat Bay System, however, shows that the thermal discharge has not caused proliferation of the species outside of Oyster Creek.

3.1.2.2. Fish

3.1.2.2.1 *Brevoortia tyrannus* (Atlantic menhaden)

Brevoortia tyrannus is the most important fish landed commercially in New Jersey by both weight and dollar value. Schools of Atlantic menhaden were observed in Barnegat Bay from April through September in 1976 and 1977. The species uses the bay primarily as a nursery area because spawning occurs outside of the estuary. Most individuals emigrate to the ocean in the fall as water temperatures in the bay drop to 9 to 11°C (48.2 to 51.8°F), but some of them, particularly the young, may overwinter in the discharge canal. Cold shock mortality of some of these overwintering fish has occurred in the past when the OCNGS shut down, but these mortalities have had no impact on the large Atlantic coast population of this species. In addition, changes in the operating mode of the OCNGS have reduced the frequency and extent of cold shock mortality of the Atlantic menhaden after an OCNGS shutdown, and further reductions in the incidence of cold shock mortality should be realized when the FRNGS begins operating.

From June through August, the Atlantic menhaden will avoid most of the discharge canal; it will avoid approximately 2.1 percent of the bay from Cedar Beach to Gulf Point at this time. The area of exclusion is well within the thermal mixing zone, however. Because the Atlantic menhaden avoids the discharge canal during the summer, heat shock mortality has not been a problem. Only one case of heat shock mortality of the Atlantic menhaden has occurred in the past. Thermal discharge from the OCNGS, therefore, does not significantly affect the protection and propagation of this species.

3.1.2.2.2 Anchoa mitchilli (bay anchovy)

Anchoa mitchilli is among the most abundant fish in Barnegat Bay, and it is an important source of food for many sport and commercial fish in the bay. From May through September in 1976 and 1977, the species occurred throughout the estuary. It was collected at water temperatures up to 31°C (87.8°F) but tended to avoid temperatures above that point in the discharge canal.

During July and August the bay anchovy may be excluded from some portion of the discharge canal and bay because of the thermal discharge, but this area of exclusion should not exceed 2.6 percent of the bay from Cedar Beach to Gulf Point. The region of exclusion lies within the thermal mixing zone and is not considered critical to the protection and propagation of the species in the bay. Because the bay anchovy avoids the discharge canal during the summer, heat shock mortality has been minimal; only two cases of heat shock mortality of this organism have been documented.

The bay anchovy may prefer the thermal plume at some time during April, May, June, September, and October. Although the fish is susceptible to cold shock mortality because of its preference for the discharge canal in the fall, cold shock mortalities have been insignificant.

Because relatively few bay anchovy are lost to heat and cold shock mortality and the area of exclusion remains inconsequential to the success of this species in the estuary, the protection and propagation of the bay anchovy in Barnegat Bay are demonstrated.

3.1.2.2.3 Gasterosteus aculeatus (threespine stickleback)

The distribution and abundance of Gasterosteus aculeatus do not appear to be influenced by thermal discharge from the OCNGS. Since individuals of this species prefer rooted vegetation, which is located mainly in the eastern bay and tidal pools around the periphery of the bay, few individuals have been found in Oyster Creek and the western bay whatever the extent of the plume. Therefore, it cannot be considered to be excluded by the elevated plume temperatures. Heat and cold shock mortality of the species have not been observed since the OCNGS began operation. In addition, the thermal discharge does not affect the reproductive processes of the fish. Therefore, the protection and propagation of the threespine stickleback are not adversely affected by thermal discharge from the OCNGS, and this condition should not be influenced by thermal discharge from the FRNGS.

3.1.2.2.4 Morone saxatilis (striped bass)

Although the striped bass is an important fish to the commerical and sport fisheries of New Jersey, few were collected in Barnegat Bay during field sampling conducted in 1976 and 1977. Its abundance has substantially decreased in the bay as well as in other New Jersey estuaries in recent years which reflects a natural fluctuation in the population of the species rather than any effect of thermal discharge from the OCNGS.

The striped bass does not utilize the bay as a nursery or for spawning purposes. Most individuals do not reside in the estuary during the summer, and heat shock mortality and exclusion of the organism from any area of the bay is not a problem during this season. A few striped bass live in the discharge canal during the spring, fall, and winter, and some of these have experienced cold shock mortality in the past at an ambient bay temperature of

1.6°C (34.9°F). The loss of these few striped bass, however, has not resulted in any impact on the overall population in Barnegat Bay or the Atlantic coast. This information indicates, therefore, that thermal discharge from the OCNGS does not harm the striped bass population in Barnegat Bay.

3.1.2.2.5 Pomatomus saltatrix (bluefish)

The bluefish was the most abundant sport fish in Barnegat Bay from 1975 to 1977. As with the Atlantic menhaden, this species utilizes the estuary primarily as a nursery, spawning in waters offshore. Adults migrate into the bay in the spring when the water temperature approximates 17°C (62.6°F), and most individuals emigrate to the ocean in the fall. Some bluefish, however, overwinter in the discharge canal and a few incidents of bluefish mortality from cold shock have occurred in the canal. These incidents have not adversely affected the overall population in Barnegat Bay or along the Atlantic coast.

During the summer months young bluefish may be excluded from one percent of the area of the bay because of thermal discharge from the OCNGS. This area exists within the thermal mixing zone, and its loss does not adversely affect the protection or propagation of the species in the bay. Thus, thermal discharge from the OCNGS does not have any appreciable impact on the bluefish population in Barnegat Bay.

3.1.2.2.6 Cynoscion regalis (weakfish)

The weakfish is a recreationally important fish species in Barnegat Bay. It enters the bay from large coastal populations in the spring and leaves in the fall. The species uses the estuary as a nursery; in the Barnegat Bay area, it spawns exclusively in the ocean.

Experimental data indicate that the species should prefer the thermal plume in April, May, October, and November, and field surveys verify this. Most individuals tend to avoid the discharge canal in the summer, and they may be excluded from 4.4 percent of the bay during this time. This area of exclusion, however, will not affect the protection and propagation of weakfish in the bay or along the Atlantic coast.

Some weakfish do not emigrate to the ocean in the fall but overwinter in the discharge canal. These individuals are susceptible to cold shock mortality. The loss of overwintering weakfish will have no impact on the overall population along the Atlantic coast, however, and should have an insignificant effect on the population residing in the bay from the spring to the fall. The potential for cold shock should be reduced by operation of FRNGS.

3.1.2.2.7 Menticirrhus saxatilis (northern kingfish)

The northern kingfish, like the striped bass, has experienced a significant decline in numbers in Barnegat Bay during the 1970's. This decline in abundance has been observed in other New Jersey estuaries as well, however, and it is unrelated to thermal discharge from the OCNGS.

Juveniles of this species were collected from July through November in Barnegat Bay in 1976 and 1977. Adults were found in the bay from May through October at temperatures up to 31°C (87.8°F).

The northern kingfish does not spawn in Barnegat Bay, and the bay is unimportant as a nursery for young of the species. During the summer the species may be excluded from about 2.6 percent of the bay because of the thermal discharge, but this area of exclusion occurs within the thermal mixing zone and does not harm the overall population in the bay. No heat shock mortality is expected in the future because the species should avoid the thermal discharge in the summer. A few individuals may suffer cold shock mortality, but this will not significantly affect the protection and propagation of the population in the bay or along the Atlantic coast.

3.1.2.2.8 Paralichthys dentatus (summer flounder)

The summer founder is a recreationally and commercially important fish in Barnegat Bay. It is a seasonal migrant which moves into the bay beginning in March and leaves the estuary between August and December. Spawning occurs in the ocean; thus, thermal discharge from the OCNGS does not affect the reproduction processes of the organism.

In July and August the summer flounder is excluded from approximately 1.9 percent of the bottom of the bay from Goodluck Point to Gulf Point, and this area of exclusion is well within the thermal mixing zone. This represents the only adverse impact of the thermal discharge on this species. The fish does not experience heat or cold shock mortality because it avoids the warmest area of the discharge during summer and does not overwinter in the discharge canal.

Based on these findings, the population of summer flounder in Barnegat Bay is not harmed by thermal discharge from the OCNGS, and it should not be affected by thermal discharge from the FRNGS.

3.1.2.2.9 Pseudopleuronectes americanus (winter flounder)

Barnegat Bay supports a local population of winter flounder, and this population utilizes the bay as a spawning and nursery area. Adults migrate into the bay in October and emigrate to the ocean in April and May. Although adults emigrate from the bay in the spring, young of the species may remain in the estuary throughout the year. Spawning occurs in the bay from January through March, and thermal discharge from the OCNGS does not exclude the species from any part of the bay during this period.

The winter flounder is attracted to the thermal plume in the winter but avoids it after early April. Adults may be excluded from less than one percent of the bay in the spring. Young of the species which do not emigrate from the bay in the spring may be excluded from 7.8 percent of the bottom of the bay from Goodluck Point to Gulf Point. This area of exclusion may be an overestimate, however, because some part of the bay bottom beneath the plume may be unaffected by the thermal discharge.

Heat shock mortality of winter flounder should not occur because the species avoids the discharge canal during the peak temperatures of summer. Cold shock mortality also is not anticipated because the species can tolerate large decreases in temperature comparable to those that take place in the discharge canal when the OCNGS shuts down during the winter. Based on these observations, the protection and propagation of the winter flounder population in the bay, are not significantly affected by thermal discharge from the OCNGS.

3.1.2.2.10 Sphoeroides maculatus (northern puffer)

The northern puffer has significantly declined in abundance in Barnegat Bay during the 1970's. This decrease in abundance also has been observed in other New Jersey estuaries and is unrelated to thermal discharge from the OCNGS.

Experimental tests conducted on this species indicate that the organism should be excluded from some portion of the discharge canal and bay from June through September. The area of exclusion should not exceed 2.1 percent of the bay which is well within the thermal mixing zone.

Because the species will avoid the discharge canal in summer, heat shock mortality is not expected. Cold shock mortality also should not occur because the northern puffer does not reside in the discharge canal during winter. Thermal discharge from the OCNGS and FRNGS, therefore, should not harm the northern puffer population in Barnegat Bay.

3.1.2.2.11 Callinectes sapidus (blue crab)

The blue crab was not designated as a representative important species for this demonstration but was included for study because of its economic and recreational significance in Barnegat Bay.

The crustacean is present in the estuary throughout the year and is active from March through December. It is most abundant from May through August. Studies indicate that thermal discharge from the OCNGS and FRNGS should not exclude the crab from most of the thermal discharge throughout the year. An area less than 1.0 percent of the bay from Cedar Beach to Gulf Point may be avoided by the species during the summer, but this is insignificant to the protection and propagation of the overall population in the bay.

Heat and cold shock mortality of this species have not been a problem in the past and should not be a problem in the future. The loss of some larvae to secondary entrainment mortality is inconsequential and has not harmed the population in the bay or along the Atlantic coast.

3.1.3 Experimental Studies for the RIS

When fishes encounter a thermal discharge (plume), the general response to the discharge is either attraction (preference) or avoidance although some fishes may demonstrate neither response but may still undergo a physiological adjustment. The response will depend on the species, the temperature to which it is acclimatized (usually ambient) the temperature of the discharge, and the difference (delta T) between the acclimatization and the discharge temperature. Occasionally, organisms also may experience a relatively sudden increase (heat shock) or decrease (cold shock) in temperature due to the operation of the facility. Heat and cold shock can at times cause mortality. Determinations of the RIS' avoidance, preference, and lethal temperatures were conducted at several acclimation temperatures simulating discharge conditions at OCNGS and FRNGS.

The temperature which elicited an avoidance or preference response was plotted against the acclimation temperature even though other variables (e.g., length of fish, light level, season) also significantly affected the response. This was because acclimation temperature accounted for most of the explained variation in avoidance response. A plot of preferred temperature, as determined during horizontal temperature preference tests, was used to determine the final temperature preferendum; that is, the temperature where the preferred temperature equaled the acclimation temperature (Fry 1947, 1964, 1967). It is the temperature an organism would ultimately select regardless of its previous thermal history. Brett (1956, 1971) and Brett et al. (1969) showed that gross food-conversion efficiency, growth rate, maximum meal size, metabolic scope for activity, cardiac scope, and swimming performance of the sockeye salmon (Oncorhynchus nerka) were highest at the final temperature preferendum. A similar relationship was assumed for most other fishes, and the final temperature preferendum was considered the optimum temperature for most physiological activiies.

The vertical temperature preference tests determined the temperature an organism ultimately would select regardless of its previous thermal history. If these data were sufficient, an analysis of variance (ANOVA) was performed to determine the relationship between the final preferendum and acclimation temperature. The estimated final preferenda obtained during the horizontal and vertical temperature preference tests were compared to check their validity.

Temperature preference and avoidance data were subjected to stepwise multiple linear regression analysis. The generalized regression equation was:

$$Y = a + b_i X_i + b_j X_j + b_k X_k + e$$

Y = the estimated preference or avoidance temperature (C)

a = constant

b_i, b_j, b_k = the regression coefficients

X_i, X_j, X_k = the independent variables

e = error term.

The data were insufficient to include the interaction variables. The independent variables were acclimation temperature (C), the mean total length (mm) of the group of fish tested, and light level (lux). The significance of the regression coefficients were determined by ANOVA ($P < 0.05$). If more than one independent variable was significant, standardized regression coefficients were calculated to evaluate their relative importance. When the regression was reduced to a linear form, the confidence interval ($P < 0.05$) for the estimated value (Y) was obtained by the expression:

$$Y \pm t \cdot S_{y.x} \sqrt{1 + \frac{1}{N} + \frac{(X - \bar{X})^2}{(N-1)\ S^2}}$$

t = student t value ($P < 0.05$) with N-2 d.f.

$S_{y.x}$ = standard error of the estimate

N = number of tests

$\bar{X}$ = mean of x

S^2 = variance of x

Regression equations were not extended beyond the highest and lowest acclimation temperature used in the equation, because the relationship may not be linear beyond the range of temperatures tested.

Cumulative percent mortality for heat- and cold-shock data was determined at 4, 24, and 48 h, and at 4, 24, 48, and 96 h, respectively. Test temperatures which resulted in 30 percent or greater mortality after a 48 h exposure (heat shock) or 96 h exposure (cold shock) were plotted against respective acclimation temperatures and the average delta T at OCNGS (10°C; 18°F). Although the maximum delta T for normal OCNGS operation is 12.7°C (22.9°F), the monthly average delta T in 1975-77 was less than 10°C (18°F) (Tables 3.1-1, 3.1-2), and this temperature increase was discussed as the operational delta T. Results from I.A.'s Experimental Laboratory at Odessa, Delaware, were included in the analyses for the Atlantic menhaden, bay anchovy, striped bass, bluefish, and weakfish (WPC, Appendix Tables 1 to 4).

Data presented in the RIS discussions were reported by Wyllie et al. (1976), Terpin et al. (1977), and Tatham et al. (1977a, Appendix C1; 1978a). Unpublished data collected by I.A.'s Experimental Laboratory at Brigantine, New Jersey, from January through October 1977 also were used. The number of experimental tests conducted with the RIS species are presented in Table 3.1-3. Pertinent data from the literature were used to interpret the analyses and to provide information for species when few tests were conducted. Additional literature on the thermal responses of the RIS appears in the WPC, Appendix Tables 5 to 17. Detailed information on the life history of all of the RIS may be found in Appendix C1 Section C1.11.

Data for some RIS fishes are incomplete. Some specimens did not exhibit typical behavioral responses to temperature under laboratory conditions. Some species were uncommon in collections, and few were obtained for testing. Little data were obtained for the threespine stickleback (nine tests), young of the striped bass (obtained from I.A.'s Delaware laboratory), the northern kingfish (no tests), summer flounder (no shock tests), winter flounder (seven shock tests), and northern puffer (six tests).

Benthic fishes generally did not demonstrate the preference or avoidance behavior (i.e., continuous swimming) typically displayed by pelagic species. Some individuals of both the summer and winter flounder remained in one location in the test apparatus regardless of temperature. In some cases, specimens showed signs of stress and attempted to burrow, a mechanism used to avoid high (stressful) temperature (Olla et al. 1969). However, some individuals remained in a specific area of the apparatus until stressful temperatures progressively forced them into the cooler portions of the trough, and the temperature at which this occurred was considered the avoidance temperature. This was not the normal avoidance response of most other fishes but indicated that flatfishes detect and avoid stressful water temperature. Because no mortality occurred when these fish were returned to ambient temperature after a test, they apparently were not subjected to lethal conditions.

The thermal plumes modeled by Lawler, Matusky and Skelly, Engineers (LMS 1978) were used to evaluate the effect of the OCNGS and FRNGS thermal discharge during summer (average bay temperature above 20°C (68°F)) and non-summer months (Table 3.1-4). The average bay temperature during each month was taken from Burns and Roe (1974). Predicted responses of the RIS to both the near and far field were discussed in light of collections made in the bay, the intake canal and the discharge canal (Figures 3.1-1 3.1-2). Since plumes were modeled with the maximum rated capacity for OCNGS (670 MWe), the temperatures predicted in the discharge canal were several degrees higher than the temperatures recorded in the canal during June (actual OCNGS output of 548 MWe), July (526), August (569), and September (580) 1976. Therefore, the observed distribution of fishes in relation to the OCNGS thermal discharge during the summer of 1976 was, in some cases, different from the predicted response.

The predicted thermal plume with the greatest surface area at the 2.2°C (4.0°F) isotherm in the bay (far field) during normal operating conditions was used to evaluate the effect of the discharge during summer (plume LMST 08) and non-summer (LMST 07) months (Table 3.1-4). The area covered by the predicted plume may not necessarily be the area of exclusion for demersal and epibenthic forms. A shoal of sediment at the mouth of the discharge canal (M.B. Roche, personal communication) and natural stratification of the bay during summer tends to direct the plume toward the surface of the bay. A significant portion of the bottom underlying the plume is unaffected by the thermal discharge (LMS, 1978).

The areas of the plume in the bay and of the bay from Goodluck Point to Gulf Point were determined with a Lietz polar planimeter. The volume of the plume in the bay and of the bay from Cedar Beach to Gulf Point were determined from either the depth of the plume or the depth ranges of the bay. The volume of the discharge canal was determined by LMS to be 0.5 million cu m. (T. Pease, personal communication).

During summer, OCNGS operates with two dilution water pumps, and this is discussed as the normal operating condition. The plume with the greatest predicted area in the bay during summer (LMST 06) occurs when only one dilution pump is running. This should rarely occur, because a third dilution pump is available to replace, if necessary, one of the two operating pumps.

When both OCNGS and FRNGS are in operation, the predicted thermal plume in the discharge canal is only 0.25°C (0.45°F) greater than when only OCNGS is in operation. When OCNGS is not in operation, the additional heat in the discharge canal from FRNGS is very small (0.25°C; 0.45°F), and little effect within the canal is expected (LMS, 1978). This operating condition is discussed under the incremental effect of FRNGS on the balanced, indigenous populations (Sections 3.2.2, 3.2.4).

3.1.4 *Crangon septemspinosa* (sand shrimp)

3.1.4.1 Introduction

The sand shrimp, *Crangon septemspinosa*, is an epibenthic decapod that is found in coastal waters from eastern Canada to Florida. The species provides forage for organisms located at higher trophic levels, particularly fish such as the striped bass, tautog, weakfish, winter flounder, and summer flounder.

During much of the year (fall, winter, spring) the sand shrimp constitutes a common or abundant element in Barnegat Bay and the intake and discharge canals of the OCNGS. The species emigrates from the bay and canals in the summer as its avoidance temperature (28°C; 82.4°F) is approached. The few specimens collected in Barnegat Bay and the two canals during July and August testifies to this emigration.

The movement of *C. septemspinosa* from the bay in the summer months precludes the possibility of exclusion of a substantial portion of the population from areas subjected to the OCNGS thermal discharge. In addition, heat shock mortality of secondarily entrained individuals is of little consequence, because few individuals are present in the system when heat shock would occur. During other seasons of the year, when the sand shrimp resides in the system, the exclusion area and secondary entrainment mortality should be small. For example, the exclusion area for the sand shrimp should not exceed 0.5 percent of the habitat from Cedar Beach to Gulf Point and secondarily entrained individuals should withstand all temperature increases experienced in the discharge canal during the fall, winter, and spring.

Cold-shock mortality of sand shrimp has not been documented in the past when individuals were attracted to the discharge canal in the winter and the OCNGS shut down. The possibility of cold-shock mortality will be reduced even further when the FRNGS begins operation because the FRNGS thermal discharge will maintain the water temperature in the discharge canal at 0.6 to 2.5°C (1.1 to 4.5°F) above the ambient bay temperature. Cold-shock mortality, therefore, is not expected to be a problem with the FRNGS operating. In effect, thermal discharge from the OCNGS does not exclude *C. septemspinosa* from a substantial area of Barnegat Bay and does not alter the natural mortality patterns of populations in the bay and the intake and discharge canals. The reproductive processes of the species also are not influenced by the thermal discharge. These conditions will not be changed by thermal discharge from the FRNGS.

3.1.4.2 Life history

The sand shrimp ranges from Baffin Bay, Canada to eastern Florida and is found from inshore waters to 450 m (1476 ft) (Whiteley 1948). It is a common resident in Barnegat Bay during most of the year, although Squires (1965) reported a probable offshore migration from shallow embayments during periods of extremely low water temperatures. This epibenthic shrimp is forage for the striped bass, tautog, weakfish, and winter flounder (Bigelow and Schroeder, 1953) and was the most important food item, by volume, of summer flounder collected near Great Bay.

Ovigerous (egg-bearing) females were collected from October through June in Barnegat Bay; the greatest numbers were taken from February through June. Using Price's (1962) estimate of the relation between the size of an individual and the number of eggs carried, the average ovigerous sand shrimp in Barnegat Bay (mean length of 43.1 mm) carried approximately 2000 eggs. Incubation of the eggs requires about ten weeks at a water temperature from 6 to 10°C (42.8 to 50°F) but only six to seven days at a temperature of 21°C (69.8°F) (Price, 1962; Haefner, 1972). A salinity of greater than 17 ppt is important for the incubation of the eggs. Price (1962) collected no ovigerous sand shrimp in Delaware Bay at a salinity less than 17.7 ppt.

The seven zoeal (larval) stages of this species (Sandifer, 1972) require relatively high salinity to develop and survive. In Chesapeake Bay, larvae were collected at a salinity of 11 to 32 ppt with maximum abundance between 20 and 25 ppt (Sandifer, 1972). Zoeae were collected throughout Barnegat Bay from Cedar Beach to Gulf Point; in 1975-77 the average monthly salinity in the bay ranged from 16.5 to 29.1 ppt.

Growth of the sand shrimp in Rhode Island was related to water temperature. Shrimp 20 to 30 mm (.8 to 1.2 in.) in length grew 0.4 mm/week (0.02 in./week) during winter and 1.1 mm/week (.04 in./week) during summer. Smaller shrimp grew faster than larger individuals, and females grew faster than males (Wilcox and Jeffries, 1973). In Delaware Bay, three age classes of females and two age-classes of males were found (Price, 1962). Juveniles and adults were taken at a salinity as low as 4.4 ppt but were most abundant at salinities above 16 ppt (Price, 1962; Haefner, 1976). The adult sand shrimp was colleced throughout Barnegat Bay from Cedar Beach to Gulf Point (range of average monthly salinity of 16.5 to 29.1 ppt).

3.1.4.3 Distribution in relation to water temperature

In Barnegat Bay, the sand shrimp was common to abundant in all seasons except summer. Although adults were collected to 31°C (35.6 to 87.8°F), few were collected during summer at a water temperature greater than 28°C (82.4°F) because most individuals probably emigrated to the ocean at this time (Williams, 1965). Specimens were collected in the discharge canal at a temperature of 6 through 27°C (42.8 through 80.6°F), but specimens remaining in the bay during summer avoided the discharge canal in August (lower discharge canal temperature of 25 to 31°C (77 to 87.8°F)). The sand shrimp was probably attracted to the heated discharge canal during December (bay temperature of 3 to 11°C, 37.4 to 51.8°F) lower discharge canal temperature of 7 to 14°C; 44.6 to 57.2°F).

Although zoeae of the sand shrimp were collected throughout the year, the highest densities occurred from mid-April to mid-July at a water temperature from 14 to 29°C (57.2 to 84.2°F).

3.1.4.4 Analysis of experimental data

3.1.4.4.1 Temperature avoidance studies

Meldrim (unpublished), reported that sand shrimp acclimated at 21°C (69.8°F) avoided 30°C (86°F) and those acclimated to 25°C (77°F) avoided 26°C (78.8°F) (WPC, Appendix Table 16).

3.1.4.4.2 Heat shock studies

Over the temperature range of 5 to 15°C (41 to 59°F), the sand shrimp tolerated a temperature increase of 10°C (18°F). Sand shrimp acclimated to 5, 10, and 15°C (41, 50, and 59°F) were subjected to temperature increases of up to 17°C (30.6°F) (WPC, Appendix Table 21). Sand shrimp acclimated to 5 and 10°C (41 and 50°F) experienced mortalities of 30 percent or less when exposed to temperature increases as great as 17°C (30.6°F). No mortality occurred for individuals acclimated at 15°C (59°F) and subjected to a temperature increase of 11°C (19.8°F) for 48 h (WPC, Appendix Table 22). Individuals acclimated at 15°C (59°F) and subjected to a delta T of 14.2°C (25.6°F) suffered 45 percent mortality after 4 h. Those acclimated to 15°C (59°F) experienced 100 percent mortality when exposed to a temperature increase greater than 14.2°C (25.6°F). Mihursky and Kennedy (1967) found that the upper lethal temperature of sand shrimp acclimated at 15°C (59°F) was

28°C (82.4°F). Huntsman and Sparks (1924) found that adults acclimated at 20°C (68°F) had an upper lethal temperature between 30.0 and 32.5°C (86 and 90.5°F) after a 24-h exposure.

Zoeae entrained through the Cooling Water System were affected at a discharge temperature above 30°C (86°F). At these temperatures they had abnormal swimming behavior in collections from the OCNGS discharge. Regnault and Costlow (1970) reported that no zoeae survived beyond 24 h at a temperature cycle from 25 to 30°C (77° to 86°F).

3.1.4.4.3 Cold-shock studies

When sand shrimp acclimated to 5 and 10°C (41 and 50°F) were subjected to temperature decreases as great as 7.7°C (13.9°F) (WPC, Appendix Tables 23, 24), no mortality occurred.

3.1.4.5 Predicted response to the OCNGS and FRNGS thermal discharge

Throughout the year, the sand shrimp was attracted to and avoided the OCNGS thermal dscharge. It was attracted to the lower portion of the discharge canal during winter (average bay temperature of 3.9 to 5.0°C; 39 to 41°F). Although the temperature in the discharge canal will exceed the avoidance temperature of this species (28°C; 82.4°F) from June through September (Table 3.1-4), this area will be unavailable to the sand shrimp as a consequence of OCNGS operation only during June, since most individuals will leave the bay anyway during July and August. Few individuals were collected in the discharge canal at temperatures above 28°C (82.4°F), but avoidance of the canal was apparent only in August 1976. During June, the sand shrimp should only be excluded from 0.5 per cent of the habitat from Cedar Beach to Gulf Point (Figure 3.1-53).

Significant heat-shock mortality did not occur until the temperature approached 28°C (82.4°F), the upper lethal temperature (WPC, Appendix Table 22). Secondary entrainment of adults and juveniles through the dilution pumps occurred primarily during spring (bay temperatures of 12 to 20°C; 53.6 to 68°F) and winter (0, 5 to 7°C, 32, 41 to 44.6°F). Little mortality should occur, because the temperature in the mixing zone during these months should be below 28°C (82.4°F). Since relatively few sand shrimp are found in the bay during summer, few will be secondarily entrained through the dilution pumps when the temperature in the discharge canal usually exceeds 28°C (82.4°F).

Zoeae of the sand shrimp may experience some mortality when secondarily entrained through the dilution pump. Abnormal behavior was observed at a temperature of 30°C (86°F), and mortality was reported in the temperature range of 25 to 30°C (77 to 86°F) (Regnault and Costlow, 1970). Temperature in the discharge canal should exceed 30°C (86°F) from June through September (Table 3.1-4). During this period, an estimated 3.3 to 7.6 percent of the population in the bay from Cedar Beach to Gulf Point was secondarily entrained through the dilution pumps each day. These percentages were considered to be overestimates, since many gravid sand shrimp occurred in the intake canal and probably reproduced there. Mortality of zoeae secondarily entrained into the plume in the bay also may occur in July and August when the temperature in some portion of the plume exceeds 30°C (86°F).

No cold shock mortality occurred for individuals acclimated at 5°C (41°F) and exposed to 1.5°C (34.7°F) for 48 h (WPC, Appendix Table 24). Although adults and juveniles may be attracted to the heated discharge in winter, they should not experience cold shock mortality. Cold shock mortality has not been documented after OCNGS shutdowns. The FRNGS thermal discharge will maintain the discharge canal at 0.6 to 2.5°C (1.1 to 4.5°F) above the ambient bay temperature after the OCNGS has shut down. This should reduce possible stress from cold shock to the populations of organisms that reside in the discharge canal.

3.1.4.6. Conclusion

In summer, most individuals of this species emigrate to the ocean, and the bay is then relatively unimportant to this population. Therefore, potential exclusion from heated portions of the bay and heat shock mortality of some secondarily entrained individuals should be relatively unimportant to the local population. When sand shrimp are present during other months, the area of the bay that will be unavailable is relatively small (0.5 percent), and secondarily entrained individuals should withstand the temperature increases.

Most gravid females were collected throughout the bay from October through June, and thus, most reproduction occurred during months when secondarily entrained zoeae would not experience lethal temperatures. Cold shock mortality of individuals attracted to the thermal discharge is not expected and has not been documented since the OCGNS began operation in 1969. In sum, the OCGNS and FRNGS thermal discharge will not exclude this species from an unacceptably large area or critical habitat, and reproduction will not be impaired nor mortality result from temperature shock.

3.1.5 Neomysis americana

3.1.5.1. Introduction

Neomysis americana is a mysid crustacean living in coastal waters of eastern North America from the intertidal zone to a depth of about 60 m (197 ft). Adults attain a length of approximately 3 cm (1.2 in) and morphologically appear much like little shrimp. The species retains a omnivorous feeding habit consuming a substantial amount of organic detritus. N. americana like C. septemspinosa, is important forage for fish in Barnegat Bay, notably winter and summer flounder, bay anchovy, and weakfish.

N. americana resides in Barnegat Bay during all months of the year. It was found to be most abundant during the spring (March and April) and least abundant during the winter (December and January) when water temperatures fell below 3°C (37.4°F), and it emigrated to the ocean. The organism was found at ambient bay temperatures up to 29°C (84.2°F) which is 2°C (3.6°F) below the upper lethal temperature for the species.

From June through September, N. americana will be excluded from the discharge canal and Oyster Creek because of high water temperatures. This represents 0.5 percent of the volume of the bay from Cedar Beach to Gulf Point. From July through August, the thermal discharge will exclude the population from the discharge canal and a small part of the bay amounting to 4 percent of the bay's volume. At this time, secondarily entrained mysids may experience heat shock mortality in the discharge canal when the temperature exceeds 31°C (87.8°F). Approximately 1.2 percent of the population in the bay from Cedar Beach to Gulf Point may suffer heat shock mortality on each day in July and August.

Cold shock mortality should not be a problem with the species since only a small population should reside in the discharge canal in the winter. Operation of the FRNGS should also mitigate any cold shock effects.

In short, operation of the OCNGS and FRNGS should not significantly impact the N. americana population in Barnegat Bay. Aberrant growth, reproduction, and mortality of the mysid are not expected to occur as a result of the station's operation.

3.1.5.2. Life history

N. americana is the most common mysid in coastal and estuarine water of eastern North America (Wigley and Burns, 1971). It ranges from the Gulf of St. Lawrence to northeastern Florida (Williams et al., 1974), but is most abundant and widely distributed between New England and Virginia. It is most common from the intertidal zone to a depth of 60 m (197 ft), and it is widespread throughout Barnegat Bay. According to studies in Great Channel, near Hereford Inlet, New Jersey (Allen 1977), it has no substrate preference.

N. americana is forage for flounder, shad, herring, and mackerel (Smith, 1879), bay anchovy (Stevenson, 1958), and weakfish (Shuster 1959; Thomas, 1971). It is an omnivore (Allen, 1977) and is important in the conversion of organic detritus to animal tissues (Percival, 1929).

N. americana was collected in Barnegat Bay during every month and was often the most abundant macrozooplankton collected at night. It generally remained on the bottom during the day and ascended in the water column at night (Williams, 1972). *N. americana* was least abundant in January (7.5/m^3) and most abundant in March and April (86-120/m^3). The decrease in abundance in January probably reflected a migration to the ocean. After the minimal water temperature was reached in February, this species returned to the bay. Allen (1977) found a similar movement near Hereford Inlet, New Jersey. The increase in abundance in March and April probably indicated its greater occurrence in the plankton rather than an actual increase in overall abundance in the bay.

Allen (1977) found one generation of *N. americana* during winter and two generations of *N. americana* during summer near Hereford Inlet, New Jersey. In winter, females had a mean clutch size of 39 eggs, and specimens maintained in the laboratory produced one to two broods. In early summer, females had a mean clutch size of 16 eggs, and in late summer the mean clutch size averaged 11 eggs. During summer, females produced as many as three broods. The sex ratio was approximately equal during most months, but in early spring males outnumbered females.

3.1.5.3 Distribution in relation to water temperature

N. americana was present in Barnegat Bay throughout the year, although its abundance decreased somewhat during December and January at water temperatures below 3°C (37.4°F). This decrease during winter resulted from the emigration of this species to the ocean. It was collected at an ambient temperature as high as 29°C (84.2°F).

3.1.5.4 Analysis of experimental data

Relatively little mortality from heat shock occurred at a shock temperature below 31°C (87.8°F). In collections at the OCNGS discharge, little (0 to 3 percent) mortality occurred below 31°C (87.8°F). At an ambient temperature between 2.0 and 19.5°C (35.6 and 67.1°F), Meldrim (unpublished) reported less than 12 percent mortality of N. americana exposed to a temperature increase of 6.0 to 8.5°C (10.8 to 15.3°F) for 4 h and held at ambient temperature for 48 h (WPC, Appendix Table 25). At an ambient temperature of 25°C (77°F), mysids exposed to a temperature of 31°C (87.8°F) (delta T of 6°C; 10.8°F) and 32.5°C (90.5°F) (delta T of 7.5°C; 13.5°F) experienced 35 percent (at 24 h) and 100 percent (at 4 h) mortality, respectively.

3.1.5.5 Predicted response to the OCNGS and FRNGS thermal plume

Since avoidance data are not available for this species, it was assumed for the purpose of this demonstration that the avoidance temperature was 29°C (84.2°F). This temperature was 2°C (3.6°F) below the upper lethal temperature and was the highest bay temperature at which N. americana was collected. During June and September, this species will be excluded only from the discharge canal (0.5 percent of the volume of the bay from Cedar Beach to Gulf Point). The thermal discharge will exclude N. americana from 4.0 percent of the volume of the bay during July and August (Figure 3.1-52).

N. americana secondarily entrained into either Oyster Creek or the thermal plume in the bay at a temperature below 31°C (87.8°F) should not experience heat shock mortality. Only during July and August will the temperature in the mixing area of Oyster Creek and a small portion of the bay (4.0 percent of the volume of the bay from Cedar Beach to Gulf Point) exceed 31°C (87.8°F), and secondarily entrained mysids may experience heat shock mortality. Based on collections taken in the bay during 1977, as much as 1.2 percent of the population in the bay from Cedar Beach to Gulf Point may be secondarily entrained into Oyster Creek on each day during July and August. This percentage of the population may suffer heat shock mortality.

Although no cold shock data are available for N. americana, it is unlikely that a substantial portion of the population will reside in the discharge canal during winter and will be susceptible to cold shock mortality. Because mysids rise in the water column at night, individuals in the canal probably will be flushed from the canal and replaced by secondarily entrained individuals. Therefore, the percentage of the population that is in the canal and susceptible to cold shock should be relatively small in relation to the number in the bay. Collections in the discharge canal from December 1976 through February 1977 did not indicate a large number of *N. americana* in the thermal discharge.

3.1.5.6 Conclusion

Exclusion of *N. americana* from the discharge canal will occur during June and September (0.5 percent of the volume of the bay) and the near field bay area and discharge canal during July and August (4.0 percent of the volume of the bay). No significant temperature shock mortality is expected to occur.

Based upon this information, it is unlikely that the OCGNS and FRNGS thermal discharge will significantly affect the *N. americana* population in Barnegat Bay. Since this species occurs and reproduces throughout the bay, no portion of the bay is a critical area and the propagation and protection of *N. americana* should be unaffected by the thermal discharge.

3.1.6 _Mercenaria mercenaria_ (northern quahog, hard clam)

3.1.6.1 Introduction

Mercenaria mercenaria (Linnaeus), also known as the hard shell, cherrystone, little neck, and quahog clam, is an infaunal pelecypod that ranges along the entire East Coast of the United States but is most abundant south of Cape Cod. The bivalve lives in intertidal and subtidal zones, often in large numbers, to a depth of about 10.7 m (35 ft) below sea level where it siphons large volumes of water and consumes various planktonic organisms. The mollusc possesses a meroplanktonic stage early in its ontogeny, and it remains in the plankton for up to three weeks prior to setting on the bottom. As the clam metamorphoses, a shell, siphon, and foot develop, and the animal burrows into the sediment. In this environment, _M. mercenaria_ may live for 25 to 40 years under optimum conditions.

Next to the eastern oyster, _Crassostrea virginica_, the hard clam is probably the most commercially important bivalve in America. It is harvested for both commerce and recreation in Barnegat Bay; annual meat yields vary from 90,700 Kg to 408,150 kg (200,000 to 900,000 lbs).

The eggs and larvae of _M. mercenaria_ are more susceptible to the vagaries of environmental conditions than juveniles and adults. As the animal ages, it becomes more tolerant of salinity and temperature extremes, with the egg stage and the cleavage stage of the larvae being most sensitive and the adult stage least sensitive. Thus, the early stages are more vulnerable to thermal discharge from the OCNGS.

Spawning of the hard clam takes place when water temperatures range from 22 to 30°C (71.6 to 86°F); thus, eggs and larvae of _M. mercenaria_ exist in the Barnegat Bay system during spring and summer. However, stressful temperature conditions on eggs and larvae will occur in the discharge canal and the mouth of Oyster Creek only when peak ambient bay temperatures, peak load conditions at the OCNGS, and a spawning event coincide. Therefore, it is highly improbable that most eggs and larvae will be affected by thermal discharge from the OCNGS. The presence of an adult population at the mouth of Oyster Creek supports this contention because larvae have successfully set in this area of the bay in the past.

Thermal discharge from the OCNGS does not result in significant harm to adult _M. mercenaria_. Growth of the adults is reduced by 10 to 25 percent at the mouth of Oyster Creek during the summer months when thermal discharge causes bottom water temperatures to approach or exceed 30°C, but this represents only a minute portion of the total population in the bay (within a 1.6 km (1 mi) radius of Oyster Creek). The lower summer growth rates in bivalves subjected to the effluent amounts to a maximum loss of 1 mm of shell per year which is inconsequential when the entire life span of the clam is taken into account.

The thermal discharge does not affect mortality of *M. mercenaria* in Barnegat Bay. No significant differences ($P < 0.05$) were found in the distribution of seasonal mortality between death assemblages of clams at the mouth of Oyster Creek and three control sites in the bay. Mortality rate curves, survivorship curves, and life tables were nearly identical for each assemblage. Indeed, transplanted life assemblages of the hard clam also showed less mortality inside of the thermal plume than outside of it. Mortality of the organism, therefore, is attributed to the natural population dynamics of the species rather than to the thermal discharge. This condition should not be affected by operation of the FRNGS.

In summary, although evidence exists for reduced growth of adult *M. mercenaria* at the mouth of Oyster Creek, this reduction is not substantial. Thermal discharge from the OCNGS does not exclude the hard clam from setting at the mouth of Oyster Creek, and an adult population exists there. Eggs and larvae of the species do not appear to be adversely affected by the thermal discharge, and adults show no aberrant mortality patterns. Operation of the FRNGS will not alter the normal population dynamics of the species.

3.1.6.2 Life history analysis

The northern hard clam, *Mercenaria mercenaria* is a filter feeding bivalve mollusc that is found from the Gulf of St. Lawrence to the Gulf of Mexico (Pratt, 1973). It is mainly an estuarine species inhabiting shallow bays and coves where the salinity ranges from 18-26 ppt.

Hard clams spawn along their range from late spring to mid-August as water temperature increases above 20°C (68°F) (Pratt, 1973). In Little Egg Harbor, New Jersey, the largest and most dense swarms of clam larvae appeared during the month of July from 1948-1951; spawning occurred over a median daily range of water temperatures of 22 to 30°C (71.6 to 86°F) while maximum frequency of spawning occurred with the 24 to 26°C (75.2 to 78.8°F) range (Carriker 1961). Spawning is a group reaction stimulated at least in part by water temperature (Carriker, 1961) and by a hormone carried in the sperm (Nelson and Haskin, 1949). Davis and Chanley (1956) reported that the total number of eggs released by individual female _M. mercenaria_ ranged from 8 to 39.5 million and averaged 24.6 million per season. Fertilization is external and the resulting pelagic larvae show considerable individual variation in rate of growth. Loosanoff et al (1951) found that at 18°C (64.4°F) setting began 16 days and ended 24 days after fertilization. At 30°C (86°F) setting began 7 days and ended 16 days after fertilization. Within the 18 to 30°C (64.4 to 86°F) temperature range, rate of growth increased with temperature.

Carriker (1961) estimated that larval survival from early to setting stages was roughly 2.6 percent. After setting, the young hard clams burrow into the substrate and during the first year many are lost to snails, crabs and other predators. At approximately 3-5 years of age and 3-4 cm in length, hard clams are harvested by commercial and recreational fishermen.

New Jersey has always supported a hard clam fishery with annual yields from Barnegat Bay ranging from 200,000-900,000 pounds of meats. In 1968 New Jersey accounted for 16.9 percent of the total Northeast hard clam landings (Pratt, 1973). In 1976, 517,300 pounds of hard clam meats worth approximately $2 million were harvested from Barnegat Bay (La Verde, personal communication, NMFS, Toms River, N.J.).

Tiller et al. (1952), in a review of the hard clam fishery of the Atlantic Coast, reported that the most productive clam grounds in New Jersey extended from the southern part of Barnegat Bay to Cape May. The best areas were Little Egg Harbor and Great Bay. These areas continue to be the most productive in the state as catches in Great Bay and Little Egg Harbor are consistently two to four times as large as those from Barnegat Bay (NMFS, Toms River, N.J.).

In 1948, Tiller et al. (1952) reported that dealers were complaining about a decrease in the supply of clams, particularly those of smaller size, and little evidence of a successful recent set. Successful sets were said to occur only occasionally, but support the fishery for several years.

Campbell (1965, 1966 and 1969) conducted pre-operational field surveys designed to determine the distribution and density of _M. mercenaria_ in the vicinity of the OCNGS. The results of the studies conducted during the summers of 1965, 1966 and 1969, indicated that the general area was rather lacking in shellfish resources and was considered suitable only for sport and limited commercial harvesting. Recruitment into the fishery was found to be at a very low level. Despite the apparent lack of substantial recruitment over the years, the hard clam catch from Barnegat Bay in 1976 was larger than any other since 1959.

Adult M. mercenaria can tolerate a wide range of tempertures, salinity, substrate types and pollution levels. According to Pesch (1971) the hard clam can survive low oxygen conditions.

Loosanoff (1939) found that the length of time during which clams remain open depends upon the temperature of the surrounding water. The highest percentage of time spent with the valves open (90 percent) was recorded at 21 to 22°C (69.8 to 71.6°F). Clams became progressively more inactive at temperatures below 9°C (48.2°F) until they finally went into "hiberation" at temperatures below 5°C (41°F). Small changes in water temperature (e.g. a 4°C (7.2°F) increase over a one hour period) had no influence upon shell movements. Henderson (1929) set the upper lethal temperature for adult M. mercenaria at 45.2°C (113.4°F). Turner (1953) reported a temperature of 23°C (73.4°F) and salinity range of 20-23 ppt as optimum for growth of adult M. mercenaria. According to Ansell (1968), the upper temperature threshold of stress on growth of M. mercenaria is 31°C (87.8°F). Populations continuously exposed to temperatures above this point showed increased mortality rates. Based upon extensive field measurements of growth and temperature collected by North American and English investigators, Ansell suggested an optimum temperature for growth of 20°C (68°F). At temperatures less than 9°C (48.2°F) and greater than 31°C (87.8°F), no growth was observed.

The thermal tolerance of the eggs and larvae of M. mercenaria have also been studied. Loosanoff, Miller and Smith (1951) observed that within a temperature range of 18 to 30°C ± 1.0°C (64.4 to 86°F ± 1.8°F), the growth rate of larvae generally increased with increasing temperatures. Mercenaria eggs placed in water at 15°C (59°F) or 33°C (91.4°F) immediately after fertilization showed abnormal development and heavy mortality. If the zygotes were kept at room temperature of approximately 22°C (71.6°F) for two days after fertilization then exposed to the experimental temperatures, rapid normal development followed.

Davis and Calabrese (1964), in a study of the combined effects of temperature and salinity on development of eggs and growth of larvae of M. mercenaria found no well defined optimum temperature for growth of clam larvae at any salinity. Maximum growth occurred with the 25 to 30°C (77 to 86°F) range in different experiments at almost all salinities. At 27.5 ppt the mean length of 12 day old larvae was greatest at a culture temperature of 30°C (86°F). According to Davis and Calabrese (1964), M. mercenaria eggs maintained at a salinity of 25.5 ppt survived within a temperature range of 17.5 to 30.0°C (63.5 to 86°F).

3.1.6.3 Distribution of Mercenaria mercenaria in Barnegat Bay

Campbell (1965, 1966, and 1969) conducted extensive field surveys of the shellfish resources in middle Barnegat Bay, prior to the beginning of operation of the OCNGS. Approximately 2,430 ha (6,000 acres) of potential shellfish beds were surveyed during the summers of 1965, 1966 and 1968. Stations were located on USCG Chart 824B using a grid system of 274 m (300 yds) intervals within a 3.2 km (2 mi) radius of Oyster Creek (Figure 3.1-3). Samples were taken with 4.9 m (16-foot), 12-tooth tongs fitted with 1.3 cm (1/2 in) wire screening. The handles were modified with chain to restrict the opening of the tongs so that each "grab" covered approximately .2 sq m (2.5 sq ft) of bottom. Two "grabs" were taken at each sampling station. The number and size of all commercially important shellfish were recorded. Vernier calipers were used to measure the longest diameter (length) of hard clams in millimeters.

Figures 3.1-4 to 3.1-6 present the results of Campbell's studies as density-distribution charts for each of three size groups of hard clams. Figure 3.1-7 presents the density-distribution chart for all sizes combined.

The estimated standing crop of hard shell clams for the area was 209,000 bu or approximately 947,815 kg (2,090,000 lbs) of meat. The hard clam appeared to be uniformly distributed, in very low densities, throughout the sampling area. One exception was the area north and east of the Forked River mouth which was almost totally devoid of clams. Densitites in general tended to increase toward the southern end of the bay. Large size hard clams (over 66 mm (2.6 in.) in length) were by far the dominant size class in the study area. "Necks" (47-66 mm; 1.8-2.6 in.) and "Sub-legals" (15-46 mm; .6-1.8 in.) were found in extremely low densities indicating a very low level of recruitment. As noted above, Campbell (1969) concluded that the area would support only a "recreational" or "moderate commercial" fishery.

3.1.6.4 Effects of thermal discharges on eggs and larvae of Mercenaria mercenaria

Carriker (1961), in a study of M. mercenaria larvae in Little Egg Harbor, New Jersey, found that during daylight hours, most M. mercenaria larvae are concentrated near the surface while at night the larvae assumed a broader, more uniform vertical distribution. Carriker (1961) noted that in the laboratory, healthy, well fed larvae pass their entire veliger stage suspended in the water, never resting on the bottom. The early life stages of *M. mercenaria* therefore, are more vulnerable to the thermal discharge than are the adults.

Ambient summer temperatures in Barnegat Bay range from 22 to 27° (71.6 to 80.6°F) (Loveland et al, 1966-1974). Carriker (1961) found that the maximum frequency of spawning of *M. mercenaria* in Little Egg Harbor, New Jersey, occurred within the temperature range of 24 to 26°C (75.2 to 78.8°F). As discussed above, during peak operating conditions, the maximum delta T at the mouth of Oyster Creek is approximately 5°C (9°F) at the surface. Eggs and larvae of *M. mercenaria* in the vicinity of the Oyster Creek mouth therefore would be exposed to a maximum temperature range of 29 to 31°C (84.2 to 87.8°F) during the peak spawning period reported by Carriker (1961).

Davis and Calabrese (1964) reported that *M. mercenaria* eggs survived within a temperature range of 17.5 to 30.0°C (63.5 to 86°F) at a salinity of 25.5 ppt. Loosanoff, Miller and Smith (1951) found that immediately after fertilization, *M. mercenaria* eggs showed abnormal development and heavy mortality when cultured at 33°C (91.4°F). If allowed to develop for two days at 22°C (71.6°F) however, the eggs showed rapid normal development upon subsequent exposure to 33°C (91.4°F).

The growth rate of *M. mercenaria* larvae was found to increase over the 18 to 30°C (64.4 to 86°F) range (Loosanoff, Miller and Smith, 1951). Davis and Calabrese (1964) found that maximum growth of larvae occurred within the 25 to 30°C (77 to 86°F) range.

Comparing the experimentally determined thermal tolerances with the range of temperatures possible during the spawning period indicates that *M. mercenaria* eggs and larvae conceivably could be exposed to stressful temperature conditions in the area around the mouth of Oyster Creek. These conditions would exist, however, only when peak ambient bay temperatures, peak load conditions at the OCNGS and a spawning by *M. mercenaria* occur concurrently. Outside of the region immediately around the Oyster Creek mouth, it is unlikely that eggs and larvae could be adversely affected by the thermal discharge since temperature decreases rapidly back to near ambient as distance from the Oyster Creek mouth increases.

If the early life stages of *M. mercenaria* were routinely exposed to stressful conditions in the Oyster Creek region, the logical result of such conditions would be the elimination of the adult population due to a failure of recruitment in this area of the bay. However, data from Kennish (1977) show that this is not the case, as a population set at the mouth of Oyster Creek in the early 1970's when the OCNGS was operating. In addition, clams have successfully set in the discharge canal during the last several years. It must be concluded, therefore, that the thermal discharge from the OCNGS does not significantly affect the survival and growth of the eggs and larvae of Mercenaria mercenaria.

3.1.6.5 Effects on thermal discharges on adult Mercenaria mercenaria

The maximum cooling water delta T across the condensers at the OCNGS is approximately 13°C (23.4°F). This temperature difference decays to approximately 5 to 7°C (9 to 12.6°F) at the U.S. Route 9 bridge and 3 to 5°C (5.4 to 9°F) at the mouth of Oyster Creek.

Studies of the physical behavior of the thermal plume (Woodward-Clyde Consultants, 1975) have indicated that outside of the immediate area around the mouth of Oyster Creek, the plume is primarily a surface phenemenon which only occasionally extends as far north as the Forked River. Vouglitois (1976) was unable to detect significant differences among bottom temperatures measured at the mouth of Oyster Creek, the mouth of the Forked River and the mouth of Stouts Creek (Appendix C9).

Kennish and Olsson (1975) and Kennish (1977) (Appendix C2) conducted studies on the effects of thermal discharge from the OCNGS on growth and motality of Mercenaria mercenaria in Barnegat Bay. Daily, seasonal, and annual growth increments were measured in valve cross-sections of clams from life and death assemblages. Mortality was monitored in populations of clams transplanted to the substrate at the mouth of Oyster Creek and a control area, Stouts Creek.

Results of the research by Kennish and Olsson (1975) indicated that M. mercenaria within approximately a 1.6 km (1 mi) radius of Oyster Creek grew at a lower rate in the summer (ten to 25 percent lower) and possessed a greater number of growth breaks (two to six more per clam) than those away from the creek. However, these differences were not shown to be statistically significant. The authors attributed the lower summer growth rates to thermal discharge from the OCNGS which caused water temperatures to rise above the optimum temperature for growth in the species. They attributed the greater number of growth breaks to thermal shock breaks generated by rapidly fluctuating temperatures associated with abrupt shutdowns, massive load reductions and rapid renewal of operations following shutdowns or load reduction periods at the OCNGS.

The reduced summer growth rates and thermal shock breaks discussed by Kennish and Olsson (1975) do not result in significant harm to M. mercenaria in Barnegat Bay. First the lower growth rates in clams subjected to the effluent amount to only 1 mm of shell per year in the worst case, which is of little consequence when the entire lifespan of the clam is taken into account. Second, the portion of the total bay populations affected by the thermal discharge is minute.

Kennish (1977; Appendix C2) compared the age-height relationship of dead clams at the mouth of Oyster Creek with those at other sites throughout Barnegat Bay (Figure 3.1-8) and determined that thermal discharges have had no apparent effect on the growth rates of death assemblages of clams in the bay (Table 3.1-5 and Figure 3.1-9 (a-e)). Growth rates at all localities were extremely uniform, with growth being fastest and nearly linear during the first three years of life, then dropping off gradually into the gerontic stage.

Mortality in transplanted populations was studied using hard clams planted directly in the substrate in order to monitor any changes in mortality patterns due to elevated temperatures or physiological shock resulting from abrupt changes in plant operations and the concomitant changes in water temperature. In June of 1975, Kennish (1977) transplanted 743 M. mercenaria from Little Egg Harbor and Barnegat Bay to the mouth of Oyster Creek, directly in the path of the thermal effluent. An equal number of clams, of comparable size (20-80 mm) were transplanted to the mouth of Stouts Creek (Table 3.1-7), outside the influence of any thermal discharge. The shell of each specimen was sanded at its growing edge to provide a microgrowth reference plane, stained with Volgers red ink, and numbered with enamel paint. One year after transplantation, the experimental populations were collected and measured for height, and empty valves were examined microscopically to determine their absolute age and season of death; 67.29 percent of the transplanted clams were recovered. At the mouth of Oyster Creek the mortality rate was 6.5 percent (Table 3.1-7). At the Stouts Creek control station the mortality rate was 11.36 percent. A chi-square test indicated that mortality was significantly greater ($0.005 < P < 0.01$) at the control station. Seasonal frequency of death was not significantly different between the two regions. The maximum mortality occurred in summer and minimum mortality in winter.

Mortality patterns in natural populations were studied by examining death assemblages from the mouth of Oyster Creek and three areas outside the influence of the thermal plume. Death frequency histograms, mortality rate curves, survivorship curves and life tables were constructed for each assemblage. No significant differences were found in the distribution of seasonal mortality between the Oyster Creek site and the three control areas (Figures 3.1-10, 3.1-11 (a-d), 3.1-12 (a-d); Table 3.1-8.

Kennish (1977) concluded that the thermal discharge does not adversely affect mortality of M. mercenaria in Barnegat Bay, but rather that mortality results from the natural population dynamics of the species.

Based upon the above results as well as the physical behavior of the thermal plume, the applicant concludes that thermal discharge from the OCNGS has not, and will not, substantially affect the growth and mortality of adult M. mercenaria in Barnegat Bay.

3.1.6.6 Incremental effect of the FRNGS on Mercenaria mercenaria

Juvenile and adult Mercenaria mercenaria are euryhaline and eurythermal, being capable of tolerating a salinity range of 15 to 32 ppt and a temperature range from below 0°C (32°F) to above 30°C (86°F). Eggs and larvae, however, tolerate a more restricted range of salinity and temperature conditions than juveniles or adults (Davis and Calabrese, 1964; Loosanoff et al, 1951).

Because no adult populations have become successfully established in the discharge canal, and salinity and temperature effects of the FRNGS will be negligible at the mouth of Oyster Creek (LMS, 1977), no impact is anticipated on post-set stages of M. mercenaria in the discharge canal and Barnegat Bay. Eggs and larvae of the species should not be subjected to salinities greater than 27 ppt. The increase in salinity due to the FRNGS discharge will be only 0.26 to 0.53 ppt some 60 m below the discharge site and the increase in temperature will be only 0.25°C (0.45°F) in the same area. These increases should have no adverse impact on eggs and larvae of the hard clam, and the species should continue to set at the mouth of Oyster Creek.

3.1.6.7 Summary and conclusions

Data collected on the distribution, growth, and mortality of M. mercenaria in the intake and discharge canals and Barneget Bay reveal the following information.

1. Middle Barnegat Bay supports a clam fishery that is of recreational to moderate commerical value. Campbell (1965, 1966, and 1969) estimated approximately 209,000 bu of clams or 447,815 Kg (2,090,000 lbs) of meat for a 2,430 ha (6,000 acre) area in the middle bay. The clams appeared to be in low densitites but uniformly distributed throughout.

2. Thermal discharge from the OCNGS has no apparent impact on eggs and larvae of the species. M. mercenaria has successfully set in the past at the mouth of Oyster Creek in an area subjected to the thermal discharge.

3. Adult clams affected by the thermal discharge at the mouth of Oyster Creek grow at a reduced rate (10 to 25 per cent) during the summer months compared to clams that are unaffected by the discharge. They also experience more breaks in growth as a result of thermal shocks from operation of the OCNGS compared to clams removed from the effluent. The net impact of these effects is a reduced rate of growth amounting to 1 mm of shell per year, but this loss of shell is of little consequence when the entire lifespan of the animal is taken into account.

4. Mortality of juvenile and adult M. mercenaria is unaffected by thermal discharge from the OCNGS.

5. Operation of the FRNGS should not impact on any ontogenetic stages of the pelecypod in the discharge canal and Barnegat Bay.

3.1.7 Corophium tuberculatum

3.1.7.1 Introduction

Corophium tuberculatum is a gammaridean amphipod which ranges from the Bay of Fundy to Florida and the eastern Gulf of Mexico (Bousfield, 1973). This species is characterized by an elongated, flattened body approximately 3 mm (0.1 in.) long and dwells in tubes either in the sediment or upon submerged surfaces. C. tuberculatum is a preferential filter feeder but may also leave its tube and feed upon detritus. Members of the genus Corophium are a minor source of forage for fish and birds.

The density of Corophium spp. in Barnegat Bay fluctuates tremendously from year to year. During at least one year, C. tuberculatum was found in greater abundance over a longer period of time, in the intake canal when compared to the discharge canal. A closely related species, C. asherusicum, is found in abundance in the discharge canal throughout the year.

The applicant concludes that although the thermal discharge from the OCNGS and FRNGS may have some seasonal effect upon the abundance and distribution of Corophium tuberculatum, this will not interfere with the preservation and propagation of the balanced, indigenous community of fish, shellfish, and wildlife.

3.1.7.2 Life history analysis

Corophium tuberculatum is a gammaridean amphipod which ranges from the Bay of Fundy to Florida and the eastern Gulf of Mexico (Bousfield, 1973). Members of the family Corophiidae are characterized by an elongated, flattened body and dwell in tubes either in the sediment or upon submerged surfaces. According to Enquist (1950), Corophiidae are preferential filter feeders but may also leave their tubes and feed upon detritus when the concentration of suspended matter is low.

There is very little information available on the life history, habits and tolerances of Corophium tuberculatum. The European species Corophium volutator, however, has been studied extensively and the available information indicates that species of the genus Corophium are tolerant of a wide range of environmental conditions.

According to Crawford (1937), C. volutator builds its tubes primarily in a muddy sand substrate while C. acherusicum and C. tuberculatum build their tubes primarily upon the surface of pilings, boats, rocks and shells. Meadows (1964) reported that C. volutator builds U-shaped tubes which extend to a maximum of 10 cm (3.9 in) below the surface and prefers a substrate previously maintained under anaerobic conditions.

Gamble (1970) found that C. volutator and C. arenarium are relatively resistant to anaerobic conditions with small individuals being less resistant than larger ones.

In laboratory studies of the effect of salinity on the survival, moulting and growth of C. volutator, McLusky (1967) found that if supplied with mud, individuals of this species survived for over 500 hours within the salinity range of 2-50 ppt. Without mud the range of salinities tolerated was 7.5-47.5. Growth occurred at a maximum rate at 15.4 ppt; below 4.4 ppt growth was progressively reduced.

In a field study of the effects of salinity on the distribution and abundance of C. volutator in the Ythan estuary in Great Britian, McLusky (1968) observed that in areas above 5 ppt, distribution and abundance were controlled by the nature of the substrate; where salinity is less than 5 ppt but substrate is suitable, the effects of salinity override the effects of substrate.

Shyamasundari (1973) studied the effects of salinity and temperature on C. triaenonyx in Visakhapathan Harbor, India. He found that this species lived normally within a range of 4 to 55 ppt and 5 to 40°C (41 to 104°F). Ambient salinity ranged from 8.7 to 34.7 ppt; ambient temperatures went up to 31°C (87.8°F).

Members of the genus Corophium are a source of food for fish (Borgeson et al, 1967; Kuhl, 1970, and Heard et al, 1972) and birds (Goss-Custard, 1969). Analyses of the stomach contents of fishes in Barnegat Bay (Tatham et al., 1978) indicate that Corophium is a minor source of forage.

3.1.7.3 Corophium tuberculatum in the intake and discharge canals and Barnegat Bay

Young and Frame (1976), studied the effects of the Oyster Creek thermal discharge on the epibenthic organisms in the intake and discharge canals between October 1970 and October 1971. Figure 3.1-13 presents the seasonal abundance of Corophium tuberculatum and Corophium acherusicum which settled on rubber test panels in the intake and discharge canals. Ovigerous females and juveniles were found during most months indicating that C. acherusicum was reproducing throughout the year in the discharge canal. Ovigerous females of this species were found only in April and May in the intake canal. In the case of C. tuberculatum, ovigerous females were found only in November in the discharge canal and from March-November in the intake canal. During the early spring, adult C. tuberculatum were more abundant in the discharge canal but totally disappeared by May. C. acherusicum, on the other hand, was found in great abundance in the discharge canal throughout the year but only sporadically, during the colder months, in the intake canal. Naylor (1965) found that C. acherusicum was abundant in the thermal discharge of the Sir John Generating Station in South Wales and observed a shift in the breeding season in comparison to a control area.

Shafto (1974; Appendix C3) in her study of boring and fouling organisms in Barnegat Bay, found Corophium to be more or less equally distributed along the western portion of the bay from the mouth of Stouts Creek to Waretown (Figure 3.1-14). Her identification of Corophium volutator as the only species present was most probably incorrect, however, as C. volutator has not been reported south of Casco Bay, Maine, and has never been identified from Barnegat Bay by previous or subsequent investigators. Densities on monthly wooden exposure panels were generally low (less than 10 per station per month) except at the condenser discharge station where 750 Corophium were found after an exposure period of March 31-May 5. According to the settling pattern reported by Young and Frame (1976) (Figure 3.1-13), these Corophium were probably both C. tuberculatum and C. acherusicum. In the Forked River, however, a total of only 110 Corophium were found at three sampling stations during the entire year.

Studies conducted by JCP&L showed that C. tuberculatum accounted for 2 percent of all amphipods entrained through OCNGS and only 28 percent of all Corophium spp. (Section 4.3.2.1.2).

It would appear then, that the density of Corophium spp. may fluctuate tremendously from year to year (compare densities of Young and Frame (1976) (Figure 3.1-13) with those of Shafto (1974) (Figure 3.1-15)) in Barnegat Bay. In addition, during at least one year (October 1970-October 1971) according to Young and Frame (1976), C. tuberculatum was found in greater abundance, over a longer period of time, in the intake canal when compared to the discharge canal.

The applicant concludes that the exclusion of C. tuberculatum from the discharge canal during the late spring and summer will not interfere with the preservation and propagation of the balanced, indigenous community of shellfish, fish, and wildlife. The abundance of C. tuberculatum and the presence of ovigerous females in the intake canal during ten months of the year indicate that this species has not been appreciably harmed by the thermal discharge in areas outside of the thermal mixing zone. Furthermore, C. tuberculatum appears to be a relatively insignificant source of food for other organisms in Barnegat Bay.

3.1.8 Hydroides dianthus (Verrill, 1873)

3.1.8.1 Introduction

Hydroides dianthus is a filter-feeding serpulid polychaete worm which ranges from Cape Cod to Florida. Larval Hydroides settle upon solid surfaces and secrete a calcareous tube which permanently affixes the worm to the substrate. The largest worms reach a length of approximately 12 cm (4.7 in) and a diameter of about 5 mm (.2 in); the maximum life span is approximately two years.

Hydroides dianthus is well known as a fouling organism which has caused serious damage to shellfish crops when it has settled in great abundance by competing for food and space and is also responsible for severe fouling of boats.

Young and Frame (1976) noted that H. dianthus settled in greater abundance in the intake canal when compared to the discharge canal and suggested that the differential settling pattern may be indicative of a "power plant effect".

Studies have indicated that compared to surrounding areas, the density of H. dianthus in Oyster Creek is very low. The relative scarcity of this species in Oyster Creek has not been adequately explained, but, since Hydroides dianthus is an abundant species which is evenly distributed in middle Barnegat Bay outside of Oyster Creek, any reduction in density apparently has been confined to the discharge canal and is not considered significant.

3.1.8.2 Life history analysis

Hydroides dianthus is a serpulid polychaete worm which ranges from Cape Cod to Florida (Turner et al 1960). According to Grave (1933), Hydroides reproduces along its range from mid-June to the end of October. Young and Frame (1976), however, reported Hydroides settling as early as April in the Forked River. The sexes are separate, fertilization is external and the pelagic larvae spend approximately ten days in the water column before metamorphosing (Grave, 1933). Subsequent to settlement upon a solid substrate, the worm secretes a calcareous tube which premanently affixes it to substrate. Stones and shells appear to be preferred rather than softer substrates such as wood (Grave 1933; Hoagland and Turner 1977). Hydroides reaches sexual maturity seven to eight weeks after metamorphosis and the young of the year may begin releasing gametes in August (Grave, 1933). The largest worms reach a length of approximately 12 cm (4.7 in) and a diameter of about 5 mm (.2 in); the maximum life span is approximately two years (Grave, 1933).

3.1.8.3 Hydroides dianthus in the intake and discharge canals and Barnegat Bay

Young and Frame (1976), in a one year study of the epibenthos inhabiting the intake (Forked River) and discharge (Oyster Creek) canals of the OCNGS, found that Hydroides settled more frequently upon rubber test pannels in the intake canal than in the discharge canal. On panels retrieved on a 28 day schedule, settlement was observed in the intake canal from April through July. No settlement was observed on the 28 day panels submerged in the discharge canal. On panels submerged for 84 days, Hydroides was found in July and October in the intake canal and only in July at the discharge canal station, the only occurrence of Hydroides at this station. Approximately 300 Hydroides per .1 sq m were found on the 84 day panel retrieved from the intake canal in July. The density on the corresponding panel from the discharge canal was 20 per .1 sq m. Young and Frame (1976) suggest that the observed differences in the settlement patterns of Hydroides in the intake and discharge canals may be indicative of a "power plan effect."

Shafto (1974; Appendix C3) studied the marine boring and fouling invertebrate community of Barnegat Bay from October 1971 to September 1972. She monitored the settlement of boring and fouling animals on wooden test panels at nine stations including Oyster Creek, Forked River and Stouts Creek (Figures 3.1-14, 15). Hydroides dianthus was found to settle from June through October with time of maximum settlement varying from location to location. The only settlement in Oyster Creek occurred in September and October when a total of six specimens were found at three stations. Maximum settlement at other stations occurred in June, July and August. As many as 7770 individuals settled on the test panels at the Waretown station during a one month period (July 19-August 18). At the Forked River mouth station, maximum settlement for a one month period occurred between July 5 and August 6 when 6089 individuals were found on the text panels. Figure 3.1-15 presents the total number of Hydroides and other dominant species which settled at each station from April 1972 through September 1972.

Shafto reported that Hydroides occurred within the narrowest salinity range (17.5 to 24 percent) of all the dominant boring and fouling organisms found during her study. The heaviest settlement occurred at the Waretown and Forked River mouth stations where salinity was found to be higher than at the other stations.

The settlement data were analyzed using Johnson's diameter method of hierarchical cluster analysis (Johnson, 1967). The results of these analyses showed that Hydroides dianthus and Bankia gouldii had the most similar settling patterns. Three major groups of species were found: 1) those which settled only at salinities greater than 17.5 ppt (Hydroides dianthus and Bankia gouldii); 2) those found settling only at salinities above 15 o/oo (Molgula manhattensis, Botryllus schlosseri, and Corophium volutator); and 3) those found at salinities below 15 ppt (Balanus eburneus, Bowerbankia gracilis, Membranipora sp., Polydoa ligni and Meltia nitida).

The first group was dominant at the high salinity, Waretown and Forked River mouth stations while the last group was dominant at the relatively low salinity, Oyster Creek and Stouts Creek stations. Shafto concluded that "there probably is a relationship between the salinity tolerances and the settling profile of a species although the direct relationship is not clear."

Shafto also found evidence which indicates that Balanus eburneus and Hydroides dianthus were competing for settling space. At most stations, Balanus eburneus reached its maximum settling rate approximately six weeks before the peak settlement of Hydroides dianthus. During the summer months, a decrease in the settlement of Balanus eburneus was observed which was apparently not due to the high summer water temperature since this species had been found settling at temperatures as high as 39.5°C (103.1°F) in Oyster Creek. Balanus reached its minimum settling rate in the bay as Hydroides was reaching its maximum settling rate. According to Shafto, Balanus continued to dominate the community during the summer months, however, at stations where low salinity may have prevented Hydroides from settling. At stations where salinity was high, Hydroides settled heavily during the summer months, presumably inhibiting further settlement of Balanus. Shafto did not clearly outline how she reached the above conclusions and her data appear to contradict them in some cases. Hoagland and Turner (1977), however, have also found evidence which suggests that there may be competition for settling space between Hydroides and Balanus.

Loveland et al (1966 to 1974) studied the benthic flora and fauna of Barnegat Bay and the possible impact of the OCNGS upon those organisms, during five pre-operational (1965 to 1969) and six operational (1970 to 1973 and 1976 to 1977) years. Based upon density per square meter, Hydroides dianthus ranked 29th out of a total of 271 species found. Since Hydrodes settles primarily upon solid substrates, Loveland et al very likely underestimated the abundance of this species as their studies concentrated on the sandy or muddy substrates found at the Stouts Creek, Forked River and Oyster Creek mouths (Figure 3.2). Hydroides occurred with equal frequency at all three sampling areas. The mean density for the 1969 to 1973 period at Stouts Creek was 18.4 per sq m; at Forked

River, 54.1 per sq m and at Oyster Creek 13.3 per sq m. Although the mean denisty at Forked River is somewhat greater than at the other two areas, this is attributable to one sample in which 1140 Hydroides per square meter were found attached to shell hash. The mean densities are not significantly different at the 0.05 level of significance.

The reasons for the apparent scarcity of Hydroides in Oyster Creek when compared to the surrounding area are not clear. Inhibition of settlement by high summer water temperatures remains a possiblity yet to be disproven. Low salinity is very likely a major limiting factor in the upper reaches of Stouts Creek but probably not in Oyster Creek. There is some evidence that barnacles (Balanus spp.) are competing with Hydroides for settling space, particularly in the discharge canal. According to Young and Frame (1976), the period of maximum settlement of Hydroides in the intake canal was April through July. Very few Hydroides settled in the discharge canal during this same period, while over 26,000 Balanus were found. In the intake canal, only 364 Balanus settled during the April-July period.

The ecological significance of a reduction in the density of Hydroides in Oyster Creek is not apparent. Hydroides has caused serious damage to shellfish crops (Arakawa, 1971), when it has settled in great abundance, by competing for food and space. The species is also responsible for severe fouling of boats (Long, 1971). Since Hydroides appears to be an abundant species which is evenly distributed in middle Barnegat Bay (Loveland et al, 1966 to 1974), any reduction in density has apparently been confined to the approximately 100 acre area of the discharge canal and is not considered significant. Operation of the FRNGS is not expected to affect this condition.

3.1.9 *Teredo* spp.

3.1.9.1 Introduction

The family Teredinidae, commonly called shipworms, is comprised of the highly specialized bivalve molluscs adapted for boring into wood. Unlike other bivalves, teredinids have a greatly reduced shell and a long, worm-like body protected by the wood in which they bore and by a calcareous tube secreted around the organisms once they have penetrated wood.

Teredinid borers are capable of causing a tremendous amount of damage to unprotected wooden structures in a relatively short period of time. For this reason, they are of substantial interest from socioeconomic viewpoint.

Four species of teredinida are known to occur in the Barnegat Bay system. *Teredo navalis* is the dominant species on the eastern side of the bay and *Bankia gouldi*, by far the most abundant species, is dominant on the west side of the bay.

The subtropical species *Teredo bartschi* has been found only in Oyster Creek. *Teredo furcifera*, another subtropical species, has been found in very low densities throughout Barnegat Bay. The subtropical species were first observed in Barnegat Bay in 1974 by Woodward-Clyde (1976).

The distribution and abundance of *Teredo navalis* are unrelated to the operation of the OCNGS. This species has been found in very low densities along the Western shore of Barnegat Bay and its pattern of distribution may reflect the sensitivity of *Teredo navalis* to the humic material in marsh runoff.

At its observed peak abundance, *Teredo furcifera* occurred in extremely low densities when compared to the endemic species, *B. gouldi*, and its distribution and abundance have become more restricted each year since 1975. The available data indicate that this species is not truly established in Barnegat Bay and its occurrence is unrelated to the operation of the OCNGS.

The fact that the distribution of *Teredo bartschi* is limited to Oyster Creek suggests a possible positive thermal effect on the population of this species. The absence of this species in other parts of Barnegat Bay however, indicates that the thermal discharge has not caused the dispersal of *T. bartschi* into the bay.

Bankia gouldi has the most extensive distribution of the marine borers found in the Barnegat Bay system. The distribution of this species is unrelated to the thermal discharge from the OCNGS as the major concentrations of *B. gouldi* occur in areas of the bay that are outside the influence of that discharge. There is some evidence that the abundance of B. gouldi could be influenced by the thermal discharge in the form of slightly earlier gonad development in specimens from Oyster Creek. No evidence has been found, however, to indicate that the early gonadal development has resulted in any increase in the abundance of B. gouldi in Barnegat Bay.

3.1.9.2 Life history analysis

The family Teredinidae, commonly called shipworms, is comprised of the highly specialized bivalve molluscs adapted for boring into wood. Unlike other bivalves, teredinids have a greatly reduced shell and a long, worm-like body protected by the wood in which they bore, and by the calcareous tube secreted around the organisms once they have penetrated wood. A single shipworm completely fills its burrow, the diameter and length of which increase with growth. When undisturbed, the siphons (an incurrent siphon for receiving oxygenated water and nutrients and an excurrent siphon for the expulsion of waste and sex products) protrude from the original larval entrance site.

When the shipworm is disrupted by, for example, removing infested wood from the water, the siphons are withdrawn into the burrow. Immediately thereafter specialized, calcareous organs called pallets effectively seal the burrow. Roch (1931) observed that Teredo navalis remained alive for six weeks in this manner. Thus, the organisms can also withstand adverse environmental conditions such as temperature and salinity changes. The ability to utilize stored glycogen (Lane, 1955) helps to explain the fact that teredinids can survive under anaerobic conditions for these extended periods of time.

A compendium of the general and species of shipworms was provided by Turner (1966). Four species of teredinids are known to occur in the Barnegat Bay system (Richards et al, 1978). Teredo navalis is dominant on the east side of the bay and Bankia gouldi is dominant on the west side of the bay. The The subtropical species, Teredo bartschi has been found only in Oyster Creek. Teredo furcifera, another subtropical species, has been found in very low densities throughout Barnegat Bay (Richards et al, 1978). The subtropical species were first observed in the bay in 1974 by Woodward-Clyde (1976).

Life histories of various species of shipworms have been discussed by Culliney (1970), Nair and Saraswathy (1971), and Turner and Johnson (1971). Sexual conditions are variable in shipworms and protandry occurs in the four shipworm species found in Barnegat Bay.

There are three known ways in which fertilization can occur in shipworms (Clapp, 1951; Turner, 1977):

1) Sexual products are extruded separately into the water column where fertilization occurs externally;

2) Sperm extruded externally to the water column may be taken into the incurrent siphon of the female such that fertilization occurs in the epibranchial cavity;

3) Fertilization may be direct where the excurrent siphon of a male transfers sperm to the incurrent siphon of a female.

Direct sperm transfer (Type 3) was witnessed in B. gouldi by Clapp (1951). In Teredo, fertilization must occur in the epibranchial cavity of the female (Type 2) since all species of this genus brood the young. At the time of fertilization, shipworm eggs released directly into the water column (Type 1) are generally from 40 to 60 microns in diameter (Nair, 1956), whereas species which brood the young, such as T. navalis, have eggs between 50 and 60 microns in diameter (Loosanoff and Davis, 1963).

The age or size of shipworms at the time of spawning is dependent on such factors as temperature, salinity, available space in wood, and nutrients. Records of age and size of shipworms have been presented by various authors. According to Grave (1937), T. navalis at Woods Hole, Massachusetts, were mature in six weeks. The tropical T. furcifera can apparently mature in 20 days (Karande et al., 1968). These observations are relative, however, and dependent upon seasonality and other factors. Although length measurements at sexual maturity are available for certain species, these records may be incomplete since "stenomorphic" shipworms (growth is stunted by lack of space or competition) are still capable of reproducing though further boring is not possible (Turner, 1966).

Concerning spawning seasons, observations of larval incidence in the plankton as well as numbers of settled larvae gives some indication as to the approximate time of spawning by shipworms. However, under fluctuating estuarine conditions, microscopic assessment of the maturity of adult gonads may be a more reliable method (Nair and Saraswathy, 1971). Gonad maturation and spawning in both oviparous and larviparous species are positively correlated with temperature. In Chesapeake Bay, Maryland, B. gouldi was reported to spawn when ambient temperatures reached 16 to 20°C (60.8 to 68°F) (Scheltema and Truitt, 1954). Under laboratory conditions, Culliney (1970) found that this species spawned both gametes and fertilized eggs at temperatures from 17.5 to 30°C (63.5 to 86°F), with mass spawning most often near 25°C (77°F) (Table 3.1-9). Under natural conditions, the larviparous T. navalis spawns in the North Atlantic above 11 to 12°C

(51.8 or 53.6°F) (Grave, 1928). In the laboratory, Culliney (1970) observed spawning of this species at temperatures from 13 to 30°C (55.4 to 86°F). Studies on the shipworms of Barnegat Bay (Shafto, in Loveland, et al, 1972; Turner 1973-1974) indicated that based upon settlement data, peak shipworm spawning occurs from late May to July when water temperatures normally range from approximately 18 to 22°C (64.4 to 71.6°F). Richards et al (1978) found that *Teredo navalis* in Barnegat Bay successfully settle from July to November with peak settlement in August when water temperatures ranged from 23 to 31°C (73.4 to 87.8°F). *Bankia gouldi* settled from July to September with peak settlement in July and August. *Teredo bartschi* settled primarily in September and October when temperatures ranged from 10 to 30°C (52 to 86°F). In the Pacific Northwest and other temperate areas, species such as *B. setacea* spawn once a year from November through February at temperatures from 14 to 19°C (57.2 to 66.2°F) (Haderlie and Mellor, 1973). In contrast, *T. navalis* populations in the Miami, Florida, area were observed to be actively breeding throughout the year (Greenfield, 1953), whereas more northerly populations are limited by winter temperatures (Grave, 1928).

Although fecundities of shipworms probably vary greatly with environmental and other conditions, oviparous species generally release far more eggs but in a less advanced state of development than larviparous forms. According to Sigerfoos (1908), *Psiloteredo megotara* produced over 100 million eggs in a single spawning, whereas *T. navalis*, a short-term larviparous species, may produce 20,000 to 50,000 veliger larvae per individual (Imai et al, 1950). A long term larviparous species such as *T. furcifera* may produce 7000 larvae in a single brood (Karande et al, 1968) however, the veligers are released fully developed. Of significance here is that the larvae of oviparous and short term larviparous forms (for example *B. gouldi* and *T. navalis*) are subject to currents, fluctuating environmental conditions, predation and other parameters for all or part of their pelagic existence. On the other hand, larvae of the long term larviparous species (for example, *L. pedicellatus* and *T. furcifera*) are ready to settle shortly after they are released from the adult. However, larvae of the same species must then compete for available space and food within a limited geographic area.

Development of teredinid eggs is rapid and appears to be similar for oviparous species studied (Turner, 1966). Cleavage and other facets of the embryology of *B. carinata* are described by Nair and Saraswathy (1971). Within four to five hours after fertilization the larvae develop cilia and become free swimming (blastula stage). The typical molluscan trochophore occurs in about 12 to 14 hours and the straight-hinge veliger from 18 to 24 hours. Larvae are capable of feeding at this stage wherein the ciliated velum collects and transports planktonic food to the mouth. Development of the umbos rounds out the D-shape of the straight-hinge veliger and in the last larval stage, the pediveliger, both the velum and a foot are present so that the larvae can swim and crawl. Once the pediveliger stage is reached, larvae are capable of penetrating wood. Culliney (1970) observed that in B. gouldi, larval life spanned an average of 25 days in the laboratory, and the shortest larval period observed was 20 days.

As noted previously, species in the genus Teredo retain the young in the gills until the veliger stage. T. navalis releases the young at the straight-hinge stage of development so that growth rate to metamorphosis is also dependent on environmental factors in the plankton. Laboratory studies by Loosanoff and Davis (1963) and Culliney (1970) noted that the average larval life span for T. navalis was 20 days; the shortest larval life span of 11 days was observed by Culliney (1970). In the waters of Barnegat Bay, Nelson (1924) estimated the free swimming period of shipworm larvae to last three to four weeks.

Long term larviparous species such as T. furcifera brood the young in the gills to the early or late pediveliger stage so that larvae are capable of settling shortly after release. These species of Teredo have been observed to crawl on the surface of wood for the first 24 to 48 hours after release whereupon the larvae position themselves for penetration into the wood on the third day. However, some T. furcifera larvae are apparently capable of immediate penetration.

Studies on the growth rates of shipworms have been conducted because these rates are proportional to the amount of damage done to wooden structures in uncrowded conditions. Quayle (1956, 1959) measured growth rates of B. setacea in British Columbia. When water temperatures were below 10°C (50°F), he found that growth rates were low (50 mm (2 in.) per month). However, at temperatures above 10°C (50°F), the average growth rate was 100 mm (4 in.) per month. Taking into account the effects of crowding, Haderlie and Mellor (1973) worked with the same species and found that the average monthly growth rate under crowded conditions was 43 mm (1.7 in.). With unlimited space, however, these authors measured average rates of 74 mm (2.9 in.) per month. That density significantly affected rates of growth in B. gouldi was also observed by Scheltema and Truitt (1954). They observed that populations have different growth rates in different localities within the same estuary. These rates depended on the number of individuals which had settled. Miller (1922) observed that the growth rate of *T. navalis* was extremely rapid during the first month, decreasing to a constant for the next two months with a further reduction through the fourth month. He implied that these decreases resulted from lowered winter temperatures and/or crowding. As mentioned previously, a stenomorphic condition in shipworms has been defined as dwarfed growth because of overcrowding.

In addition to density dependent factors, temperature, salinity and other parameters affect growth rates in shipworms. Nagabhushanam (1961) observed that maximum growth of *T. furcifera* coincided with the highest environmental temperature recorded (30.9°C; 87.6°F).

Reproduction, survival and growth of shipworms are dependent on a number of environmental factors, as discussed previously. These include temperature, salinity, presence of wood and the effects of crowding. Similarly, the main factors influencing the distribution of shipworms are temperature, salinity, the presence of wood, currents, competition and other chemical parameters. A discussion of each of these environmental factors follows in terms of shipworm distribution and dispersal.

Temperature is an important parameter controlling shipworm distribution (Turner, 1966) since the species studied to date all appear to have optimum temperatures for spawning and survival of the young (Table 3.1-9), i.e., species living in different geographic locations are limited by different ranges of temperature. Temperatures that are too low or high for one species may be favorable or tolerable for others (Nair and Saraswathy, 1971). The minimum, optimum and maximum temperatures will vary with the species and may change through periods of acclimatization. Consequently, shipworms can become established in various habitats. For example, Naylor (1965) suggests that warm effluents in Southampton Water, England, were responsible for extending the range, growing and breeding periods of *Teredo* sp. Apparently limiting winter temperatures and minimal summer heat determines distribution in higher latitudes; limiting maximal temperatures for survival occur in summer and minimal temperatures for reproduction and growth in winter determine the boundaries of shipworm distribution towards the equator. Uniformly high tropical temperatures hasten metabolic activities and accelerate growth rates, leading to the attainment of sexual maturity at a surprisingly early age (Nair and Saraswathy, 1971).

Adult shipworms are known to survive wide ranges in temperature since they can readily seal off the burrow until more favorable conditions are encountered. This facilitates transportation through wider geographic areas. In higher latitudes, a slight increase in normal summer temperatures seems to increase activity (Clapp, 1935) whereas activity may be retarded during long and/or severe winters. Further, extreme temperatures (heat or cold) may decimate entire populations when occurring during the more vulnerable larval stages.

Specific responses to temperature vary depending on the species and the area. For Atlantic coast populations of *T. navalis*, 22.5°C (72.5°F) appears to be optimum whereas 7.5°C (45.5°F) is unfavorable (Anon., 1927 as cited in Nair and Saraswathy, 1971). In Sweden, *T. navalis* is most active between 15°C (59°F) and 25°C (77°F) and can tolerate a range from 5 to 30°C (41 to 86°F). Additionally, this species has been shown to survive for some time at the freezing temperature of sea water (-1.4°C; 29.5°F) (Roch, 1932). Greenfield (1952) found that *T. navalis* attacks in San Francisco were heaviest during summer and autumn (14 to 20°C; 57.2 to 68°F) whereas activity decreased when water temperatures fell below 14°C (57.2°F). This was confirmed by Imai et al 1950). In the Black Sea, Zvorykin (1941) found that -1°C (30.2°F) was lethal for *Teredo* sp. whereas moderate activity was observed up to 5°C (41°F). The same author also found a decrease in activity above 25°C (77°F) with death occurring at 30 to 38°C (86 to 100.4°F). In studies of the waters of Barnegat Bay, Turner (1973) noted that *T. navalis* adults tolerated a temperature range from 2 to 35°C (35.6 to 95°F). Turner's report further noted that spawning occurred between 13°C (53.4°F) to 30°C (86°F). This agrees well with the data of Grave (1928), Nelson (1928), Loosanoff and Davis (1963), and Sullivan (1948). Sexual maturity was apparently attained 33 days after settling when temperatures were 22 to 25°C (71.6 to 77°F), and in 24 days when temperatures were 26 to 30°C (78.8 to 86°F) (Turner, 1973).

Later studies in Barnegat Bay by Richards et al (1978) showed that *Bankia gouldi* occupied wooden exposure panels where, over the course of the study, water temperature ranged from 0 to 30.3°C (32 to 86.5°F). *Teredo bartschi* was found only in Oyster Creek over a range of temperatures from 3.0 to 30.3°C (37.4 to 86.5°F). *Teredo navalis* and *T. furcifera* were found in areas where temperatures ranged from 0.0 to 32°C (32 to 89.6°F) and 0.0 to 30.3°C (32 to 86.5°F) respectively. Teredinid larvae were observed in plankton samples from May through October when temperatures ranged from 7.2 to 32.0°C (44.9 to 89.6°F).

The optimal temperature range for larval development in *T. navalis* was found to be 18 to 27°C (64.4 to 80.6°F) by Kudinova-Pasternak (1962). The lower lethal limit for the larvae of T. navalis was given as 10°C (50°F) (Turner, 1974). However, if such populations become acclimatized to higher ambient temperatures, their lower lethal temperature may be elevated, as occurs in other aquatic species (Brett, 1970). Thus, decreased resistance to lower temperatures is correlated with acclimatization to higher temperatures, although larvae reared in higher temperatures may have a competitive advantage in growth over those reared at lower temperatures. Non-lethal lower temperatures may prolong the pelagic life of oviparous and short term larviparous species.

The response of shipworms to different salinities varies widely since some species tolerate high salinities, others tolerate wide salinity ranges and a few can tolerate very low salinities (Nair and Saraswathy, 1971). As is true for temperature tolerances, intraspecific variation occurs within different geographic locales. However, this may also be a result of temperature since effects of salinity can be modified by temperature (Kinne, 1963).

Each species of shipworm requires different salinity conditions for optimal survival, growth and especially spawning. Table 3.1-10 gives these optima and ranges for three species found in Barnegat Bay. However, it should be remembered that adults can withstand unfavorable salinities by sealing the burrow with the pallets. The utilization of glycogen under anaerobic conditions while sealed in the burrow probably facilitates survival at these times (Lane, 1955). Thus, distribution may be assured despite brief exposure to unfavorable environmental conditions.

Shipworms can only penetrate wood during the short larval period when free swimming. Shipworm populations are small in areas where little wood is available for settlement and consequently, populations never become firmly established under such conditions. On the other hand, where wood is plentiful and hydrological conditions are favorable, population explosions are likely. However, regardless of the abundance of wood, shipworms must still compete for available space with individuals of the same and other species of borers, as well as marine fouling communities. As discussed previously, once larvae settle and begin to bore, growth is, in part, density dependent (Clapp, 1925; Isham et al, 1951).

The response of shipworms to various types of woods was discussed by Nair and Saraswathy, (1971). Although no wood is indefinitely immune to attach, woods with appropriate quantities of silica, alkaloids or tannins (especially tree bark) or man-made chemical treatments offer resistance to the larvae. The American Wood Preservers Association recommends that wooden structures be given a minimum creosote treatment of 20 lbs. per cu. ft. in order to remain free of teredinid attack for any length of time. It is well known that wood must be "conditioned" prior to penetration whereby toxic substances are probably replaced by saturation with water (Isham and Tierney, 1953). Moreover, a suitable microflora is normally required on the surface of the wood prior to attack.

It is known that larvae of certain species must encounter wood within a relatively short time as pediveligers or death may result. In *T. furcifera*, Turner and Johnson (1971) noticed that ability to penetrate seemed to decrease when pediveliger larvae were deprived of wood. The larvae lost the ability to swim, the velum degenerated and the larvae metamorphosed without having penetrated. Apparently, such a process is common in long term larviparous species (those that brood the young to the pediveliger stage) such as *T. furcifera*. However, short term larviparous species (*T. navalis* and others) and oviparous species (i.e. *B. gouldi*) may delay metamorphosis for longer periods.

In addition to temperature and salinity, other water quality considerations, such as oxygen, pH and pollutants may have a significant effect on the distribution of shipworms.

In studies with *T. navalis* from Sweden, Roch (1932) observed little effect at dissolved oxygen concentrations as low as 0.98 mg/l. Because shipworms can remain sealed in their burrows under adverse conditions, survival is probably facilitated by the utilization of glycogen under anaerobic conditions (Lane, 1959).

The hydrogen ion concentration, however, may significantly affect the distribution of shipworms. Because sea water is naturally buffered (pH=7.5-8.5), previous selection in shipworm species for fluctuating hydrogen ion concentrations is not evident. Chellis (1948) noted that any marked deviation from this pH range is fatal to shipworms. Allen and Carter (1924) found that *B. gouldi* in Beaufort, North Carolina, were sensitive to increased acidity of the medium.

Turbidity, chemical pollutants and other substances also seem to adversely affect shipworm distribution. Although nutrients are often absorbed by silt particles which could serve to feed larvae, Nair (1962) noticed that crustacean and molluscan borers were less active when bottom sediments were continually stirred. Several authors also note that waters containing industrial effluents or influenced by

H_2S were comparatively free from shipworms (Hill, 1922). Studies by Roch (1926) and Nair (1962) also showed that polluted harbor waters were unfavorable habitats for shipworm activity.

3.1.9.3 Distributional analysis in the intake and discharge canals and Barnegat Bay

Instances of destructive borer attack in Barnegat Bay have been recorded since 1885 (Table 3.1-11). Railroad bridges built in 1886 across the southern part of the bay at Manahawkin were damaged to the extent that they had to be rebuilt with creosoted timbers after only eleven years of service. Another railroad bridge, located near Toms River in the northern part of the bay, was under constant repair following construction in 1880 and finally had to be rebuilt with creosoted timbers in 1899 (Atwood and Johnson, 1924). Piers and bulkheads owned by the West Jersey and Seashore Railroad in Longport and Somers Point, New Jersey also showed shipworm attack. These two locations are in Great Egg Harbor Inlet just south of Barnegat Bay.

During the National Research Council Investigation of 1922, untreated soft pine blocks, 5.1 x 10.2 x 12.7 cm (2 x 4 x 5 in.) were placed at Point Pleasant just north of Barnegat Bay. The blocks submerged at Barnegat City (located near the inlet from the ocean) August 16, 1922, were honeycombed by _Teredo navalis_ in two months. Nelson (1922) reported that during the 1921-1922 season, his oyster spat platform was completely destroyed by _Teredo navalis_ in five weeks, and another borer, _Xylotria fimbriata_ (_Bankia gouldi_ Bartsch), was also in nearby timbers and pilings. His raft was located in Sloop Creek approximately 8.8 km (5.5 mi) north of Oyster Creek. Nelson also reported the shipworm attack to be lighter in 1923 than in 1922.

Additional records received in 1922 from the Pennsylvania Railroad (Atwood and Johnson, 1924) reported reconstruction of piers damaged by borers in Barnegat Bay.

In their summation of the 1922 borer activity in New Jersey, Atwood and Johnson (1924) stated, "All wooden structures in salt water on the New Jersey Coast are liable to a destructive attack by shipworms. Piles may be destroyed in two or three years, and therefore if a structure of any importance is to be built, the piles should be protected. The records furnished by the Pennsylvania Railroad indicate that well-creosoted and undamages piles may be expected to have an average life exceeding twenty years. Probably on account of the shallow and consequently warmer water on the New Jersey Coast, the season of inactivity is shorter than in New York and New England. It may be expected to extend from about October 1 to June 15."

A large gap exists in the reliable data concerning shipworm activity in Barnegat Bay between 1923 and 1948. It may be assumed that marine borers were active in the bay during this period, but no records are available. Atwood (1934) stated that the New Jersey seacoast from Sandy Hook to Cape May has had severe marine borer attack for years, and that engineers on the coast reported an increase in attack from 1930 to 1934. It is documented (Table 3.1-11) that a bridge between Brielle and Point Pleasant collapsed in 1946 due to borer attack.

The William F. Clapp Laboratories (Richards and Belmore, 1975) had exposure panels at the Barnegat Bay United States Coast Guard Lifeboat Station from 1948 to 1967. It was necessary to reduce the rotation cycle of the exposure panels from eight to four months due to the severity of attack by _Teredo navalis_. The presence of _Bankia gouldi_ was also recorded. The incidence of the crustacean borer, _Limnoria_, was very light, averaging less than three per square inch during the peak months of July to October. Data are also available for panels exposed for intermittent periods between 1949 and 1959 from the Barnegat Lightship located approximately 12.8 km (7.5 nautical mi) east of Barnegat Inlet. A moderately heavy _Teredo_ attack was recorded, and _T. navalis_ and _T. megotara_ were identified from this location.

A data gap exists in shipworm activity in Barnegat Bay between 1967 and 1971, consequently, there is no concrete scientific evidence to show the extent of borer activity during this period. Shipworms were probably active in the bay and in Oyster Creek during this period, but there are no data to support this assumption.

Prior to the construction of the OCNGS the Forked River and Oyster Creek were described as slow-flowing, freshwater creeks with the lower reaches probably under tidal influence up to the middle of the OCNGS site on the South Branch of the Forked River, and up to 2500 ft east of US Route 9 on Oyster Creek (AEC, 1974). Plant construction began in 1965, and from October to December 1966, Oyster Creek was dredged from the mouth of the creek westward as far as the Route 9 bridge. Dredging in the Forked River was completed from its mouth up to the Route 9 bridge by the following April. A canal connecting the two creeks was then completed. The result of this dredging activity was an increase in the depth and flow in Oyster Creek and the Forked River; the salinity of both streams became equal to that of Barnegat Bay. The onset of OCNGS operation in 1969 resulted in a reversal of the flow of the Forked River and the creation of a unidirectional stream up the Forked River towards the OCNGS and down Oyster Creek, away from the OCNGS. The water temperature in Oyster Creek was increased by 5 to 7°C (41 to 44.6°F) at the Route 9 Bridge and 3 to 5°C (37.4 to 41°F) at its mouth, a thermal plume of varying size extended into Barnegat Bay. The resulting hydrographic conditions in Oyster Creek and the Forked River were within the range necessary for teredinid borer survival and propagation approximately 5-35 ppt and 2 to 35°C (35.6 to 95°F), Turner (1973).

During the early 1970s, the presence of large numbers of shipworms in Barnegat Bay prompted five investigators to conduct studies of marine borers in Barnegat Bay and the possible relationship of the operation of the OCNGS to their abundance and distribution. All investigators used some form of wooden exposure panel to collect at least part of their data. All investigators located at least one exposure site in Oyster Creek but the type of panel used, the period of exposure, the number and location of additional sites, and the purposes for the exposure varied. The following section discusses the results of these early studies.

Wurtz (1971) submerged four samplers in Oyster Creek and three samplers in Stouts Creek for 127 days from August 4 to December 9, 1971. Each sampler consisted of two 91.4 cm (36-in.) pieces of 5.1 x 10.2 cm (2 x 4-in.) fir suspended 15 inches apart, and immersed horizontally so that the lower bar was less than one foot above the bottom. Wurtz found 26 Bankia gouldi in the samples from Oyster Creek and eight from the Stouts Creek samples with the majority of shipworms burrowing into the bottom bars. When he restricted the borer count to the lower bar of each sampler, he established an abundance ratio of 2:1 for Oyster Creek versus Stouts Creek.

Shafto (1974; Appendix C3) conducted a study of fouling organisms and shipworm larval settlement. Exposure panels consisting of two 15.3 x 7.6 x 5.1 cm (6 x 3 x 2-in) Douglas fir boards were submerged monthly at Waretown, Oyster Creek mouth, Oyster Creek Marina, the Forked River mouth, and the Forked River county bridge (Figure 3.1-14) for the period of October 1971 through September 1972. Similar samples were submerged at the Oyster Creek outfall, Forked River intake, Stouts Creek mouth, and Stouts Creek at Winthrop Street from March through September, 1972. One hundred and forty-three samples were retrieved, and approximately 28 showed shipworm attack. Shafto's data show that *Bankia* larvae settled from May through September, 1972. She also confirmed that *Bankia gouldi* tend to settle near the mudline and usually in the under-portion of the panel. The *Bankia* attack was heaviest at Waretown, followed in decreasing order by Forked River, Stouts Creek, and Oyster Creek.

Loveland et al (1972) continued Shafto's studies through 1973 and placed exposure panels at six of Shafto's sampling locations: Waretown, Oyster Creek, discharge canal, intake canal, Forked River county bridge and Stouts Creek mouth. The results from the 1973 exposure panels were consistent with those of 1971-72 in terms of distribution. The amount of settlement, however, increased noticeably, particularly at the Waretown and Forked River stations. Loveland et al (1974) reported more *Bankia* (> 2000) found in one June-July sample from Waretown than in all their samples during the previous year.

Turner (1973, 1974a, 1974b) has had exposure panels in Barnegat Bay since September 1971. Seven sets of twelve soft pine panels measuring 20.3 x 10.2 x 1.9 cm (8 x 4 x 0.75 in.), plus monthly controls, were exposed in Oyster Creek. Additional sets were placed at Stouts Creek and Holly Park for the 12-month period of September 17, 1971 through August 18, 1972. The same procedure was repeated during the period of August 18, 1972, through August 20, 1973. A third series was submerged August 20, 1973. Two shipworm species were identified, *Bankia gouldi* and *Teredo navalis*. Turners data showed that the *Bankia* attack for the 1972 season was much heavier than that recorded for the 1971 season. The monthly panel data showed that woodborer spawning took place in Oyster Creek in July and August, 1972 and 1973, but that spawning at Holly Park only occurred in July. That spawning was following by successful settlement and growth was shown by a heavy attack present in the long-term panels that were removed from October 1972, through March 1973, after four to seven months' exposure. Figures for the growth rates of the *Bankia* in Oyster Creek were comparable to published figures for the outer bay near the inlet (W. F. Clapp Laboratories, Inc., 1960) but were higher than those for Holly Park.

Turner found ripe gonads in an unspecified number of adult *Bankia* specimens from Oyster Creek in February, March, and April, 1973. Settlement took place in Oyster Creek in November 1973, and an unspecified number of larvae were found in a plankton sample taken from the creek in early December. The number of borers increased in 1973 at Oyster Creek, Stouts Creek and Holly Park. Turner's data indicated that shipworm breeding started earlier and lasted longer in 1973 than in 1971 or 1972 at those locations.

Woodward-Clyde (1976) used monthly exposure panels at 67 locations throughout the Barnegat Bay area to obtain shipworm settlement data. The panels, constructed of 30.5 x 12.7 x 1.5 cm (12 x 5 x 0.75-in.) pine were first submerged at ten selected sites. Settlement was recorded in panels from 53 stations. Data from the monthly panels indicated that teredinid settlement throughout Barnegat Bay began in June 1974 and continued into October. The greatest amount of settlement in September and October was recorded in the Forked River and Oyster Creek areas.

Twenty-four teredinid specimens obtained from scrapwood samples taken from Oyster Creek on October 22 and November 11, 1974, were identified from size of larvae in the brood pouch as *Teredo furcifera* or *Teredo bartschi*. These species are considered to be subtropical species (Turner, 1966) and had not been found in Barnegat Bay prior to the Woodward-Clyde observation.

Results of studies of the gonads of adult *Bankia gouldi* removed from Oyster Creek in early April 1974 indicated two out of ten specimens examined showed a few motile sperm. No specimens from any other area examined in April 1974 showed any sexual development. Specimens collected on May 8, 1974, from Cedar Creek, Waretown and Conklin Island as well as Oyster Creek showed sexual development, but were not ready to spawn. Mature shipworm specimens including *Bankia gouldi* were found in the Forked River and Oyster Creek in September 1974. Five specimens of *Teredo* spp., two teredinids from Oyster Creek, and one teredinid from the Forked River with larvae in the brood pouch were recorded in October. Fourteen *Teredo* spp. and three teredinids with larvae in the brood pouch were found in Oyster Creek in November while no sexually active specimens were found at the other sampling stations. No maturing specimens were found at any sampling stations subsequent to November 1974, except at Oyster Creek where seven out of 29 specimens obtained in January 1975 and four out of 29 specimens obtained in February 1975 had larvae present in the brood pouch.

The data obtained in these early investigations establish that molluscan borers were present and active, at times in very large numbers, in the Barnegat Bay system since at least the 1880s. Originally a freshwater creek as far downstream as 2500 ft east of the Route 9 bridge, Oyster Creek had been altered before the construction of the OCNGS; by 1961, a sandbar had been dredged from the mouth of Oyster Creek to provide navigation for the four marinas and four residential lagoons in Oyster Creek all of which allowed further saltwater intrusion from the bay. Following the construction and operation of the OCNGS, Oyster Creek became a unidirectional stream, with increased velocity and temperature, and with salinity levels at or near those of Barnegat Bay. The resulting temperature and salinity in Oyster Creek and the Forked River are within the range necessary for teredinid survival and propagation.

Data collected by Wurtz (1971) over a five-month period in 1971 indicate that Bankia settlement in Oyster Creek was approximately twice as heavy as that in a control area, Stouts Creek. Shafto (1974) and Loveland et al (1974), however, found that the Bankia attack at Oyster Creek was lighter than that at Stouts Creek, Forked River or Waretown during the 1971-1973 period.

Stouts Creek and Cedar Creek are considered to be similar to Oyster Creek prior to its modification relative to plant construction and operation (dredging, reversal of flow, etc.) and are therefore often used as "control" stations in biological studies of Barnegat Bay. In 1974, shipworm settlement in Stouts Creek and Cedar Creek began in June, peaked in July and August, and tapered off from September through October (Woodward-Clyde, 1976). This settlement period conforms with what Atwood and Johnson (1924) considered normal. Settlement in Oyster Creek and the Forked River was observed from June through October, peaking in September 1974, indicating that spawning took place in September, concurring with Turner's 1973 results. Both Turner's and Woodward-Clyde's data also show that settling occurred in November in Oyster Creek, indicating an extended breeding season in Oyster Creek during that period. Turner (1973) also found molluscan borer larvae in Oyster Creek as late as December and complete gonad development in adult Bankia was found as early as February.

The 1974 gonadal studies of Teredo and Bankia by Woodward-Clyde provided further evidence for an extended breeding season in Oyster Creek. Approximately 40 percent (17 of 43) of the borers from Oyster Creek that were examined in November had developed enough for sexual determination and contained larvae in the brood pouch. No sexual development was observed in any of the 43 specimens from the Forked River. The number of off-season samples obtained from other areas of Barnegat Bay were insufficient to establish whether or not any gonadal maturation was taking place during that period.

Data from the William F. Clapp Laboratories (Richards and Belmore, 1975) panels exposed at Barnegat Light show that from 1949 through 1967 the normal settling period for *Teredo navalis* extended from August through November. In 1948 and 1949, however, settlement was recorded in December and in 1953, settlement was recorded in January, indicating to some extent that extended breeding periods have existed in the past in Barnegat Bay.

Figure 3.1-16 compares the monthly shipworm settlement or gonadal development as reported from the Barnegat Bay areas studied in 1972, 1973, and 1974. From these studies it appears that shipworm breeding, in areas of Barnegat Bay outside Oyster Creek, is confined to a shorter period than that which occurs in Oyster Creek. Although occasional off-season settlement does not prove that an extended breeding season is permanent, when the period during which water temperatures are within the optimal limits for molluscan woodborer breeding (13° to 30°C) (55.4 to 86°F) is extended, the organisms are capable of breeding for longer periods of time and may produce several broods per year.

In order to determine the duration of the breeding period in Oyster Creek and the degree to which any extended breeding period was related to overall woodborer activity in Oyster Creek and Barnegat Bay, in June 1975, JCP&L contracted William F. Clapp Laboratories (Appendices C4 and C5) to establish an extensive marine borer monitoring program in Barnegat Bay. The monitoring program, which is an ongoing study, consists of three major parts: A wooden exposure panel study, a teredinid larvae sampling program (terminated in 1977), and histological studies of teredinid gonads.

The exposure panels were initially installed at 17 stations in Barnegat Bay and contiguous waters. An additional exposure panel station was added after the first 20 months of study. The stations were carefully selected to include areas within the thermal plume as well as points throughout the bay beyond the reaches of the plume (Figure A1, Appendix C4). Consideration was also given to establishing stations near locations that had been used by earlier investigators. Each exposure panel array was hung from a near-shore structure to monitor shipworm damage near real structures. The exposure panel arrays consisted of seven 1.9 x 8.9 x 25.4 cm (0.75 x 3.5 x 10 in.) untreated soft pine panels plus two soft pine panels treated with marine grade creosote at 20 pound per cu ft. At each station, the panels were submerged, removed, and replaced in sequence so that after the first six months each long-term panel was exposed for a six-month period. The short-term panels were removed and replaced monthly. The creosoted panels were not removed but were visually inspected each month for the presence of the crustacean borer *Limnoria*.

In the laboratory, the panels are examined macro- and microscopically for the presence of marine borers. Sizes, numbers and amount of damage to the panel are recorded. The individual borers are identified to the lowest possible taxon and sexual determinations are made whenever possible.

The second portion of the monitoring program involves plankton studies to monitor the distribution and density of teredinid larvae. Samples were collected on a monthly basis during the first year and twice monthly during the second year of study at the following stations: The mouth of Oyster Creek, the South Branch of the Forked River, the mouth of the Forked River, Holly Park, Barnegat Bay and between Barnegat Inlet and Oyster Creek channel (Appendix C4, Fig. A4). The plankton samples were fixed with buffered formalin and returned to the laboratory for examination for the presence of teredinid larvae.

The third portion of the program is the histological examination of teredinid gonads collected throughout Barnegat Bay in order to determine if the shipworms in the area of the thermal plume experience an extended breeding season.

A detailed description of the materials and methods used in all phases of this monitoring program is included in Appendices C4 and C5.

In April and May of 1975, just prior to the initiation of Clapp Laboratories' woodborer monitoring program, JCP&L removed all the extraneous wood from Oyster Creek. In the spring of 1976 all of the untreated pilings were removed from the three marinas purchased by the applicant. JCP&L undertook the wood removal effort in order to comply with condition 7.(b) of the Nuclear Regulatory Commission's full term operating license for the OCNGS. A major limiting factor for borer survival and propagation is the amount of wood present that is suitable for borer infestation. The anticipated result of the wood removal program was that the adult teredinid population and concomitantly the number of teredinid larvae that could be released in Oyster Creek would be substantially reduced. The results of Clapp Laboratories' monitoring program, discussed below, indicate that the desired result was obtained.

Appendix C4 presents a detailed discussion of all aspects of Clapp Laboratories' woodborer monitoring program. The following section discusses the results of that program as they relate to the effect of the thermal discharge from the OCNGS.

Four species of teredinids were found in the Barnegat Bay system from 1975-1977. Confirming the results of earlier investigators, the major and historically endemic species, *Bankia gouldi*, was present primarily on the west side of the bay with the heaviest *Bankia* attack occurring at stations north of Oyster Creek. These finds are consistent with those of Hoagland and Turner (1976, 1977a, 1977b, 1977c).

The second endemic species, *Teredo navalis*, was dominant on the east side of the bay, particularly at Barnegat Inlet (Appendix C1, Figure A4). A few *Teredo navalis* were found on the west side of the bay, although not in large numbers such as reported by Nelson (1922).

The presence of the two remaining species, *Teredo furcifera* and *Teredo bartschi*, in Barnegat Bay was first observed in 1974 (Woodward-Clyde), 1976). Considered to be subtropical species (Turner, 1966), they were introduced into Barnegat Bay by unknown means (possibly by boats that previously had been in subtropical areas) and some have survived.

Teredo navalis

Teredo navalis was found throughout the Barnegat Bay system in very low densities from 1975-1977 (Appendix C4, Tables A3-A21). The abundance of the species declined from 1975 to 1976 and again from 1976 to 1977. The decreases in density can probably be attributed to the severe winters of 1975-76 and 1976-77 during which water temperatures throughout the bay were below the recognized lethal levels for survival of adult teredinids.

Teredo navalis was the dominant marine borer at stations 1, 2 and 17 (Figure 3.1-17) and was particularly abundant at Barnegat Inlet (station 1). According to Hoagland et al (1976), *T. navalis* is the more oceanic of the two teredinid species native to Barnegat Bay and therefore its apparent "preference" for the eastern portion of the bay, near the inlet, is not surprising. Furthermore, Culliney (1973, in Turner, 1974b) has shown that the larvae of *T. navalis* are far more sensitive to humic materials in the water than are the larvae of *Bankia gouldi*. The western shore of Barnegat Bay is bordered by extensive marshes and the humic material in the runoff from these areas may be an important limiting factor for the survival of the larvae of *T. navalis*.

The distribution of *T. navalis* in Barnegat Bay does not appear to be limited by water termperature or salinity. This species is active and reproduces in salinities from normal seawater to as low as 9.0 ppt (Miller, 1926) and adults can tolerate salinities as low as 4 ppt (Blum, 1922). The larvae tolerate salinities from 10 ppt to 30 ppt (Turner, 1974). Adult *T. navalis* can tolerate temperatures ranging from 2 to 35°C (35.6 to 95°F) and the larvae are released at temperatures ranging from 13 to 30°C (55.4 to 86°F) (Turner, 1974).

Water temperatures and salinities along the western shore of Barnegat Bay fall within the range necessary for survival, growth and reproduction in *T. navalis* throughout most of the year (Appendix C4, Tables D1-D76), and yet fewer than 150 specimens were found at four of the 14 stations along the western shore during the 1977 season. In Oyster Creek, only one *T. navalis* was found during 1975, fewer than 30 in 1976 and none in 1977.

Three years of teredinid borer monitoring indicate that the distribution and abundance of *Teredo navalis* are not related to the operation of the Oyster Creek Nuclear Generating Station. This species has been found in very low densities along the western shore of Barnegat Bay and its pattern of distribution may reflect the sensitivity of *Teredo navalis* to the humic material in marshland runoff.

Teredo furcifera

Teredo furcifera was first observed in Barnegat Bay in 1974 (Woodward-Clyde, 1976). Turner (1966) considered *T. furcifera* to be a subtropical species and it is suggested that the species may have been introduced into the bay via boats that had passed through subtropical areas. The presence of subtropical species as far north as Barnegat Bay is not unusual; Turner (1966) found *T. furcifera* in a boat moored in Long Island Sound, but if it can become established in an area it would indicate that environmental conditions are favorable. According to Turner (1975), *T. furcifera* is becoming world wide in its distribution. Karande (1968) called *T. furcifera* a gregarious species which is tolerant of a wide range of temperatures (24 to 33°C) (75.2 to 91.4°F) and salinities (6-34 o/oo).

During the 1975 season, *T. furcifera* were identified in panels from seven stations. The majority of these *T. furcifera* were found at station 2, Manahawkin Bay, approximately 19 km (12 mi) south of Oyster Creek; Station 11, at the mouth of the Forked River, and station 17, at Island Beach on the eastern side of the bay. No _T. furcifera_ were found in Oyster Creek during the 1975 season. In 1976, _T. furcifera_ were found at only three stations including one individual from the long-term panel removed from station 2 (Manahawkin Bay) in August, one individual from the long-term panel removed from station 7 (Oyster Creek) in September and 4 individuals were taken from the long-term panel removed from station 11 (the mouth of the Forked River) in January. No _T. furcifera_ were found by the Clapp Laboratories' investigators during 1977.

Hoagland et al (1976, 1977a, 1977b, 1977c) conducted similar exposure panel studies in Barnegat Bay during 1976 and 1977. A total of 36 _T. furcifera_ were found in the one-month panels exposed from April through November 1976. Only one individual was found in Oyster Creek, in a panel exposed during the month of July. The majority (25) were taken from the panels exposed at Bayside Beach Club, approximately 0.5 miles north of Oyster Creek (Figure 3.1-17). Fifty-one _T. furcifera_ were taken from the long-term panels removed in December 1976 and January-February 1977. Eleven of these were found in Oyster Creek, the remainder from as far north as Holly Park and as far south as Manahawkin. From March through May 1977, Hoagland et al (1976, 1977a, 1977b) found 22 _T. furcifera_ in Barnegat Bay, all from panels exposed at Waretown. Two panels exposed in the Waretown area for one year and removed in July 1977 each contained one _T. furcifera_. One-year panels removed in August 1977 from the Forked River mouth and Cedar Creek contained two and one _T. furcifera_, respectively.

Three years of intensive woodborer monitoring in Barnegat Bay by two independent investigators reveal the following facts about _T. furcifera_:

1) The distribution and abundance of this species has become more restricted each year since 1975, suggesting that this species is not truly established in Barnegat Bay.

2) At its peak observed abundance (1975 season), _T. furcifera_ occurred in extremely low densities when compared to the endemic species, _B. gouldi_, and therefore does not constitute serious threat to wooden structures in Barnegat Bay.

3) The distribution and abundance of T. furcifera are unrelated to the thermal discharge from the OCNGS. No T. furcifera were found in Oyster Creek in 1975 and 1977. A total of 13 individuals were found in Oyster Creek by William F. Clapp Laboratories (Appendix C4) and Hoagland et al (1976, 1977a) in 1976. Minor concentrations of this species have been found on the eastern side of the bay off Island Beach, in Manahawkin Bay, 19 km (12 mi) south of Oyster Creek, and at Bayside Beach Club, just north of Oyster Creek.

Teredo bartschi

The presence of Teredo bartschi in Barnegat Bay was first observed in 1974 (Woodward-Clyde, 1976). Along with T. furcifera, this species is considered to be a subtropical (Turner, 1966) which was introduced into Barnegat Bay. Teredo bartschi, which has been found only in Oyster Creek, was present in 1975 at two locations (stations 5 and 6, Figure 3.1-17) at the mouth of Oyster Creek. This species, which according to Clapp (1923) is usually found in association with Bankia gouldi, appears to show a preferential settling pattern and settled mostly in September and October (Appendix C4, Tables A3-A21). It was the dominant teredinid at the stations at which it occurred in 1975. Adult T. bartschi containing embryos at the umbonate stage were found each month in the long-term panels removed from Oyster Creek stations 5 and 6 (Figure 3.1-17) from August 1975 through February 1976. The embryos and adult specimens removed from stations 5 and 6 in February were dead. It is probable that the heated discharge water was favorable for maturation and breeding, but the drop in water temperature resulting from an OCNGS shut down on December 26, 1975, and the very low ambient bay temperatures in January 1976 apparently caused their death.

T. bartschi did not settle at stations 5 and 6 in 1976 and 1977 but was the dominant species at station 7, which is west of the Oyster Creek mouth (Figure 3.1-17).

The fact that T. bartschi was able to become established on the exposure panels near the mouth of Oyster Creek suggests that the larvae of this species could be carried out of Oyster Creek and become established elsewhere in Barnegat Bay. The absence of T. bartschi outside Oyster Creek may be attributed to its behavior. Lane et al (1954) reported that T. bartschi near Miami, Florida, were free swimming for not more than 72 hours. If the pelagic larval stage of T. bartschi from Barnegat Bay is as brief as that reported by Lane et al (1954), their dispersal would be severly limited.

Water temperature is another factor which could limit the distribution of *T. bartschi* in Barnegat Bay. Data collected by Clapp Laboratories (Appendix C4, Table A-23) show that this species settles primarily in September and October when temperatures at the Oyster Creek exposure panels ranged from 11.1 to 30.0°C (52 to 86°F). Ambient temperatures in Barnegat Bay fall within this range from May through November, clearly indicating that water temperature does not limit the settlement of *T. bartschi* to Oyster Creek. Winter water temperatures in areas outside Oyster Creek, however, may be below the lower lethal limit of this species as evidenced by the death of the adult and embryonic *T. bartschi* in Oyster Creek following the December 26, 1975, station shutdown. This would prevent the successful overwintering of *T. bartschi* outside Oyster Creek and account for its limited distribution.

The available data on the distribution of *T. bartschi* suggest a positive thermal effect on the population of this species in Oyster Creek, but the absence of this species in other parts of Barnegat Bay indicates that the thermal discharge has not caused the dispersal of this species into the bay.

Bankia gouldi

Bankia gouldi has the most extensive distribution of the marine borers found in the Barnegat Bay system. This species was found primarily on the west side of the bay, with the heaviest attack occurring at locations north of Oyster Creek. These findings are consistent with those of Hoagland et al (1976, 1977a, 1977b, 1977c).

B. gouldi was found at all sampling locations in Barnegat Bay and was the dominant species at station 4 and stations 8-15 (Figure 3.1-17) throughout the July 1975 through December 1977 period. This species successfully settled from July to September with the greatest number settling in July and August.

Settlement in short term (one month exposure) panels indicates that teredinid larvae at the settlement stage were in the water and environmental parameters were conducive to their successful penetration into wood. Thus, these panels provide data concerning the season of the year that borer attack is initiated.

The number of successful penetrations per month in the short term panels showed a decline from 1975 to 1977 at all locations where *B. gouldi* was the dominant species. This general decline in borer activity may be due to the severe winters of 1975-76 and 1976-77, and in Oyster Creek to the removal of the unnecessary untreated wood. Unpublished data from Clapp Laboratories show a similar decrease in attack at other areas along the Atlantic Coast.

Eight of the fourteen sampling stations located along the western shore of Barnegat Bay could conceivably be directly influenced by the thermal discharge from the OCNGS. These stations include station 4 (Waretown), stations 5-8 (Oyster Creek) and stations 9-11 (Forked River) (Appendix C4, Figure A1). If the thermal discharge from the OCNGS enabled B. gouldi to breed for an extended period of time in the Oyster Creek area when compared to areas outside of the influence of the thermal discharge the following results might be anticipated: 1) the Oyster Creek area would become the major source of marine borer larvae in Barnegat Bay and 2) the amount of damage to wooden structures caused by marine borers should be greatest in areas where those larvae could be carried to in insignificant numbers.

The results of the studies by William F. Clapp Laboratories have shown that there is, in fact, an indication of a slightly earlier gonad development in teredinid specimens from Oyster Creek, but there was no evidence of any early release of larvae or gametes (Appendix C4, Figures C1-C6). In addition, the teredinid plankton sampling program has shown that there was no significant difference in the mean number of teredinid larvae captured at any of the stations located on the west side of the bay (Appendix C4, Figure B-2). Thus, the Oyster Creek teredinid population did not contribute a greater number of larvae to the bay when compared to areas outside of the influence of the thermal discharge.

In terms of the amount of damage caused by marine borers in Barnegat Bay, when the sampling stations are ranked according to the amount of destruction to the panels, two Oyster Creek stations, 5 and 6, ranked in the upper third in 1975, and dropped to the middle third in 1976 and 1977 (Appendix C4, Table A-29). Much of this decrease may be attributed to the removal of the trash wood from Oyster Creek. Station 7, also located in Oyter Creek, ranked in the upper third in 1976 and 1977, but the destruction at that station was due to Teredo bartschi, not B. gouldi. Stations 13 and 14 (Cedar Creek and Holly Park), which are located 4.8 and eight km (three and five mi) north of the northernmost extent of the thermal plume, ranked in the upper third from 1975 through 1977. The amount of destruction was significantly ($P = .05$) greater at these stations than at all other stations along the western shore except station 11 (the mouth of the Forked River). There was no significant difference in the destruction to panels from stations 4, 5, 7, 10, 12 and 15 (Figure 3.1-17).

Bankia gouldi was the only species identified at station 13 and was the dominant species at station 14. The greatest amount of settlement by B. gouldi occurred at station 11 (mouth of the Forked River). As the normal water flow in upper Barnegat Bay is north to south (Carpenter, 1967), and since Bankia are oviparous and consequently have a relatively long planktonic life (approximately 25 days), it is possible that the larvae released at the northern stations (13 and 14) may be drawn into the Forked River.

Reference to Appendix C4, Table A-23 shows that in July 1976 a total of 73 successful settlements occurred in short-term panels from stations 4-14 in contrast to 28 settlements in July 1977. All but seven settlements in 1976 and five in 1977 occurred at stations outside Oyster Creek. In August 1976 the ratio was 20 settlements north of Oyster Creek to none in the creek and in September 1976 the ratio was 20 to 2. Of a total of 35 settlements in August 1977, 28 occurred outside Oyster Creek. These data suggest that most settlement by B. gouldi occurred in areas beyond the influence of the thermal discharge.

During periods in 1976 when the water in Oyster Creek was 6 to 7°C (42.8 to 44.6°F) warmer than in other parts of the Barnegat Bay system, more successful settlement occurred north of Oyster Creek (Appendix C4, Table 1). The greatest amount of settlement was observed at stations 11, 13 and 14. In 1977, when the OCNGS was not operating and all water temperatures were ambient, the same settlement pattern was observed. It would appear then, that the major source of B. gouldi larvae is the northwestern section of the bay.

The applicant concludes, therefore, that the distribution of Bankia gouldi in the Barnegat Bay system is unrelated to the thermal discharge from the Oyster Creek plant as the major concentrations of this species occur in areas of the bay that are outside the influence of that discharge. There is some evidence that the abundance of B. gouldi could be influenced by the thermal discharge in the form of slightly earlier gonad development in specimens from Oyster Creek. No evidence has been found, however, to indicate that the early development of the gonads has resulted in any increase in the abundance of B. gouldi in Barnegat Bay.

3.1.9.4 Incremental effect of FRNGS

With both OCNGS and FRNGS in operation, most of the water in the discharge canal will pass through either the OCNGS Cooling Water System or the dilution pumps. Normal operating conditions at OCNGS include the use of four circulating water pumps (total flow of 460,000 gmp) and either one (984,100 lpm; 260,000 gpm) or two (1,968,200 lpm; 520,000 gpm) dilution pumps. The discharge of FRNGS (121,120 lpm; 32,000 gpm) under these conditions will account for only 4.25 percent and 3.16 percent of the water in the discharge canal, depending upon whether one or two dilution pumps are in operation. The volume discharged from FRNGS would account for only 9.27 percent of the water in the discharge canal when only three circulating water pumps and no dilution pumps (1,305,823 lpm; 345,000 gpm total flow) are operated at OCNGS. The volume discharged by FRNGS during the winter will vary between 75,700 and 113,550 lpm (20,000 and 30,000 gpm) and the percentage of water in the discharge canal that is attributable to FRNGS will decrease relative to the summer percentage. LMS (1978) reported that the heat added by FRNGS (24,580 BTU/sec) will be only 2 percent of the heat added by OCNGS (1,213,420 BTU/sec).

Water discharged from FRNGS will be 12.7°C (22.9°F) warmer than the ambient water during winter (average bay temperature of 5.0°C (41°F) and 3.3°C (5.9°F) warmer during summer (average bay temperature of 26.1°C (79.°F). This water will be released into the discharge canal in the area where the heated discharge from OCNGS and ambient temperature water from the dilution pumps mix, and the water in this mixing area will be 6 to 7°C (10.8 to 12.6°F) warmer than the ambient water. The FRNGS discharge will be about 6°C (10.8°F) warmer than the water in the discharge canal during winter and will be cooler than this water during summer. Due to the low volume and high velocity (1.5 m/sec; 4.9 ft/sec) of the FRNGS discharge, the increase in temperature attributable to the FRNGS discharge (with OCNGS operating) will be only 0.25°C (0.45°F) approximately 60 m below the point of discharge (LMS, 1978).

The FRNGS cooling tower will increase the salinity of the FRNGS discharge a maximum of 1.5 times. From September 1975 through August 1976, the average salinity in the intake canal just east of the Route 9 bridge ranged from about 20 to 26 ppt. The salinity of the FRNGS discharge should average from 30 to 39 ppt over a year and the increase in salinity some 60 m below the discharge will be only 0.26 to 0.53 ppt (LMS, 1978).

The FRNGS discharge therefore, will have an extremely small effect on the temperature and salinity regimes in Oyster Creek and Barnegat Bay. The minor changes in temperature and salinity which result from the FRNGS discharge should have no effect on the teredinid populations in Oyster Creek and Barnegat Bay.

3.1.10 Brevoortia tyrannus (Atlantic menhaden)

3.1.10.1 Introduction

The Atlantic menhaden is a euryhaline fish occurring in neritic waters and coastal embayments along the Atlantic coast from Nova Scotia to eastern Florida (Bigelow and Schroeder 1953). In New Jersey, it constitutes a significant portion of the New Jersey fishery, being the most important fish landed commercially by both weight and dollar value. For example, Atlantic menhaden ranked first in fish landings in New Jersey from 1972 through 1974 with the annual landings averaging about 60.5 million kg.

The Atlantic menhaden has a life expectancy of about 10 years (June and Roithmayr, 1960; Reintjes, 1969), but most specimens collected in Barnegat Bay from September 1975 through August 1977 were younger than four years of age. The age structure observed in Barnegat Bay is a reflection of the natural preference of mature adults for offshore waters. Of the Atlantic menhaden examined in the bay, 67.3 percent were 0 + to 2 + and 23.6 percent were 3 +. Some 80 percent of these specimens were immature, and only one female was ripe. Few age 1 + fish were observed, which is similar to the findings of Nicholson (1972) for coastal waters of central and northern New Jersey. The size of individuals surveyed in the estuary were: age 1 (102 mm, 4 in.), 2 (152 mm, 6 in.), 3 (206 mm, 8 in.), and 4 (237 mm, 9 in.).

Schools of Atlantic menhaden were observed in Barnegat Bay from April through September in 1976 and 1977. Most individuals of the species began to emigrate from the bay in the fall as water temperatures fell to 9 to 11°C (48.2 to 51.8°F), but some individuals were collected in the discharge canal during all months of the year, indicating that they overwintered in the canal.

When the species is in the bay, it seems to prefer the thermal plume much of the time. However, from June through August, temperatures in the discharge canal generally exceed 30°C (86°F) and most of the canal is avoided at this time. Approximately 2.1 percent of the bay from Cedar Beach to Gulf Point may be avoided by Atlantic menhaden during July and August, but it is unlikely that loss of this small area will affect the population because schools of this fish occur throughout the bay from April through October and no portion of the bay is a critical area.

Exclusion of Atlantic menhaden from the discharge canal in the summer reduces the probability of heat shock mortality; only one incident of heat shock mortality has occurred in the past. Overwintering of a population in the discharge canal has resulted in substantial cold shock mortality which remains a potential impact. However, changes in operating procedures of the OCNGS have reduced the extent of cold shock mortality after shutdown. In addition, the thermal discharge from the FRNGS should provide a stablizing effect on discharge canal temperatures during an ONGS shutdown, further reducing the potential for cold shock mortality.

Atlantic menhaden will not suffer the loss of a large portion of its nursery area or experience reduced survival as a result of the thermal discharge. Substantial losses in the population through temperature shock mortality should not occur in the future.

3.1.10.2 Life history

The Atlantic menhaden occurs in coastal water along the Atlantic coast from Nova Scotia to eastern Florida (Bigelow and Schroeder, 1953). Adults usually arrive along the New Jersey coast in March and leave by October and November. However, some young (age 0+) may remain in the inshore ocean through January and early February. It is a planktivore, and its diet includes diatoms, copepods, and unicellular plants (Reintjes, 1969; Hildebrand, 1963).

In New Jersey, the Atlantic menhaden is the most important fish landed commercially by both weight and dollar value. It ranked first in landings in New Jersey from 1972 through 1974 and averaged about 60.5 million kg (133.4 million lbs) a year. Historically, landings ranged from 210.5 million kg (464.2 million lbs) in 1959 to 5.9 million kg (13 million lbs) in 1966.

Spawning occurs primarily at sea and in areas close to shore from late spring through early winter (Mansueti and Hardy, 1967; Hildebrand, 1963). Higham and Nicholson (1964) reported that the annual number of eggs produced per female ranged from 38,000 (length of 216 mm, 8.5 in.) to 631,000 (345 mm; 13.6 in.). However, 80 percent of the specimens collected in Barnegat Bay from September 1975 through August 1976 were immature, and only one female was ripe. A few eggs were collected in the bay during June 1976.

Larvae move shoreward and into estuaries soon after hatching (Mansueti and Hardy, 1967). The few larvae collected in Barnegat Bay were taken primarily during November and December. Larvae were collected in low densities in the inshore ocean off Little Egg Inlet, New Jersey during May of 1973 and 1974 and from September through December of 1972 through 1975.

Larvae transform into juveniles in estuaries (June and Chamberlin, 1959) and remain through the summer and early fall. Although migration to offshore waters was reported to begin at a water temperature of 15°C (59°F) (Reintjes, 1975), some young were collected in New Jersey estuaries and the inshore ocean at a temperature as low as 3°C (37.4°F). Juveniles from northern and mid-Atlantic areas generally spend the winter south of Cape Hatteras (Kroger and Guthrie, 1973).

The Atlantic menhaden may live about 10 years (June and Roithmayr, 1960; Reintjes, 1969), but most specimens collected in Barnegat Bay were younger than age 4. Older fish remain in the ocean and are uncommon in estuaries (McHugh et al, 1959). Some 67.3 percent of those examined were age 0+ to 2+ and 23.8 percent were age 3+. Relatively few age 1+ Atlantic menhaden were collected; Nicholson (1972) reported similar findings for coastal waters of central and northern New Jersey.

Schools of the Atlantic menhaden were found throughout Barnegat Bay from April through September. The size of individuals was calculated for each year of life: age 1 (102 mm, 4 in.), 2 (152 mm, 6 in.), 3 (206 mm, 8 in.), and 4 (237 mm, 9 in.). During the summer, growth of young and age 1+ individuals was about 0.83 mm/day (.03 in./day) (Kroger et al, 1974).

3.1.10.3 Distribution in relation to water temperature

From 1972 through 1975, the Atlantic menhaden was first taken in Great Bay and the ocean in the vicinity of Little Egg Inlet during April at a water temperature of 7.5 to about 9°C (45.5 to 48.2°F). In 1976, the Atlantic menhaden was first seen in Barnegat Bay in late March when the bay temperature was 10°C (50°F). In 1976 and 1977, substantial numbers of the Atlantic menhaden were first impinged at OCNGS in early to mid-April when the bay temperature was 11 to 12°C (51.8 to 53.6°F). In the Gulf of Maine, Atlantic menhaden appear in the spring at a water temperature of about 10°C (50°F) (Bigelow and Schroeder, 1953).

In April 1976 at bay temperature of 10°C (50°F), the Atlantic menhaden was common in the warmest area of the condenser discharge. Since many fish were also present in the ambient temperature water in the discharge of the dilution pump, current may also contribute to the attraction and concentration of these fish.

The Atlantic menhaden was collected in the bay and the discharge canal from April through September, but it was less numerous in the immediate area of the OCNGS discharge as temperature increased. In the discharge canal, most fish avoided a temperature over 30°C (86°F), but a few were taken at a temperature of 36°C (96.8°F). In the bay, fish were collected at a temperature as high as 28°C (82.4°F).

The Atlantic menhaden begins its movement out of estuaries in the fall when the water temperature is lower than the ocean temperature (June and Chamberlin, 1959). Reintjes (1975) reported that the peak of the fall emigration occurs when the water temperature declines to about 15°C (59°F). During 1975 and 1976, the Atlantic menhaden began to leave Barnegat Bay at a water temperature of 9 to 11°C (48.2 to 51.8°F). The Atlantic menhaden was attracted to the discharge canal when the bay temperature was between 4 and 8°C (46.4°F). Bigelow and Schroeder (1953) reported that the species appears to leave the Gulf of Maine in fall at a temperature of about 10°C (50°F). In the ocean near Little Egg Inlet, young Atlantic menhaden were regularly taken in low numbers from late fall through February at a bottom water temperature from 3 to 9°C (37.4 to 48.2°F).

3.1.10.4 Analysis of experimental data

3.1.10.4.1 Temperature preference studies

Temperature preference tests were conducted with the Atlantic menhaden (WPC, Appendix Table 18) at an acclimation temperature from 10 to 25°C (50 to 77°F). The mean observed preferred temperature for Atlantic menhaden acclimated at 10°C (50°F) and tested under both a high and low light intensity was 18.3 and 17.1°C (64.9 and 62.8°F), respectively. Those acclimated at 25°C (77°F) preferred a mean temperature of 24.6 and 23.9°C (76.3 and 75.0°F) when tested under a high and low light intensity, respectively. Acclimation temperature and light intensity were the only significant variables (Table 3.1-12). However, light intensity accounted for only 2 percent of the variation, and the multiple regression was reduced to a linear regression (Table 3.1-13, Figure 3.1-18).

As acclimation temperature increased, the preferred temperature increased (Figure 3.1-18). The final temperature preferendum (and presumably the optimum temperature) for Atlantic menhaden was 25.0°C (77.°F). This estimate corresponded closely to the mean final preferendum of 24.3°C (75.7°F) obtained during the vertical temperature preference studies (WPC, Appendix Table 19; Table 3.1-14, Figure 3.1-19).

3.1.10.4.2 Temperature avoidance studies

Avoidance tests were conducted with the Atlantic menhaden (WPC, Appendix Table 20) at an acclimation temperature from 10 to 25°C (50 to 77°F). The mean observed avoidance temperature for specimens acclimated at 10°C (50°F) was 30.9°C (87.6°F) and 28.2°C (82.8°F) when tested under a high and low light intensity, respectively. Those acclimated at 25°C (77°F) avoided a mean temperature of 33.9°C (93.0°F) when tested under either a high or low light intensity. The highest observed avoidance temperature (35.2°C) (95.4°F) occurred at the highest acclimation temperature 25°C (77°F).

Acclimation temperature and total length of the fish were the only significant variables (Table 3.1-15). Avoidance temperature was directly related to acclimation temperature but inversely related to total length; i.e., larger specimens avoided lower temperatures than smaller specimens. Total length only accounted for 2.3 percent of the variation whereas avoidance temperature accounted for 70.7 percent. Thus, the multiple regression equation was reduced to a linear regression (Table 3.1-16, Figure 3.1-20).

3.1.10.4.3 Heat shock studies

Heat shock tests were conducted with the Atlantic menhaden (WPC, Appendix Tables 1, 21) at an acclimation temperature from 10 to 30°C (50 to 86°F) and at temperature increases of up to 21°C (37.8°F). Fish acclimated at the lower temperatures experienced less mortality than those acclimated at the higher temperatures when exposed to similar temperature increases (WPC, Appendix Tables 2, 22). In general, mortality greater than 50 percent was associated with temperature increases exceeding 10°C (18°F) or at test temperatures above 33°C (91.4°F). Experimental temperatures which resulted in greater than 30 percent mortality of the Atlantic menhaden were plotted against the respective acclimation temperature (Figure 3.1-21).

3.1.10.4.4 Cold shock studies

Cold shock tests were conducted with the Atlantic menhaden (WPC, Appendix Tables 3, 23) at acclimation temperatures from 10 to 27°C (50 to 80.6°F) and temperature decreases as great as 18°C (32.4°F). In general, mortality greater than 50 percent was associated with temperature drops exceeding 10°C (18°F) or at test temperatures below 10°C (50°F) (WPC, Appendix Tables 4, 24). Experimental temperatures which resulted in greater than 30 percent mortality of the Atlantic menhaden were plotted against the respective acclimation temperature (Figure 3.1-22).

3.1.10.5 Predicted response to the OCNGS and FRNGS thermal plume

When the Atlantic menhaden is in the bay, it may prefer the plume much of the time. When it entered the bay (bay temperature of 10°C (50°F)) in March, it was attracted to the plume and did not avoid the maximum temperature. Based on the lowest 10°C (50°F) and highest 25°C (77°F); acclimation temperature used in the linear regression of temperature preference (Table 3.1-13), the Atlantic menhaden should prefer a temperature of 18.5°C (65.3°F) and 25.0°C (77°F), respectively, and the preferred temperature was generally higher than the ambient temperature up to 24°C (75.2°F) (Figure 3.1-18). At a bay temperature above 20°C (68°F), the Atlantic menhaden may avoid some portion of the discharge canal (average delta T of 10°C (18°F)), (Figure 3.1-20). The Atlantic menhaden at an ambient temperature of 10 and 25°C (50 and 77°F) should avoid a temperature of 28.9 and 33.3°C (84 and 91.9°F), respectively (Table 3.1-16). The predicted avoidance temperature during summer (average bay temperature above 20°C (68°F) is slightly higher than the temperature the Atlantic menhaden seemed to avoid in the discharge canal during 1976. Few individuals were collected in the canal aove 30°C (86°F).

From June through August, the temperature in the discharge canal generally exceeds 30°C (86°F) and most of the discharge canal may be avoided during these months (Figure 3.1-20). The plume in the bay to the 3.3°C (5.9°F) isotherm (2.29 million m^3, 2.1 percent of the bay from Cedar Beach to Gulf Point) was also 30°C (86°F) or above during July and August (Figure 3.1-23).

The Atlantic menhaden should not experience substantial mortality due to heat shock during the summer. The Atlantic menhaden would experience some mortality if exposed to the average delta T (10°C; 18°F) when the ambient temperature is above 20°C (68°F), but it probably would avoid the area of maximum delta T (Figure 3.1-20). The relationship between mortality greater than 30 percent and the average delta T (10°C; 18°F) is shown in Figure 3.1-21. One incidence of heat shock mortality has been documented. It occurred in August 1973 when the one operating dilution pump shut down. The temperature increased rapidly, and fishes were exposed to a maximum discharge temperature of 41.1°C (106°F) (Section 3.2.4.6). Because of operational changes instituted subsequent to this incident, this condition is unlikely to occur again.

The Atlantic menhaden in the discharge canal should not experience substantial mortality from cold shock when the bay temperature is above 7.8°C (46°F). At a bay temperature between 0.8 and 5.8°C (33.4 annd 42.4°F), the Atlantic menhaden may experience some mortality when subjected to a temperature decrease of 10°C (18°F). Historically, mortality of the Atlantic menhaden in the discharge canal has occurred during the winter when OCNGS has shut down at a bay temperature below 5.5°C (41.9°F) (Section 3.2.4.6). Cold shock mortalities are discussed more completely in Section 3.4. After fall of 1973 several operational procedures were implemented to reduce the incidence of cold shock. First, two dilution pumps are put into operation when the intake water temperature falls below 15.6°C (60°F). The dilution flow reduces discharge temperatures and minimizes the attraction of the thermal plume to overwintering fish. Second dilution pumps are stopped immediately upon OCNGS shutdown and circulating water discharges are continued for as long as there is residual heat available. This reduces the rate of temperature decay in the discharge canal, and maintains a warm water area near the dilution pump discharge. Since these changes were made, no significant instances of cold shock have occurred.

Abell and Burton (1976) exposed fish acclimated at 15°C (59°F) to several rates of thermal decrease down to 5°C (41°F). They found that the rate of mortality (to 120 h) decreased with a slower rate of temperature decrease; the likelihood of mortality was substantially reduced when this decrease occurred in six or more hours. However, the lower lethal temperature of young of the Atlantic menhaden is from 2 to 5°C (35.6 to 41°F) (Lewis and Hettler, 1968; unpublished IA data), and when OCNGS shuts down at these bay temperatures, mortality of young may occur regardless of the rate of temperature decrease. However, the thermal discharge of the FRNGS may maintain an area of the discharge canal above the lower lethal temperature of this species.

If the OCNGS shuts down during winter, the FRNGS thermal discharge may help maintain the population of and mitigate the cold shock to Atlantic menhaden that reside in the discharge canal during winter. After the OCNGS is shut down, the FRNGS thermal discharge will maintain the discharge canal at a temperature of 0.6 to 2.5°C (33.1 to 36.5°F) above ambient bay temperature.

3.1.10.6 Conclusion

The Atlantic menhaden utilizes the bay primarily as a nursery area; no reproductive activity occurs there. Although the Atlantic menhaden may be excluded from about 2.1 percent of the bay from Cedar Beach to Gulf Point during July and August, it is unlikely that loss of this small area will affect the population because schools of this fish occur throughout the bay from April through October and no portion of the bay is a critical area. Heat shock mortality is uncommon (one incidence) because this species will avoid stressful temperatures in the discharge canal during summer. During winter, changes in operating procedures of the OCNGS have apparently reduced the extent of cold shock mortality after shutdown. In addition, the thermal plume from the FRNGS should further mitigate cold shock mortality. Even the potential loss of most of the fish which reside in the thermal discharge during winter will have little effect on the large population of the Atlantic menhaden on the Atlantic coast. The loss of as many as one million fish (the greatest estimated loss during a winter shutdown) was the equivalent of only 20 sets of a purse seine by a single commercial fishing vessel off the coast of New York (Reintjes, 1969) and was less than the 1.3 million fish lost in a single incident of natural mortality of this species in Chesapeake Bay (Maryland State Fisheries Administration, 1974, 1975). In sum, this species will not suffer the loss of a large portion of its nursery area, have reduced reproduction, or suffer a substantial loss of the population through temperature shock mortality.

3.1.11 *Anchoa mitchilli* (bay anchovy)

3.1.11.1 Introduction

The bay anchovy is the most abundant fish in Barnegat Bay. It represents important forage for many sport and commercial fishes such as the striped bass, bluefish, weakfish and summer flounder; therefore, it is important to the food chain of the bay.

In New Jersey waters, the species migrates into estuaries in March and early April and emigrates to offshore areas in November and December. From 1976 through 1977, the bay anchovy entered Barnegat Bay in April at temperatures between 9 and 11°C (48.2 and 51.8°F). It occurred throughout Barnegat Bay from May through September and was collected at temperatures up to 31°C (87.8°F); however, the organism avoided the discharge canal when temperatures exceeded 31°C (87.8°F).

During June and September the bay anchovy may be excluded from some portion of the discharge canal; during July and August the fish may be excluded from some portion of the discharge canal and bay. The exclusion area should never exceed 2.6 percent of the volume of the bay from Cedar Beach to Gulf Point, and this area is not considered critical to the protection and propagation of the species in the bay.

Because the bay anchovy avoids temperatures greater than 31°C (87.8°F) in the discharge canal, heat shock mortality has not been a major problem in the past. Only two cases of heat shock mortality of the organism have been documented.

During April, May, June, September and October, the bay anchovy may prefer most of the discharge canal. The attraction of some individuals to the thermal plume in the fall makes the fish susceptible to cold shock, but cold-shock mortality has never been a chronic or serious problem.

The small incremental change in the thermal discharge to Oyster Creek and Barnegat Bay which will be caused by operation of the FRNGS will not produce any observable adverse impact. Indeed as discussed above, two plant operation should stabilize winter temperatures in Oyster Creek and minimize the potential for cold shock mortality as a consequence of OCNGS shutdown.

3.1.11.2 Life history

The bay anchovy occurs from Maine to Texas (Bigelow and Schroeder, 1953) and is found in the ocean, bays and low-salinity tidal waters. It is the most abundant fish along the Atlantic coast of the United States (McHugh, 1967). Along the New Jersey coast, it moves inshore in March and early April and offshore in November and December. It is forage for many sport and commercial fishes such as the striped bass (Schaefer, 1970; Bason, 1971), bluefish, weakfish (Thomas, 1971), and summer flounder (Smith, 1969).

The bay anchovy spawned throughout Barnegat Bay from May through August, but most eggs were collected in June and July. Most eggs are apparently spawned at night and incubate in about 24 h at a temperature of 27.2 to 27.8°C (81 to 82°F) (Mansueti and Hardy, 1967). Larvae were common throughout the bay from June through August and were most abundant in July.

In Barnegat Bay, most bay anchovy smaller than 35 mm (1.4 in.) in length were immature, and most specimens larger than 40 mm (1.6 in.) were mature. Stevenson (1958) reported that females from 50 to 59 mm (2.0 to 2.3 in.) in length contained about 2000 ripe eggs, those from 60 to 69 mm (2.4 to 2.7 in.) about 2680 ripe eggs, and those from 70 to 79 mm (2.8 to 3.1 in.) about 2720 ripe eggs.

During summer and early fall, the growth of larvae to juveniles was rapid. Stevenson (1958) reported that the growth rate of young (age 0+) was 4 mm/week (0.2 in/week) for the first month and 3 mm/week (0.1 in/week) for the rest of the summer. Marcellus (1972) noted a growth rate of 1.26 mm/week (0.05 in/week) for young in Barnegat Bay. The growth of young in Barnegat Bay from July through September 1975-76 was 1.05 mm/week (0.04 in/week).

The size distribution of the population in Barnegat Bay was unimodal from March through June but bimodal from July through December. The two size groups present after June were young and age 1+ fish. Most adults in Barnegat Bay were apparently 1+ years old although a few may have been age 2+. Schools of both juveniles and adults were common throughout the bay during spring, summer and fall.

3.1.11.3 Distribution in relation to water temperature

From 1976 through 1977, the bay anchovy entered Barnegat Bay in April at temperatures between 9 and 11°C (48.2 and 51.8°F). Large schools were observed in the immediate vicinity of the OCNGS discharge in April 1976 at a discharge temperature of 18°C (64.4°F). The number of specimens taken in the ocean off Little Egg Inlet increased in April (bottom temperature of 41 to 10°C; 50°F) as the bay anchovy migrated into this area and then rose sharply in May (bottom temperature of 9 to 16°C (48.2 to 60.8°F). This increase in catch corresponded to the inshore movement of this species during rising spring water temperature.

The bay anchovy occurs throughout Barnegat Bay from May through September and was collected at a temperature as high as 31°C (87.8°F). In the discharge canal, however, the bay anchovy apparently avoided a temperature above 31°C (87.8°F). The movement from estuaries to the ocean occurred from September through November and began when the water temperature in the bay decreased to about 15 to 18°C (59 to 64.4°F). Many bay anchovy were collected in the ocean near Little Egg Inlet from September through November as individuals, primarily young, left the bays. Attraction of the bay anchovy to the discharge canal was observed during fall of 1972 (Section 3.2.4) and 1976.

Most spawning occurs from May through August at a water temperature above 22°C (71.6°F). Most larvae were collected from June through early September at a temperature above 20°C (68°F). The highest temperature at which an egg or larva was collected in the OCNGS intake canal was 29°C (84.2°F).

3.1.11.4 Analysis of experimental data

3.1.11.4.1 Temperature preference studies

Temperature preference tests were conducted with the bay anchovy (WPC, Appendix, Table 18) at an acclimation temperature from 10 to 22°C (50 to 71.6°F). The mean observed preferred temperature for fish acclimated to 10°C (50°F) and tested under a high and low light intensity was 22.9 and 18.0°C (73.2 and 64.4°F), respectively. Those acclimated at 21°C (69.8°F) preferred a mean temperature of 24.0°C (75.2°F) under a high light intensity. Those acclimated at 22°C (71.6°F) preferred a mean temperature of 24.7°C (76.5°F) under a low light intensity.

The acclimation temperature was the only variable that significantly affected preferred temperature (Table 3.1-16, Figure 3.1-24). Although the regression was significant, it accounted for only 17.3 percent of the variability.

As acclimation temperature increased the preferred temperature also increased (Figure 3.1-24). If the regression line is extended, the final preferendum for the bay anchovy would be 25.5°C (77.9°F). This estimate corresponds closely with the final preferendum of 27.0°C (80.6°F) determined for the bay anchovy by Meldrim et al. (1977). The mean final preferendum for the bay anchovy determined in the vertical temperature preference apparatus was 20.0°C (68°F) (WPC, Appendix Table 19). The variation between these values may be attributed to the erratic behavior exhibited by specimens in the vertical temperature preference apparatus.

3.1.11.4.2 Temperature avoidance studies

Temperature avoidance tests were conducted with the bay anchovy (WPC, Appendix Table 20) over a range of acclimation temperatures from 10 to 22°C (50 to 21.6°F). No avoidance temperatures were observed for the bay anchovy acclimated to 10°C (50°F). At an acclimation temperature of 15°C (59°F), the bay anchovy avoided a mean temperature of 28.5°C (83.3°F). The highest observed avoidance temperature 32°C (89.6°F) occurred for individuals at the highest acclimation temperature 22°C (71.6°F). Acclimation temperature was the only variable which significantly affected the avoidance temperature (Table 3.1-18, Figure 3.1-25).

3.1.11.4.3 Heat shock studies

Heat shock tests were conducted with the bay anchovy (WPC, Appendix Tables 1, 21) at an acclimation temperature of 10 to 27°C (50 to 80.6°F) and a temperature increase as great as 17°C (30.6°F). Fish acclimated at lower temperatures experienced less mortality than those acclimated at higher temperatures when exposed to a similar temperature increase (WPC, Appendix Tables 2, 22). In general, mortality greater than 50 percent was associated with temperature increases exceeding 10°C (18°F) or increases to a temperature above 33°C (91.4°F). Experimental temperatures which resulted in greater than 30 percent mortality of the bay anchovy were plotted against the respective acclimation temperature (Figure 3.1-26).

3.1.11.4.4 Cold shock studies

Cold shock tests were conducted with the bay anchovy (WPC, Appendix Tables 3, 23) at an acclimation temperature of 10 to 29°C (50 to 84.2°F) and a temperature decrease as great as 19°C (34.2°F). In general, mortality greater than 50 percent was associated with a temperature decrease in excess of 6.5°C (11.7°F) (WPC, Appendix Tables 4, 24). Experimental temperatures which resulted in greater than 30 percent mortality were plotted against the respective acclimation temperature (Figure 3.1-27).

3.1.11.5 Predicted response to the OCNGS and FRNGS thermal plume

The bay anchovy may prefer the thermal plume during much of the time it is in the bay. When it enters the bay (bay temperature about 9°C (48.2°F)) in April, it would prefer the temperature of the plume and would not avoid the maximum temperature. The bay anchovy should prefer a temperature of 21.9 and 24.6°C (71.4 and 76.3°F) at an acclimation temperature of 10 and 22°C (50 and 71.6°F), respectively (Table 3.1-17). The preferred temperature was consistently higher than ambient temperature to 22°C (71.6°F) (Figure 3.1-24).

When the average bay temperature is 20°C (68°F) or greater, the bay anchovy may avoid areas of the plume where the temperature is above 31°C (87.8°F). Based on the linear regression of temperature avoidance (Table 3.1-18), the bay anchovy at an acclimation temperature of 22°C (71.6°F)) should avoid a temperature of 31.4°C (88.5°F). This predicted avoidance temperature is very close to the temperature that the bay anchovy seemed to avoid in the discharge canal; few individuals were collected in the discharge canal above 31°C (87.8°F). The relationship between the average delta T (10°C, 18°F) and avoidance temperature indicated that at an ambient temperature of 20°C (68°F) or less, all avoidance temperatures were above the 10°C (18°F) average delta T (Figure 3.1-25).

In June and September, only the area in the upper portion of the discharge canal may be avoided, but under normal operation in July and August, most of the discharge canal (0.5 million m^3; T. Peace, LMS, personal communication) should be avoided (Table 3.1-4). In August 1976, few bay anchovy were caught in the discharge canal (Section 3.2.4.4). During July and August, the bay anchovy may also avoid areas of the plume in the bay above the 3.3°C (5.9°F) isotherm (2.29 million m^3, 2 percent of bay from Cedar Creek to Gulf Point).

Bay anchovy in the OCNGS discharge canal should not experience mortality from heat shock during the summer. At ambient temperatures above 20°C (68°F), the bay anchovy might experience some mortality if exposed to a temperature increase of 10.0°C (18°F) (Figure 3.1-26), but it should avoid the areas of the discharge canal which are 10°C (18°F) warmer than the bay (Figure 3.1-25). Heat shock mortality of the bay anchovy has been documented twice since OCNGS began operation. One incident involved an abrupt cessation of dilution water pumping and subsequent exposure of fish to a discharge temperature of 41.1°C (106°F). The second incident was partially attributed to a rapidly increasing bay temperature and a reduction in dilution pumping (Section 3.2.4.4).

Bay anchovy in the OCNGS discharge canal may suffer some mortality from cold shock during fall. The relation between mortality greater than 30 percent and the average delta T (10°C, 18°F) is shown in Figure 3.1-27. Some individuals, however, are attracted to the plume in the fall. Cold shock mortality of 20 individuals occurred after OCNGS shut down in January 1973 (bay temperature of 5.5°C (41.9°F)) and thousands of dead bay anchovy were observed in the discharge canal in December 1976 (bay temperature of about 0°C (32°F)) even though OCNGS was in operation (Section 3.2.4.4). During winter, the FRNGS thermal discharge will maintain the discharge canal at a temperature of 0.6 to 2.5°C (1.1 to 4.5°F) above ambient bay temperature after OCNGS is shut down. This may help maintain the population of and mitigate the cold shock to bay anchovy that reside in the discharge canal.

3.1.11.6 Conclusion

The OCNGS thermal plume may exclude the bay anchovy from some portion of the discharge canal during June and September and from the discharge canal and some of the plume in the bay during July and August. Exclusion from the entire discharge canal and a portion of the bay should have little effect on the bay anchovy since this area of exclusion is only 2.6 percent of the volume of the bay from Cedar Beach to Gulf Point (Figure 3.1-28) and no area of the bay is considered critical. The bay anchovy utilizes this entire area of the bay as a spawning and nursery area and also spawns in the inshore ocean. During April, May, June, September and October, it may prefer most of the discharge canal. Historically, neither heat shock nor cold shock mortality has been a chronic problem. The two cases of heat shock mortality occurred during unusual conditions; once due to OCNGS operation and once to natural conditions. Some bay anchovy were attracted to the heated discharge in fall, and cold shock mortality has occurred on two occasions. However, these few individuals are an inconsequential part of the millions of individuals in the bay and the larger coastal population of this species.

3.1.12 Gasterosteus aculeatus (threespine stickleback)

3.1.12.1 Introduction

Relatively few individuals of the threespine stickleback have been collected in Barnegat Bay in studies from 1966 to 1970, 1971 to 1972, and 1975 to 1977. Too few individuals of the species were sampled during these studies to accurately determine either the distribution of the organism in relation to temperatures in the bay or changes in abundance during these years.

The distribution of this species in the bay seems to be more strongly controlled by vegetation than water temperature. Many individuals prefer the rooted vegetation found in the eastern bay, and this precludes their exclusion from areas affected by the thermal plume.

No documented cases of heat and cold shock mortality of the threespine stickleback have occurred since the OCNGS began operation. In addition, thermal discharge from the OCNGS should not influence the propagation of the species because adults and young are primarily associated with vegetation and most vegation is found in the eastern bay which is unaffected by the thermal discharge. The FRNGS discharge should not alter this situation.

3.1.12.2 Life history

On the Atlantic coast of North America, the threespine stickleback occurs from Hudson Bay to Chesapeake Bay and is found in fresh, estuarine, and oceanic waters (Leim and Scott, 1966). Although relatively few specimens were collected in Barnegat Bay in 1976 and 1977, this species was also uncommon during previous studies in 1966 to 1970 (Marcellus, 1972) and 1971 (McClain 1973). The threespine stickleback was collected in Great Bay and Little Egg Harbor primarily in winter and spring, and most were collected in Barnegat Bay during February and March. Too few specimens were collected to approximate their distribution in the bay, but most studies have found it primarily associated with shore vegetation (Leim and Scott, 1966).

The threespine stickleback spawns from May through July in brackish estuaries at Woods Hole, Massachusetts (Bigelow and Schroeder 1953). It spawned during early spring in tide pools in the marsh in Great Bay. Males build a nest of vegetation in shallow areas with dense rooted vegetation (Lippson and Moran, 1974). The female spawns 100 to 150 eggs into the nest, and the male guards both eggs and young. In Europe, the threespine stickleback attains a size of 40 to 50 mm (1.6 to 2.0 in.) at age 2 and 50 to 55 mm (2.0 to 2.2 in.) at age 3 (Bigelow and Schroeder, 1953). Specimens collected in Barnegat Bay ranged from 22 to 69 mm (.8 to 2.7 in.). Individuals 50 mm (2.0 in.) in length were sexually mature (Bigelow and Schroeder, 1953).

3.1.12.3 Distribution in relation to water temperature

Too few individuals were collected to accurately approximate their distribution in relation to water temperature. In Great Bay, most specimens were collected in winter and spring. The average temperature in Barnegat Bay from December through May ranged from 5.0 to 17.8°C (41 to 64.0°F) (Burns and Roe, 1974).

3.1.12.4 Analysis of experimental data

3.1.12.4.1 Temperature preference studies

Tests were conducted at an acclimation temperature from 15 to 21°C (59 to 69.8°F) (WPC, Appendix Table 18, Figure 3.1-29). Fish acclimated at 15°C (59°F) preferred a temperature between 10.7 and 19.0°C (51.3 and 66.2°F). Individuals acclimated at 21°C (69.8°F) preferred temperatures of 13.8 and 15.3°C (56.8 and 59.5°F). In a vertical preference study, the threespine stickleback demonstrated a preference for the bottom of the tank rather than for a particular temperature (WPC, Appendix Table 19).

3.1.12.4.2 Temperature avoidance studies

Eight tests were conducted at an acclimation temperature of 15 and 18°C (59 and 64.4°F) (WPC, Appendix Table 20). Fish acclimated at 15°C (59°F) avoided temperatures between 26.2 and 27.1°C (79.7 and 80.8°F). Those acclimated at 18°C (64.4°F) avoided temperatures between 26.6 and 29.3°C (81.7 and 84.7°F).

3.1.12.4.3 Temperature shock studies

Altman and Dittmer (1966) found an upper tolerance limit of 31.7 to 33.0°C (89.1 to 91.4°F) for adults and 31.7°C (89.1°F) for larvae. Snyder et al. (1970) reported 20 percent mortality of individuals acclimated at 15°C (59°F) and subjected to a temperature increase of 10°C (18°F). Those acclimated at 18°C (64.4°F) and exposed to a temperature increase of 7 and 11°C (12.6 and 19.8°F) experienced a mortality of 50 and 100 percent, respectively.

3.1.12.5 Predicted response to the OCNGS and FRNGS thermal plume

Although temperature preference and avoidance data are incomplete, available data indicate that the threespine stickleback would not prefer the thermal plume at an ambient temperature above 15°C (59°F). However, vegetation is probably more important in determining the distribution of this species than is temperate. Since most of the vegetation is located in the eastern bay in an area unaffected by the thermal discharge and the discharge canal has little rooted vegetation, it is unlikely that the thermal discharge will exclude this fish from a large portion of its habitat because the species would rarely occur in this area whatever its thermal regime.

The threespine stickleback should not experience any mortality from heat or cold shock. Adults do not occur in local estuaries during the summer when the potential for heat shock is greatest, and young were not taken in the discharge canal. Snyder et al. (1970) reported that threespine stickleback at an ambient temperature of 15°C (59°F) did not experience substantial mortality if exposed to a temperature increase of 10°C (18°F), the average OCNGS delta T. Although some mortality might occur at an ambient temperature of 18°C (64.4°F), no specimens were collected at this temperature or higher. Heat shock or cold shock mortality of the threespine stickleback has not been documented since OCNGS began operation.

3.1.13 Morone saxatilis (striped bass)

3.1.13.1 Introduction

The striped bass is an important fish to the commercial and sport fisheries of New Jersey. For example, the species ranked sixth by weight in Atlantic County commercial landings from 1972 through 1975, but the legal sport catch has decreased greatly in numbers since 1975.

Few individuals of the species were collected in Barnegat Bay, although the striped bass is anadromous and usually spawns in fresh or brackish tidal water. Based on the natural occurrence of the striped bass and temperature data in the literature, heat shock mortality is not expected in the discharge canal or bay. Older individuals tend to avoid the estuaries along the New Jersey coast in summer, and few striped bass will reside in the discharge canal at this time.

A few striped bass may live in the discharge canal during the winter, because some individuals in the canal experienced cold shock mortality at an ambient may temperature of 1.6°C (34.9°F). However, operation of the FRNGS should mitigate or eliminate this effect by maintaining the discharge canal at a temperature of 0.6 to 2.5°C (33.1 to 36.5°F) above ambient bay temperature when the OCNGS is shutdown.

Barnegat Bay is not a nursery or spawning area for the striped bass. Because few striped bass reside in the estuary during the summer months, heat shock mortality exclusion of the organism in the the discharge canal and will be of no consequence to the overall population along the Atlantic coast, and this loss should be mitigated when the FRNGS begins operation.

3.1.13.2 Life history

The striped bass is found along the Atlantic coast of North America from the St. Johns River, Florida, to the St. Lawrence River (Raney, 1952). Most of the striped bass north of Virginia originate from Chesapeake bay. Some of these fish move as far north as Maine during spring and summer but return southward in the fall. A few individuals, primarily juveniles, are found in New Jersey coastal estuaries during summer. Some individuals overwinter in estuaries along the coast (Merriman 1937, Vladykov and Wallace, 1952), and some striped bass, mostly two to four years of age, overwinter locally in the lower Mullica River and portions of Great Bay. Some of these fish migrate north in the spring to Long Island and southern New England.

The striped bass is important to the commercial and sport fisheries. Although landings have been small in Ocean County in recent years, it ranked sixth by weight in Atlantic County landings from 1972 through 1975. From 1972 through 1974, it also ranked sixth (3.3 percent of the total catch) in the sport catch of several charter boats which fished out of Great Bay, but the local sport catch has declined substantially over the past several years. McHugh (1977) estimated that the total sport catch for the Atlantic coast in 1970 was 6.5 times the commercial catch.

The striped bass is anadromous and usually spawns in fresh or slightly brackish tidal water (Mansueti, 1958). The semidemersal eggs hatch in two days at about 18°C (64.4°F). The newly hatched larvae are found in open water but, at a size of about 12.7 mm (0.5 in.), they move inshore and remain through the summer (Raney, 1952). Only a few eggs and larvae were collected in the Mullica River and this spawn was of little significance. No eggs, larvae, or young were collected in Barnegat Bay.

The fecundity of the striped bass varies with the size of the female. Worth (1904) reported as few as 14,000 eggs in a 1.4 kg (3.1 lb) fish and as many as 3.2 million in a 22.7 kg (50.1 lb) individual. Bigelow and Welsh (1925) reported that as many as 10 million eggs might be produced by a 34 kg (75 lb) female.

Bason (1971) calculated the fork length of the striped bass from the Delaware River estuary at the end of each year of life: age 1 (102 mm, 4 in.), 2 (218 mm, 8.6 in.), 3 (319 mm, 12.6 in.), 4 (530 mm, 20.9 in.), and 6 (630 mm, 24.8 in.). Merriman (1937) calculated that the growth of the striped bass from spring to October was from 28 to 37 cm (11 to 14.6 in.), for age 2+ fish, from 40 to 46 cm (15.7 to 18.1 in.) for age 3+, and from 48 to 53 cm (18.9 to 20.9 in.) for age 4+. Individuals collected in Barnegat Bay, the Great Bay-Mullica River estuary, and the ocean in the vicinity of Little Egg Inlet were two to five years of age. The ratio of females to males was three to one.

3.1.13.3 Distribution in relation to water temperature

Few striped bass were collected in Barnegat Bay and the following discussion is based on collections in Great Bay and the ocean near Little Egg Inlet. Schools of northward-migrating striped bass generally appeared in the ocean during mid- to late March when the bottom water temperature was about 6°C (42.8°F). It was taken around the inlets by sport fishermen in spring and summer. Schools of southward-migrating fish reappeared in the ocean near Little Egg Inlet in late September when the surface and bottom water temperature was approximately 20°C (68°F). The species was common from October until December when the surface and bottom water temperature declined to about 9 to 10°C (48.2 to 50°F). Some striped bass entered Great Bay in the fall and overwintered in the Mullica River, and some fish were also found in the inshore ocean during January and February.

3.1.13.4 Analysis of experimental data

3.1.13.4.1 Temperature preference studies

Temperature preference tests were conducted with the striped bass (WPC, Appendix Table 18) at an acclimation temperature from 10 to 25°C (50 to 77°F) for fish acclimated at 10°C (50°F). This wide range of preferred temperatures occurred because some specimens were acclimated to rising water temperatures and others to falling temperatures. Those acclimated at 25°C (77°F) preferred temperatures between 24.5 and 28.3°C (76.1 and 82.9°F).

The acclimation temperature was the only variable which significantly affected preferred temperature (Table 3.1-19), and as the acclimation temperature increased, the preferred temperature also increased (Figure 3.1-30). However, for fish acclimated above 21°C (69.8°F), the preferred temperature remained near 27°C (80.6°F). A mean final temperature preferendum of 24.1°C (75.4°F) was obtained in the vertical temperature preferendum studies (WPC, Appendix Table 19; Table 3.1-20, Figure 3.1-31).

3.1.13.4.2 Temperature avoidance studies

Temperature avoidance tests were conducted with the striped bass at an acclimation temperature from 10 to 25°C (50 to 77°F) (WPC, Appendix Table 20). Individuals acclimated at 10°C (50°F) avoided a mean temperature of 29.8°C (85.6°F) when tested under a high or low light intensity. Those acclimated at 25°C (77°F) avoided a mean temperature of (33.3°C (91.9°F) regardless of light intensity. The highest avoidance temperature (33.9°C (93.0°F), was observed at an acclimation temperature of 23°C (74.3°F). Acclimation temperature accounted for about 77 percent of the variability and was the only variable that significantly affected the avoidance temperature of the striped bass (Table 3.1-21, Figure 3.1-32).

3.1.13.4.3 Heat shock studies

Gift and Westman (1971) found upper tolerance limits of 31.5°C (88.7°F) and 33.6°C (92.5°F) for adults acclimated above 21.0°C (69.8°F). Talbot (1966) reported an upper thermal tolerance limit of 34.7°C (94.5°F) for juvenile striped bass. Meldrim and Gift (1971) reported that juveniles acclimated at 26.1°C (79°F) survived for only 15 min when exposed to 34.5°C (93.9°F)

3.1.13.4.4 Cold shock studies

Cold shock tests were conducted with striped bass (WPC, Table 3) acclimated at a temperature from 5 to 28°C (41 to 82.4°F) and subjected to a temperature decrease of up to 19°C (34.2°F) (WPC, Appendix Table 4). In general, mortality greater than 50 percent was associated with temperature decreases of 19°C (34.2°F) or a temperature of 0°C (32°F).

3.1.13.5 Predicted response to the OCNGS and FRNGS thermal discharge

The use of the temperature preference and avoidance regressions (Tables 3.1-19, 21) is limited because most individuals tested were young (age 0+). Young are tolerant of a wider range of temperatures than the older fish generally found in the bay.

Young of the striped bass at an ambient temperature of 10 and 25°C (50 and 77°F) should prefer a temperature of 25.4 and 28.2°C (90 and 91.8°F), respectively (Table 3.1-21). The relationship between the average delta T (10°C, 18°F) and avoidance temperature indicated that below 22.5°C (72.5°), nearly all avoidance temperatures are above the 10°C (18°F) delta T (Figure 3.1-32). Although young may avoid the average delta T of 10°C (50°F) when the ambient temperature is above 22.5°C (72.5°F), no young were collected in Barnegat Bay. Most individuals collected were age 2+ or older, and they generally avoided the bays in summer. During fall, winter, and spring, some older fish have been attracted to the thermal discharge (Freeman, 1977).

Based on temperature data in the literature (WPC, Appendix Table 8) and the natural occurrence of the striped bass, heat shock mortality is not expected. Older fish generally avoid the bays along the New Jersey coast during summer, and striped bass are not expected in the discharge canal during summer.

The striped bass should not experience cold shock mortality when the ambient temperature is between 5.5 and 10.5°C (41.9 and 50.9°F) (WPC, Appendix Table 4). At a bay temperature below 5.5°C (41.9°F), the striped bass may experience some mortality when subjected to a decrease in temperature. A few striped bass in the discharge canal during winter apparently experienced cold shock mortality at a bay temperature of 1.6°C (34.9°F) (Section 3.2.4.6). However, the operation of the FRNGS should maintain the population of and mitigate the cold shock to striped bass that reside in the discharge canal. After the OCNGS is shut down, the FRNGS thermal discharge will maintain the discharge canal at a temperature of 0.6 to 2.5°C (33.1 to 36.5°F) above ambient bay temperature.

3.1.13.6 Conclusion

With the possible exception of the area near Barnegat Inlet, Barnegat Bay is relatively unimportant to the striped bass. No reproduction occurs and the bay is not a nursery area for the striped bass. Heat shock mortality of striped bass in the discharge canal and exclusion from a portion of the bay during summer are unlikely because few striped bass are present in Barnegat Bay during this season. The individuals that occur in the discharge canal during spring, fall and winter would be of little consequence to the population of the striped bass along the Atlantic coast.

3.1.14 Pomatomus saltatrix (bluefish)

3.1.14.1 Introduction

The bluefish is a commercially important species; it was the most abundant fish landed by sport fisherman in New Jersey during 1975 and in Barnegat Bay from 1975 to 1977.

Spawning of the bluefish occurs offshore, and juveniles move into Barnegat Bay during the first summer of life, where they utilize the estuary as a nursery. Adults migrate into the bay in the spring when temperatures approach 17°C (62.6°F). Sampling showed the fish to be common throughout the bay from May through October, but most individuals (77.5 percent) were young. Specimens were captured at temperatures up to 31°C (87.8°F). Most individuals emigrated to offshore waters in the fall, but some overwintered in the discharge canal. A few overwintering bluefish experienced cold shock mortality, but this was of no consequence to the overall population along the Atlantic coast.

Thermal discharge from the OCNGS does not result in substantial harm to the bluefish population in the discharge canal, Barnegat Bay, or the Atlantic coast. In the summer months young bluefish may be excluded from an area less than 1 percent of the volume of the bay from Cedar Beach to Gulf Point, and in the winter cold shock mortality of a few individuals may occur in the discharge canal. However, neither of these effects adversely affect the coastal population of the species. In addition, operation of the FRNGS should mitigate both effects.

3.1.14.2 Life history

The bluefish ranges along the Atlantic coast of North America from Cape Cod to the Florida Keys and is occasionally taken in the Gulf of Maine (Clark, 1973). Adults appear along the New Jersey coast in May and leave in November. Bluefish (0.45 to 1.36 kg; 1 to 3 lbs) from the mid-Atlantic Bight migrate south and occur along the eastern coast of Florida during winter. These individuals and larger bluefish migrate north of Cape Hatteras in the spring (Freeman and Turner, 1976).

The bluefish is an important commercial fish, and from 1972 through 1975 it ranked eighth by weight in New Jersey landings. It was the second most abundant fish landed in Ocean County from September 1975 through August 1977. The bluefish comprised 16.4 percent of the sport fish taken in upper Barnegat Bay from December 1971 through November 1972 (Halgren, 1973), and was the most abundant sport fish landed in New Jersey (416,000 fish) during 1975 (Figley, 1977) and in Barnegat Bay from 1975-77. McHugh (1977) estimated that the sport catch of the bluefish in 1970 was 22 times greater than the commercial catch for the entire Atlantic coast.

The bluefish spawns in the ocean. Spawning occurs well offshore of the Cape Hatteras area in early April (Bigelow and Schroeder, 1953) and about 32 to 80 km (20 to 50 mi) offshore of New Jersey during June and July (Clark 1972). Off the Chesapeake Bight, most (88 percent) larvae were collected more than 55 km (34.4 mi) from shore (Norcross, et al., 1974). No eggs and few larvae were collected in Barnegat Bay.

The bluefish was common throughout the bay, and young (age 0+) spawned from several areas along the Atlantic coast move into the bay and utilize it as a nursery area during their first summer of life. Although bluefish of 1+ through 3+ years of age were collected in Barnegat Bay, 77.5 percent of the individuals were young. Young usually leave the bays and migrate south when the water temperature decreases to about 15°C (59°F) (Lund and Maltezos, 1970).

Clark (1973) reported that the bluefish reached a length of about 250 mm at the end of the first summer. Young collected in Barnegat Bay averaged 180 mm (7.1 in.) at the end of the first summer. Richards (1976) backcalculated the mean fork length of age 1 (230 mm, 9.1 in.), 2 (400 mm, 15.7 in.), 3 (490 mm, 19.3 in.), 4 (580 mm, 22.8 in.), and 5 (640mm, 25.2 in.) bluefish from Long Island Sound.

3.1.14.3 Distribution in relation to water temperature

The bluefish is a warm-season migrant in New Jersey coastal waters (Bigelow and Schroeder, 1953). It first arrives in Barnegat Bay and in the bays and ocean near Little Egg Inlet in May. Lund and Maltezos (1970) reported that the bluefish arrived at Long Island, New York, when the water temperature reached 12 to 15°C (53.6 to 59°F). This temperature range coincides with the temperatures in Barnegat Bay during early May.

The bluefish was common in the discharge canal and the bay from May through October. It was collected at a bay temperature as high as 31°C (87.8°F). Many individuals were taken by sport fisherman and by various fisheries gear in the discharge canal although few were collected in the canal above 32°C (89.6°F).

In Barnegat Bay and the bays and ocean near Little Egg Inlet, the bluefish began its movement to offshore water in November. In Long Island, the bluefish emigrated to the ocean during fall when the temperature declined to about 13 to 15°C (55.4 to 59°F) (Lund and Maltezos, 1970). Some bluefish did not leave Barnegat Bay in the fall, but remained in the discharge canal. The bluefish was collected in the canal from November 1976 (bay temperature of 5°C (41°F), discharge canal temperature of 14°C (57.2°F)) through January 1977. Some bluefish probably spend the winter in the canal because a few specimens were found after OCNGS shutdowns in January 1974 and February 1975. Lund and Maltezos (1970) reported that adults survived temporarily at a temperature as low as 7.5°C (45.5°F), while juveniles would not tolerate a water temperature below 10°C (50°F). Olla and Studholme (1971) observed stress and disruption of daily rhythmic activity of bluefish 550 to 650 mm (21.7 to 25.6 in.) in length when the water temperature declined to about 12°C (53.6°F) and rose to about 30°C (86°F).

3.1.14.4 Analysis of experimental data

3.1.14.4.1 Temperature preference studies

Temperature preference tests were conducted with the bluefish (WPC, Appendix Table 18) at an acclimation temperature from 10 to 25°C (50 to 77°F). Bluefish tested under high light intensity and acclimated at 10°C (50°F) preferred temperatures of 18.3 and 20.0°C (64.9 and 68°F). Those acclimated at 25°C (77°F) preferred 25.1°C and 24.5°C (77.2 and 76.1°F) when tested under high and low light intensity, respectively.

Acclimation temperature was the only variable that significantly affected the preferred temperature of the bluefish (Table 3.1-22, Figure 3.1-33) and it accounted for 62 percent of the variability. As acclimation temperature increased, the preferred temperature also increased (Figure 3.1-33). The final temperature preferendum (25°C, 77°F) determined for the bluefish in the horizontal test apparatus was lower than the mean observed final preferendum of 28.3°C (82.9°F) determined in the vertical temperature apparatus (WPC, Appendix Table 19).

3.1.14.4.2 Temperature avoidance studies

Temperature avoidance tests were conducted with the bluefish (WPC, Appendix Table 20) at an acclimation temperature from 15 to 25°C (59 to 77°F). The mean avoidance temperature for fish acclimated at 15°C was 32.4°C (59°F was 90.3°F). Those acclimated at 25°C (77°F) avoided a temperature of 34.3 and 33.5°C (93.7 and 92.3°F) when tested under high and low light intensity, respectively. The highest observed avoidance temperature (35.3°C, 95.5°F) occurred at the highest acclimation temperature (25°C, 77°F).

Acclimation temperature and total length significantly affected the avoidance temperature of the bluefish (Table 3.1-23). Avoidance temperature was directly related to both variables; larger bluefish avoided higher temperatures than smaller bluefish. The more important variable in estimating the avoidance temperature of the bluefish was acclimation, and the regression coefficient for acclimation temperature was 1.3 times greater than that for length. Thus, avoidance temperature was plotted against acclimation temperature regardless of size, and the regression was calculated using the mean length (122 mm, 4.8 in.) of the fish tested (Figure 3.1-34).

3.1.14.4.3 Heat-shock studies

Heat-shock tests were conducted with the bluefish (WPC, Appendix Tables 1, 21) at an acclimation temperature of 15 to 25°C (59 to 77°F) and temperature increases of up to 17°C (30.6°F).

Fish acclimate at lower temperatures experienced less mortality than those acclimated at higher temperatures when exposed to similar temperature increases (WPC, Appendix Tables 2, 22). In general, mortality greater than 50 percent was associated with temperature increases excedding 10°C (18°F) or temperatures above 32°C (48°F). Experimental temperatures which resulted in more than 30 percent mortality were plotted against the respective acclimation temperature (Figure 3.1-35).

3.1.14.4.4 Cold shock studies

Cold shock tests were conducted with the bluefish (WPC, Appendix Tables 3, 23) at an acclimation temperature of 20 to 27°C (68 to 80.6°F) and temperature decreases as great as 15°C (27°F). In general, mortality greater than 50 percent was associated with temperature decreases in excess of 9°C (16.2°F) (WPC, Appendix Tables 4, 24). Experimental temperatures which resulted in greater than 30 percent mortality of the bluefish were plotted against the respective acclimation temperature (Figure 3.1-36).

3.1.14.5 Predicted response to the OCNGS and FRNGS thermal plume

When the bluefish enters Barnegat Bay in spring at a temperature of about 17°C (62.6°F), it should prefer the plume.

Bluefish at an ambient temperature of 10 and 25°C (50 and 77°F) should prefer a temperature of 20.,3 and 25.4°C (68.5 and 77.7°F), respectively (Table 3.1-22). The preferred temperature of bluefish was higher than ambient temperature up to 23.5°C (74.3°F) (Figure 3.1-33), and it should not be excluded from any area of the discharge canal. Young will also be attracted to the canal during fall. At an ambient temperature above 23.5°C (74.3°F), however, the bluefish may avoid a temperature below the average delta T of 10°C (18°F) and in June and September (average bay temperature of 23.3 and 22.2°C (72.1 and 72°F), respectively), it may avoid the relatively small area near the OCNGS discharge canal where the average delta T is 10°C (18°F). Specimens acclimated to 25°C (77°F) avoided a temperature of 33.9°C (93°F) (Table 3.1-23), and during summer, few individuals were collected in the discharge canal at a temperature greater than 32°C (89.6°F). Young are common in the sport fishery in the discharge canal in September but during operation of OCNGS at its full-rated capacity in July and August, it may be excluded from most of the canal (Figure 3.1-37).

Bluefish in the discharge canal should not experience heat shock mortality. During June and August (average bay temperature of 25°C (77°F) or greater), the bluefish may experience some mortality if exposed to the delta T of 10°C (18°F)(Figure 3.1-35). However, during these months, the bluefish should avoid areas of the canal above 32°C (89.6°F) and should not be exposed to these temperature increases (Figure 3.1-34). Since OCNGS began operation, no heat shock mortality of the bluefish has been documented.

Bluefish attracted to the discharge canal during fall and residing there during winter should not experience substantial mortality due to cold shock when the bay temperature is above 10.8°C (65.8°F) (Figure 3.1-36). At an ambient temperature above 10.8°C (65.8°F), mortality greater than 50 percent was associated with a temperature decrease greater than 10°C (18°F). No cold shock tests were conducted at an ambient temperature below 10.8°C (65.8°F), but cold shock mortality of bluefish overwintering in the discharge canal has occurred at a bay temperature from 1.7 to 3.3°C (35.1 to 37.9°F) (Section 3.2.4.6) and stressed individuals were observed after OCNGS shut down in November 1975 (bay temperature of 8.5°C (47.3°F). In December 1975, mortality of about 200 young occurred when the temperature in the discharge canal decreased from 17°C (62.6°F) (discharge canal temperature) to 3°C (37.4°F) (bay temperature) some 13 hours after shutdown. The operation of the FRNGS may help to maintain the population of and mitigate the cold shock to bluefish which overwinter in the discharge canal. After the OCNGS is shut down, the thermal discharge from the FRNGS will maintain the discharge canal at a temperature of 0.6 to 2.5°C (1.1 to 4.5°F) above ambient bay temperature.

3.1.14.6 Conclusion

The OCNGS should not have an adverse effect on the population of bluefish either in Barnegat Bay or along the Atlantic coast. Reproduction occurs in the ocean and young of this species utilize the entire bay primarily as a nursery and feeding area. Exclusion of young from the thermal discharge during summer should be unimportant because the area of exclusion is less than 1 percent of the volume of the bay from Cedar Beach to Gulf Point (Figure 3.1-37) and young are found throughout this area. Mortality from heat shock should not occur, and cold shock mortality was limited to the few individuals which overwintered in the discharge canal. The loss of these fishes would be insignificant to the large coastal population of this species.

3.1.15 *Cynoscion regalis* (weakfish)

3.1.15.1 Introduction

The weakfish is an important commercial fish which ranked third in Ocean County landings of finfish from September 1975 through August 1977. It comprised 17 percent of the sport catch of finfish in upper Barnegat Bay from December 1971 through November 1972.

Spawning of weakfish in New Jersey waters is confined to the ocean, and eggs and larvae were not found in Barnegat Bay. Adults migrate into the bay at an ambient temperature of 13 to 17°C (23.4 to 30.6°F). Weakfish are attracted to the OCNGS discharge canal in the spring and fall, and experimental data show that the species should prefer the thermal plume in April, May, October and November when the average bay temperature is below 18°C (32.4°F). They emigrate to the ocean from August to December, but some individuals overwinter in the discharge canal.

The fish may avoid the discharge canal from June through September, and heat shock mortality is not anticipated because of this effect. Heat shock mortality has not been observed since the OCNGS began operation. Although some weakfish overwinter in the discharge canal, no cold shock mortality of this species has been recorded.

The weakfish is similar to the bluefish in its migratory habits, entering the bay from large coastal populations in the spring and leaving in the fall. Both utilize the bay as a nursery ground, avoid the thermal discharge during summer and, in some cases, overwinter in the discharge canal. In the winter some individuals may die from cold shock in the discharge canal; in the summer the population may be excluded from 4.4 percent of the central bay. However, these effects will not affect the protection and propagation of weakfish in the bay or along the Atlantic coast.

3.1.15.2 Life history

The weakfish ranges along the Atlantic coast from the eastern coast of Florida to Massachusetts Bay, and its center of abundance is from North Carolina to New York (Bigelow and Schroeder, 1953). It usually arrives along the New Jersey coast and in Barnegat Bay in early April and leaves by the end of November.

It is an important commercial fish and ranked fourth by weight in New Jersey landings from 1972 to 1975. It was third in Ocean County landings of finfish from September 1975 through August 1977. From 1972 through 1974, it ranked second in the catch of a few charter boats which fished out of Great Bay, New Jersey. In upper Barnegat Bay, weakfish comprised 17 percent of the finfish from December 1971 through November 1972 (Halgren, 1973).

Spawning in Delaware Bay occurred from late May through early August with a peak in early June and a second peak in early July (Daiber, 1957). Along the New Jersey coast, spawning apparently is restricted to the ocean, and no eggs and few larvae were collected in Barnegat Bay. Off Little Egg Inlet, larvae were collected from late June through mid-September; most were taken in July. The larvae soon settle to the bottom and apparently utilize subsurface currents to move into estuaries.

Young (age 0+) generally use deeper waters of estuaries as a nursery. They grow rapidly and average about 190 to 195 mm (7.5 to 7.7 in.) at age 1 and 240 to 246 mm (9.4 to 9.7 in.) at age 2 (Daiber, 1957; Thomas 1971). In Barnegat Bay, young comprised 96 percent of all specimens collected and were common throughout the bay. Some age 3+ individuals were collected, and in fall they ranged in length from 290 to 345 mm (11.4 to 13.6 in.).

3.1.15.3 Distribution in relation to water temperature

The weakfish is a warm-season migrant in New Jersey coastal waters (Bigelow and Schroeder, 1953). Adults first appeared in Barnegat Bay and areas in southern New Jersey at an ambient temperature of 13 to 17°C (55.4 to 62.6°F). Weakfish were attracted to the OCNGS heated discharge canal in April and May.

Young were collected in the bay at a temperature as high as 26°C (78.7°F). They usually began their movement from the bays to the ocean in August, and by November or December (bottom temperature of 9 to 10°C (48.2 to 50°F)), most had left the area. Abbe (1967) reported that weakfish were scarce in Delaware Bay after the water temperature fell below 10°C (50°F). Maximum impingement of young at OCNGS was in November at a bay temperature of 8 to 9°C (46.4 to 48.2°F). Weakfish were apparently attracted to the discharge canal during their fall emigration. Specimens were collected in the discharge canal during November and December 1976 when the water temperature in the canal was 10°C (50°F) and the bay water temperature was 0°C (32°F).

3.1.15.4 Analysis of experimental data

3.1.15.4.1 Temperature preference studies

Acclimation temperature was the only variable which significantly affected the preferred temperature of the weakfish (Table 3.1-24, Figure 3.1-38) and preferred temperature increased as acclimation temperature increased (Figure 3.1-23).

Temperature preference tests were conducted (WPC, Appendix, Table 18) at an acclimation temperature of 10 to 25°C (50 to 77°F). Weakfish acclimated at 10 and 25°C (50 to 77°F) preferred a mean temperature of 18.3 and 25.6 (64.9 and 78.1°F), respectively. The estimated final temperature preferendum for weakfish was about 27.5°C (81.5°F). The final temperature preferenda obtained during vertical preference studies ranged from 18 to 27°C (64.4 to 80.6°F) (WPC, Appendix, Table 19). The wide range of final temperature preferenda may be due to the limited number of observations and the relatively large size range of fish tested.

3.1.15.4.2 Temperature avoidance studies

Temperature avoidance tests were conducted with the weakfish (WPC, Appendix, Table 20) at an acclimation temperature from 10 to 25°C (50 to 77°F), and all tests were conducted under high light intensity. Weakfish acclimated at 10°C (50°F) avoided a mean temperature of 26.2°C (79.2°F), and those acclimated at 25°C (77°F) avoided a mean temperature of 31.0°C (87.8°F). The highest observed avoidance temperature was 31.5°C (88.7°F). Acclimation temperature was the only variable which significantly affected avoidance temperature (Table 3.1-25, Figure 3.1-39).

3.1.15.4.3 Heat shock studies

Heat shock tests were conducted with the weakfish (WPC, Appendix, Table 1) at an acclimation temperature of 22 to 30°C (71.6 to 86°F) and temperature increases of up to 10°C (18°F). Fish acclimated at lower temperatures experienced less mortality than those acclimated at higher temperatures when exposed to similar temperature increases (WPC, Appendix, Table 2). In general, mortality greater than 50 percent was associated with a temperature increase in excess of 7°C (12.6°F) or a temperature above 34°C (93.2°F). Experimental temperatures which resulted in greater than 30 percent mortality of weakfish were plotted against the respective acclimation temperature (Figure 3.1-40).

3.1.15.4.4 Cold shock studies

Cold shock tests were conducted with the weakfish at an acclimation temperature of 22 and 30°C (71.6 and 86°F) and temperature decreases as great as 21°C (37.8°F) (WPC Appendix, Table 3), but mortality greater than 50 percent generally was associated with temperature decreases exceeding 10°C (18°F) (WPC, Appendix, Table 4). Experimental temperatures which resulted in more than 30 percent mortality were plotted against the respective acclimation temperature (Figure 3.1-41).

3.1.15.5 Predicted response to the OCNGS and FRNGS thermal plume

The weakfish should prefer the plume and not be excluded from the discharge canal in April, May, October and November (average bay temperature less than 18°C, 64.4°F). The catch of weakfish in the discharge canal in spring was greater than the catch in the intake canal. At the lowest (10°C, 50°F) and highest (25°C, 77°F) acclimation temperature, young of the weakfish preferred a temperature of 18.9 and 26.7°C, (66 and 80.1°F), respectively (Table 3.1-24). The relationship between the average delta T (10°C, 18°F) and avoidance temperature suggested that all avoidance temperatures are above 10°C (50°F) at an ambient temperature below 18°C (64.6°F) (Figure 3.1-39).

From June through September, at an average bay temperature above 18°C (64.4°F), the discharge canal may be avoided by the weakfish most of the time because at an ambient temperature above 18°C (64.4°F), the weakfish may avoid a temperature below a delta T of 10°C (18°F)(Table 3.1-4). Weakfish acclimated to a temperature of 25°C (77°F) avoided a temperature of 29.9°C (85.8°F) (Table 3.1-25). During July and August, the portion of the plume in the bay greater than a delta T of 2.2°C (4.0°F) (4.27 million m^3) may also be avoided. Few young were caught in the discharge canal in August and September 1976.

Young of the weakfish should not experience heat shock mortality during the summer because most of the discharge canal will probably be avoided (Figure 3.1-39). The relationship between mortality greater than 30 percent and the average delta T is shown in Figure 3.1-40. No mortality of young of adults has been observed since OCNGS began operation.

Young residing in the discharge canal during winter may experience cold shock mortality. The relation between mortality greater than 30 percent and the average delta T is shown in Figure 3.1-41. Although the cold shock data for temperatures between 6 and 15°C (42.8 and 59°F) are incomplete, weakfish at these temperatures may experience some mortality when subjected to a temperature decrease (WPC, Appendix, Table 4). Although cold shock mortality of fish residing in the discharge canal during winter has not been recorded during OCNGS shutdowns, one or two dead individuals were seen in the discharge canal during the winter. The operation of the FRNGS after the OCNGS has shut down will maintain the temperature in the discharge canal at 0.6 to 2.5°C (1.1 to 4.5°F) above ambient bay temperature. This may help maintain the population of and mitigate the cold shock to weakfish that reside in the canal.

3.1.15.6 Conclusion

The effect of the OCNGS on the weakfish is very similar to that on the bluefish (Section 3.1.14). Both species are migratory fishes from large coastal populations, utilize the entire bay primarily as a nursery area, avoid stressful temperatures in the thermal discharge during summer, and have a few individuals that overwinter in the discharge canal. Although weakfish may be excluded from 4.4 percent of the central bay (Figure 3.1-42) and overwintering individuals may die during a winter shutdown, these effects will be insignificant to either the population of fishes in the bay or the larger coastal population.

3.1.16 Menticirrhus saxatilis (northern kingfish)

3.1.16.1 Introduction

The northern kingfish was common in Barnegat Bay from 1929 to 1933 and from 1965 to 1970. However, it was uncommon in 1971, and from 1975 to 1977. The northern kingfish does not reproduce in Barnegat Bay, and although young are collected in the bay, it is not important as a nursery for young of the species.

Spawning of the northern kingfish apparently occurs in the ocean, and no eggs or larvae were recovered in Barnegat Bay. Juneniles were collected in the bay from May through October and young from July through November. Specimens were captures at temperatures up to 31°C (87.8°F).

Heat shock mortality of the northern kingfish has not been documented since the OCNGS began operating. One incident of cold shock mortality occurred in December 1975 when the ambient bay temperature was 3°C (37.5°F).

During the summer individuals should avoid the thermal discharge, being excluded from 2.6 percent of the volume of the bay from Cedar Beach to Gulf Point. This area of exclusion should be inconsequential to the overall population in the estuary and along the Atlantic coast. Because of summer exclusion, heat shock mortality should not occur in the future. A few northern kingfish may suffer cold shock mortality, but this will not result in substantial harm to the population in the bay. Operation of the FRNGS should not alter these conditions. Although operation of FRNGS during winter may stablize temperature in the discharge canal in the event of an OCNGS shutdown, and thereby minimize cold shock mortalities.

3.1.16.2 Life history

The northern kingfish is distributed from Florida to Cape Cod (Bigelow and Schroeder, 1953), but its greatest abundance is north of Chesapeake Bay (Welsh and Breder, 1923). In the Gulf of Maine, it appears in inshore coastal waters from May through October (Bigelow and Schroeder, 1953) and was caught from August to December in Delaware Bay (Abbe, 1967). It was the eighth most abundant fish in the upper Barnegat Bay sport fishery from December 1971 through November 1972 (Halgren, 1973). In the New York Bight, it is more important to the recreational fishery than to the commercial fishery (McHugh, 1977).

Spawning apparently occurs in the ocean and no eggs or larvae were collected in Barnegat Bay. Welsh and Breder (1923) reported that spawning began off New Jersey in

June and continued until August. The nursery area of small young is not well known. In North Carolina, all young were collected along coastal beaches (Hildebrand and Cable, 1934), and it was more abundant in the ocean and surf near Little Egg Inlet, New Jersey, than in adjacent bays.

The northern kingfish grows rapidly and can reach a length of 260 mm (10.2 in.) at age 1, 335 mm (3.2 in.) at age 2, and 375 mm. 14.8 in.) at age 3 (Schaefer, 1965). Few live beyond three years.

Although the northern kingfish was common in Barnegat Bay from 1929 to 1933 (Thomas and Milstein, 1974) and from 1965 and 1970 (Marcellus, 1972), it was uncommon during 1971 (McClain, 1973) and from 1975-77. It reportedly was once an important local sport fish along ocean beaches and in the bays of Atlantic County, New Jersey, but it has been uncommon there in recent years. Similar marked fluctuations in abundance have been noted for populations at Corson's Inlet, New Jersey (Phillips, 1914) and Great South Bay, New York (Bean 1901).

3.1.16.3 Distribution in relation to water temperature

Too few individuals were collected to accurately approximate the distribution of the northern kingfish in relation to water temperature. Generally, adults were collected from May (average bay temperature of 17.8°C, 64.0°F) through October 15.5°C, 54.9°F). Young were collected from approximately July (average bay temperature of 26.7°C (80.1°F) through November 10.0°C (50°F). During summer it was collected at a temperature as high as 31°C (87.8°F).

3.1.16.4 Analysis of experimental data

Gift and Westman (1971) found that northern kingfish acclimated at a temperature above 21.0°C (69.8°F) avoided a temperature of 30.5 to 30.8°C (86.9 to 87.4°F). Avoidance breakdown was reported at a temperature about 3.0 to 4.5°C (37.4 to 40.1°F) above the avoidance temperature.

3.1.16.5 Predicted response to the OCNGS and FRNGS thermal plume

The northern kingfish has an upper avoidance temperature of about 30.5°C (86.9°F) (Gift and Westman, 1971), and it may be excluded from most of the discharge canal from June through August. The portion of the plume above the 3.3°C (5.9°F) isotherm (2.29 million m^3) also may be avoided during July and August (Figure 3.1-44) although young were collected in the bay at a temperature as high as 31°C (87.8°F). The upper portions of the discharge canal may be avoided in June.

Heat shock mortality of the northern kingfish has not been documented since OCNGS began operation. The northern kingfish may not be susceptible to a lethal temperature because it may avoid the warmest areas of the discharge during summer.

Some individuals may be attracted to the heated discharge during fall, and one incident of cold shock mortality has been documented. A few individuals died after OCNGS shut down in December 1975; the bay temperature was 3°C (37.4°F).

3.1.16.6 Conclusion

Although the population of the northern kingfish in Barnegat Bay has declined substantially since the 1960s, this decline also may occurred in many other estuaries along the Atlantic coast. The maximum area from which this fish may be excluded is 2.6 percent of the volume of the bay from Cedar Beach to Gulf Point (Figure 3.1-43) and this area of exclusion should be inconsequential. Reproduction does not occur in the bay, and the bay is relatively unimportant as a nursery for young; most young are collected along coastal beaches (Hildebrand and Cable, 1934). Heat shock mortality should not occur during the summer because individuals should avoid the warmest area of the thermal discharge. The possible loss of the few fish attracted to and residing in the discharge canal during winter will not affect the larger population along the Atlantic coast.

3.1.17 *Paralichthys dentatus* (summer flounder)

3.1.17.1 Introduction

The summer flounder was selected as an RIS for this demonstration because it is an important recreational and commercial fish species in Barnegat Bay and along the entire New Jersey coast. From December 1971 through November 1972 the fish comprised 13 percent of the sport catch of finfish in upper Barnegat Bay. It ranked first in commercial landings by weight for Ocean County from September 1975 through August 1977.

In Barnegat Bay the summer flounder is a seasonal migrant, being present in the estuary from March through December. Individuals were collected at temperatures up to 28°C 82.4°F), but relatively few were taken during the summer months. No overwintering summer flounder were found, and most of the fish had left the bay when the water temperature was 5°C (41°F).

Because the summer flounder avoided the thermal plume during the summer, no heat shock mortality occurred. The absence of an overwintering population prevented the species from experiencing cold shock mortality.

Assuming complete vertical mixing of the water column, the summer flounder may be excluded from 1.9 percent of the bottom area from Goodluck Point to Gulf Point during July and August as a result of the thermal discharge on this species. However a ledge of sediment at the mouth of Oyster Creek and natural stratification of the bay during summer tends to direct the plume toward the surface and the heated discharge, may not touch the bottom in all areas underlying the plume. Therefore, the exclusion area for this demersal form may be less than the predicted area of the surface plume. The thermal discharge does not affect the reproductive processes of the organism and and does not generate heat and cold shock mortality in the species. The exclusion of the summer flounder from 1.9 percent of the bottom area of the bay will not substantially affect the overall population in Barnegat Bay or the Atlantic coast. In addition, thermal discharge from the FRNGS should not influence this population.

3.1.17.2 Life history

The summer flounder is found from Maine to South Carolina (Leim and Scott, 1966). It generally moves inshore in late March and April and is found in bays and the inshore ocean from late spring in fall (Lux and Porter, 1966). It occurs in Barnegat Bay from March through December. It migrates offshore from September through December and is found between the 73 and 155 m (240 and 509 ft) contour in the winter and early spring (Lux and Porter, 1966).

The summer flounder ranked first in the commercial landings by weight for Ocean County from September 1975 through August 1977 and fifth in the New Jersey landings from 1972 through 1975. From 1972 through 1974, it ranked first in the sport catch (31 percent of the total catch) of several charter boats which fished out of Great Bay. In upper Barnegat Bay, it comprised 13 percent of the sport catch of finfish from December 1971 through November 1972 (Halgren, 1973) and 11 percent of that catch from September 1975 through August 1976.

The summer flounder matures by its fourth summer (Smith, 1969) and spawns in the fall as it moves offshore. Most eggs are found over the continental shelf, particularly between the 36 to 73 m (118 to 240 ft) contour, and larvae were taken in New Jersey inlets from October through March (Festa, 1974). However, very few larvae were collected in Barnegat Bay.

The habitat and life history of the young (age 0+) have not been well documented, and relatively few young are taken in New Jersey estuaries. From September 1975 through August 1976, 10.1 percent of the summer flounder in Barnegat Bay were young; most specimens (74.3 percent) were age 2+. Festa (1975) found that 85 percent of the summer flounder in the sport catch from Great Bay were age 2+. Very few specimens over age 4 were taken although very large individuals were occasionally caught by sport fisherman. Too few specimens were collected to approximate its distribution in the bay.

3.1.17.3 Distribution in relation to water temperature

The summer flounder is a seasonal migrant in New Jersey estuaries and the inshore ocean. Although too few were collected to determine their time of arrival in the bay in spring, numerous individuals were impinged at OCNGS in May (average bay temperature of 17.8°C (64°F). Some individuals were collected in the discharge canal in April and early May at a bay temperature as low as 10°C (50°F). Individuals were collected throughout the summer and at a temperature as high as 28°C (82.4°F). After an initial attraction to the discharge canal in

April and May, relatively few individuals were collected during the summer months, and they apparently were not attracted to the discharge canal in fall. No overwintering individuals were found, and most fish left the bay by December (average bay temperature of 5.0°C (41°F).

3.1.17.4 Analysis of experimental data

3.1.17.4.1 Temperature preference studies

Four tests were conducted at an acclimation temperature of 21 to 25°C (Appendix, Table 18). In general, summer flounder showed little response in the horizontal test apparatus (Section 3.1.1).

3.1.17.4.2 Temperature avoidance studies

Temperature avoidance tests were conducted at an acclimation temperature from 10 to 25°C (50 to 77°F) (WPC, Appendix, Table 20). Mean avoidance temperature was between 28.3 and 31.8°C (74.8 and 89.2°F) regardless of acclimation temperature (Figure 3.1-44). It was not significantly affected by any variable and for this analysis was taken as the mean value of 30°C (86°F) (Tables 3.1-26, 27).

3.1.17.5 Predicted response to the OCNGS and FRNGS thermal plume

Although the temperature preference of the summer flounder was not determined, it was attracted to the discharge canal when the summer flounder entered the bay (bay temperature of 10°C, 50°F) in April. At an ambient temperature of 18°C (64.4°F) or less, the avoidance temperature of the summer flounder was above the 10°C (18°F) delta T (Figure 3.1-44), and it should not be excluded from any portion of the discharge canal. The mean avoidance temperature, regardless of acclimation temperature, was 30.0°C (86°F).

From June through September (average bay temperature above 20°C, 68°F), the summer flounder should avoid most of the discharge canal (0.16 million m^2) may also be avoided in July and August although stratification of the bay may reduce the area of the bottom influenced by the plume (Figure 3.1-45).

The summer flounder should not experience mortality from heat shock during the summer because it apparently avoids the discharge canal when the temperature there is above 30°C (86°F). Mortality of individuals acclimated to 21°C (69.8°F) occurred at about 33°C (91.4°F). The attraction to and overwintering of the summer flounder in the discharge canal has not been documented, and therefore it is unlikely that summer flounder will suffer cold shock mortality.

3.1.17.6 Conclusion

The sole effect of the OCNGS thermal discharge is the possible exclusion of the summer flounder from 1.9 percent of the bottom area from Goodluck Point to Gulf Point during July and August (Figure 3.1-45). Even this area of exclusion may be an overestimate because the heated plume often does not reach the botton of the bay in this area and therefore this area may still be available to this demersal fish. The exclusion of the population in the bay from this small area should be of little significance. The operation of the OCNGS and FRNGS will not affect reproduction of this species because spawning occurs in the ocean. Heat shock and cold shock mortality should not occur because the summer flounder avoids the warmest areas of the discharge during summer and is not attracted to the thermal discharge during its fall emigration from the bay.

3.1.18 *Pseudopleuronectes americanus* (winter flounder)

3.1.18.1 Introduction

A local winter flounder population utilizes Barnegat Bay as a spawning and nursery area. In addition, the population is recreationally and commercially important.

The winter flounder is a common resident of Barnegat Bay in the winter, and is most abundant at temperatures from 5 to 10°C (41 and 50°F). Adults enter the bay in October where they spawn and feed prior to emigrating to the ocean in April and May. In the winter, the winter flounder becomes attracted to the thermal plume, and a sport fishery exists in the discharge canal at this time. Although adults emigrate from the bay in the spring, young of the species were collected during most of the year at temperatures as warm as 31°C (87.8°F). However, the young avoided the discharge canal in July and August, whereas adults avoided it after early April.

In the spring, adults may be excluded from <1 percent of the area of the bay because of the thermal discharge. In the summer young of the species may be excluded from < 5 percent of the shoreline from Gulf Point to Goodluck Point. These exclusion areas will not result in significant harm to the local population.

Heat shock mortality of winter flounder should not occur because the species avoids the discharge canal during peak temperatures. The species also can tolerate large decreases of temperature comparable to those that take place in the discharge canal when the OCNGS shuts down during winter. Thus, cold shock mortality of winter flounder is not anticipated in the discharge canal or bay. Operation of the FRNGS should not affect this condition.

3.1.18.2 Life history

The winter flounder is found from Labrador to Georgia (Bigelow and Schroeder, 1953) and requires bays and estuaries as spawning and nursery areas. The population from each estuary or coastal area is an independent stock, and although some mixing occurs, each population is essentially reproductively isolated from other populations (Lobell, 1939; Perlmutter, 1947; Saila, 1961). Adults are found in mid-Atlantic estuaries during late fall, winter and early spring (Lobell, 1939; McCracken, 1963; Howe and Coates, 1975) and spend the summer in deeper, offshore waters. Young and immature specimens remain in or near the estuary until maturity.

Spawning occurs in southern New Jersey bays from mid-January through March when the water temperature is coldest. Topp (1968) reported that fecundity of winter flounder from Massachusetts ranged from 0.4 million eggs (age 3) to 3.3 million (age 5), but fecundity estimates were lower (0.26 to 0.64 million eggs) for age 3 to 5 females in Rhode Island (Saila, 1961). Eggs are demersal and adhesive (Bigelow and Schroeder, 1953). Rogers (1976) reported that the largest viable hatch occurred at 3.0°C over a salinity range of 15 to 35 ppt and that the viable hatch decreased as water temperature increased. The mean incubation period at 3.0°C (37.4°C) was 25 days.

Larvae were abundant throughout Barnegat Bay from February through mid-April, and the maximum densities occurred in March. The variable success of year-classes is probably related to environmental factors, primarily water temperature (Jeffries and Johnson, 1974). Larvae metamorphose from a pelagic to a demersal stage at 8 to 9 mm (.3 to .4 in.) in length (Bigelow and Schroeder, 1953).

Young (age 0+) were found in the shore zone from spring through fall and were fairly evenly distributed throughout the shoreline of the bay. They moved into the deeper waters of bays and into the nearby ocean in winter. During the summer, young are subject to considerable predation by the summer flounder (Poole, 1964) and, in Barnegat Bay, by the bluefish.

Adults enter the bays in early November, spawn, and remain to feed before moving to the ocean in April and May. They were found throughout Barnegat Bay (Figure 3.1-46). Adults were most abundant in the ocean off Little Egg Inlet in May and June before moving offshore.

In Barnegat Bay, 70 percent of the males matured by their first winter, and all age 1+ and older males were mature. No age 0+ females were mature, but 60 percent of the age 1+ and almost all older females had matured.

Growth was rapid during the first two years, and males were significantly smaller than females after the first year. Calculated growth for winter flounder taken in Barnegat Bay (Table 3.1-28) was similar to growth in Long Island estuaries (Poole, 1966). Few specimens taken in southern New Jersey were older than 4 years.

The populations of the winter flounder in southern New Jersey have declined during the past few years. Catches of the winter flounder by trawl in the vicinity of Little Egg Inlet decreased every year from 1972 to 1976. Winter flounder catches in Barnegat Bay were larger in 1971-72 (McClain, 1973) than in 1975-76. The winter flounder ranked fifth in Ocean County commercial landings from September 1975 through August 1977.

3.1.18.3 Distribution in relation to water temperature

Adults begin to return to Barnegat Bay in October (average bay temperature of 15.6°C, 60.1°F) and are common throughout the winter at temperatures from 5 to 10°C (41 to 50°F). Adult winter flounder are attracted to the heated discharge in winter, and a sport fishery for those in the canal exists during these months. Winter flounder apparently avoided the heated discharge after early April when the temperature in the canal was greater than 15°C (59°F). By late April (bay temperature of 15 to 20°C, 59 to 68°F) most mature fish had emigrated from the bay to the offshore ocean.

Larvae were collected from late February through mid-April, and the greatest density of larvae was taken from March through early April (bay temperature of 7 to 12°C, 44.6 to 53.6°F). However, factors other than temperature may affect the distribution of young in the discharge canal because when OCNGS did not operate from May through July 1977, young were collected there at a temperature of 30°C (86°F).

3.1.18.4 Analysis of experimental data

3.1.18.4.1 Temperature preference studies

Temperature preference tests in the horizontal apparatus were conducted at an acclimation temperature of 4 to 25°C (39.2 to 77°F) (WPC, Appendix Table 18) but the winter flounder showed little response to temperature (Section 3.1.1).

3.1.18.4.2 Temperature avoidance studies

Temperature avoidance tests were conducted at an acclimation temperature of 10 to 25°C (50 to 77°F)(WPC, Appendix Table 20). The mean avoidance temperature for winter flounder acclimated at 10°C (50°F) was 23.7°C (74.7°F). Those acclimated at 25°C (77°F) avoided a mean temperature of 27.8°C (82°F). Gift and Westman (1971) found that young fish acclimated above 21°C (69.8°F) avoided a temperature of 26.7°C (80.1°F). Adults of the winter flounder reportedly became inactive when the temperature rose above 22°C (7.16°F) (Olla et al, 1969), and 1-year-old fish acclimated above 21°C (69.8°F) avoided a temperature of 23.9°C (75°F) (Gift and Westman, 1971).

Acclimation temperature was the only variable that significantly affected temperature avoidance (Table 3.1-24), and the multiple regression was reduced to a linear regression (Table 3.1-30, Figure 3.1-47).

3.1.18.4.3 Heat shock studies

Heat shock tests were conducted at an acclimation temperature from 5 to 20°C (41 to 68°F) (WPC, Appendix, Table 21). Fish acclimated at the lower temperatures experienced less mortality than those acclimated at the higher temperatures when exposed to similar temperature increases (WPC, Appendix, Table 22, Figure 3.1-48). In general, mortality greater than 50 percent was associated with temperature increases exceeding 19.5°C (35.1°F) or a test temperature above 28°C (82.4°F). Hoff and Westman (1966) reported that the upper incipient lethal temperature for the winter flounder was 29.1°C (84.4°F).

3.1.18.4.4 Cold shock studies

Tests for cold shock were conducted at an acclimation temperature from 6 to 20°C (42.8 to 68°F) (WPC, Appendix, Tables 23, 24). No mortality occurred at temperature decreases as great as 15°C (27°F).

3.1.18.5 Predicted response to the OCNGS and FRNGS thermal plume

No valid temperature preference data were obtained experimentally. However, adults were attracted to the heated discharge during winter and were common in the immediate vicinity of the OCNGS discharge. The avoidance temperature is above the average OCNGS delta T 10°C (18°F) at an ambient temperature of 10°C (50°F) (Figure 3.1-47).

Although winter flounder acclimated to 10°C (50°f) avoided a temperature of 24.2°C (75.6°F) (Table 3.1-30), few adults were taken in the canal when the temperature exceeded 15°C (59°F). When the bay temperature was above about 18°C (64.6°F), only young remained in the bay, and they avoided much of the plume. At ambient temperatures above 18°C, the winter flounder may avoid a temperature below the average delta T of 10°C (18°F). Although most young acclimated to summer temperatures avoided a temperature of about 287.8°C (82°F) in the experimental apparatus, few were collected in the discharge canal in July and August when the temperature exceeded 24°C (75.2°F). Other factors (e.g., current) may also influence their distribution because young were taken in the discharge canal at an ambient temperature of 30°C (86°F) when OCNGS did not operate.

Winter flounder in the OCNGS discharge should not experience mortality from heat shock. Adults were collected at normal discharge temperatures (delta T of 10°C, 18°F), during winter but avoided the discharge canal by early April. At ambient temperatures above 20°C (68°F), young may experience some mortality if exposed to a temperature increase equal to the OCNGS delta T of 10°T (18°F). However, young of the winter flounder should avoid the area of the maximum delta T (Figure 3.1-47); few were collected in the discharge canal during July and August 1976. Heat shock mortality of the winter flounder has not been documented since OCNGS began operation.

3.1.18.6 Conclusion

Barnegat Bay serves as a reproduction and nursery area for a local population of the winter flounder. During the reproductive season (January through March), adults will not be excluded from any area of the bay by the thermal discharge, although, just prior to emigration to the ocean in spring, they will be excluded from a very small portion ($<$ 1 percent) of the bay (Figure 3.1-49). During June and September, young are primarily in the shore zone and the thermal discharge may exclude them from the relatively small area ($<$ 5 percent of the shoreline from Gulf Point to Goodluck Point) of the shore zone within the 4.4°C (39.9°F) isotherm. As young move to the deeper areas of the bay during July and August, about 7.8 percent (6.7 million m^2) of the bottom area of the bay from Goodluck Point to Gulf Point (86.08 million m^2) may be unavailable to the winter flounder (Figure 3.1-50). However, according to the LMS thermal model, this estimated nursery area lost probably is be an overestimate because much of the bottom underneath the plume is unaffected by the thermal discharge. Young also are found in the area of the bay north of Goodluck Point and south of Gulf Point. Therefore, exclusion from this area is not expected to significantly reduce the nursery area available to or recruitment of this species.

Heat shock mortality of adults or young is not expected because they avoid stressful temperatures in the discharge canal. The winter flounder will also tolerate the 10°C (18°F) temperature decrease that would occur in the discharge canal if OCNGS shut down during winter.

3.1.19 <u>Sphoeroides</u> <u>maculatus</u> (northern puffer)

3.1.19.1 Introduction

The northern puffer, once a common constituent of the fish community in Barnegat Bay, has declined significantly in abundance in Barnegat Bay and other Middle-Atlantic estuaries during the late 1960's and 1970s. Although it has little commercial value, it is commonly taken by recreational fishermen; 14 percent of the sport catch of fish in upper Barnegat Bay was the northern puffer. Decline of this species also has been observed in other estuaries.

Few northern puffer were collected in Barnegat Bay between 1975 and 1977; however, experimental tests indicate that the thermal plume may exclude the species from parts of the discharge canal and bay from June through September. The exclusion area in the bay could amount to 2.1 percent of the central bay but will not result in significant harm to the population. Because of this exclusion, heat shock mortality should not occur in this species. Cold shock mortality also should not take place because the northern puffer does not reside in the discharge canal during winter. Thermal discharge from the FRNGS should not impose any additional stress to the bay's population.

3.1.19.2 Life history

The northern puffer is a seasonal resident of inshore ocean and estuarine waters from Newfoundland to Florida (Laroche and Davis, 1973). Most specimens were collected in Barnegat Bay during May and June. It spends the winter on the bottom in deeper ocean waters (Bigelow and Schroeder, 1953).

In recent years, the populations of the northern puffer in New Jersey estuaries have declined greatly. In 1966-67, it ranked fourth (8.4/coll) in seine collections in Barnegat Bay, but by 1969-70 it declined to tenth (0.3/coll) in abundance (Marcellus, 1972). This decline in the population of the northern puffer also has occurred in Great Bay and in Delaware Bay (Miller, 1978). In 1972, the northern puffer accounted for 14 percent of the sport catch of fish in upper Barnegat Bay, and an estimated 30,062 fish were caught (Halgren, 1973).

The northern puffer spawns demersal eggs in both estuarine and oceanic waters from May through August (Lippson and Moran, 1974; Welsh and Breder, 1923). In Barnegat Bay, a few larvae were collected from May through July. Females become sexually mature at age 1. Fecundity ranged from 54,000 eggs per female at age 1 to 288,000 per female at age 4 (Merriner and Laroche, 1977).

Growth of the northern puffer was rapid, and females grew faster and to a larger size than males. Laroche and Davis (1973) reported that the average length of females in Chesapeake Bay was significantly larger than that of males at the same age: age 1 (140 mm, 5.5 in. versus 125, 4.9 in.), age 2 (205, 8.1 in. versus 175, 6.9 in.), age 3 (235, 9.3 in. versus 210, 8.3 in.), and age 4 (260, 10.2 in. versus 225, 8.9 in.). The mean size of age 1+ and 2+ females in Barnegat Bay was not significantly different from the size of those from Chesapeake Bay.

3.1.19.3 Distribution in relation to water temperature

Relatively few individuals were collected from May through October. They occurred at a temperature from 17 to 31°C (62.6 to 87.8°F).

3.1.19.4 Analysis of experimental data

3.1.19.4.1 Temperature preference studies

Five tests were conducted at an acclimation temperature of 15, (59), 22 (71.6) and 25°C (77°F) (WPC, Appendix, Table 18). A mean preferred temperature of 16.53°C (61.7°F) and a mean final temperature preferendum of 24.0°C (75.2°F) were selected by fish acclimated at 15°C (59°F). Those acclimated at 25°C (77°F) preferred 26.7°C (80.1°F).

3.1.19.4.2 Temperature avoidance studies

Five tests were conducted at an acclimation temperature of 18 (64.6), 21 (69.8), and 25°C (77.1°F) (WPC, Appendix, Table 20). Fish acclimated at 18°C (64.8°F) avoided a temperature of 28.7°C (83.7°F) and those acclimated at 25°C (77°F) avoided 31.4°C (88.5°F).

Gift and Westman (1971) found that individuals acclimated above 21.0°C (69.8°F) avoided a temperature of 30.0 and 31.1°C (86 and 88°F) (WPC, Appendix, Table 14). These fish experienced a breakdown of avoidance behavior when the temperature increased 2.5 to 3.6°C (4.5 to 6.5°F) above the avoidance temperature.

3.1.19.5 Predicted response to the OCNGS and FRNGS thermal plume

The northern puffer may prefer some portion of the plume when the ambient temperature is between 15 and 25°C (59 and 77°F) (WPC, Appendix, Table 18), but from 1975 to 1977 the northern puffer was not attracted to the discharge canal during spring. However, the population of this fish has been at low levels recently, and few were collected in the bay during these years. During June (average bay temperature of 23.3°C, 73.9°F) and September (22.2°C, 72°F), the northern puffer may avoid some area of the discharge canal. In July and August, the discharge canal and an area of the bay to the 3.3°C (5.9°F) isotherm should be avoided (Table 3.1-4, Figure 3.1-51).

Temperature shock mortality of this species should not occur. The northern puffer should not experience mortality from heat shock because it should avoid the warmer portions of the canal during much of the summer. The northern puffer should not experience cold shock mortality because it was not attracted to the heated discharge during the fall. To date, neither heat shock nor cold shock mortality have been documented.

3.1.19.6 Conclusion

The thermal plume may exclude the northern puffer from portions of the discharge canal and bay from June through September (Figure 3.1-51). However, this exclusion should be inconsequential because of the discharge canal (0.5 percent of the volume of the bay from Cedar Beach to Goodluck Point), and the area of the bay (2.1 percent) from which this fish will be excluded is a small portion of the central bay. The northern puffer should avoid the discharge canal during summer, and therefore should not be subject to heat shock. Likewise, it does not reside in the thermal discharge during winter and should not be subject to cold shock after an OCNGS shut down.

3.1.20 *Callinectes sapidus* (blue crab)

3.1.20.1 Introduction

The blue crab ranges from Nova Scotia to northern Argentina, primarily from shallow water to 35 m (115 ft). This swimming crab is a year-round resident in New Jersey estuaries and is taken in Barnegat Bay from late March through December, being most abundant from May through August. Although the blue crab was not designated as a representative important species by the regional administrator, it was included in the RIS analysis because of its importance to both the recreational and commercial fisheries in Barnegat Bay.

Studies conducted by the applicant show that the combined OCNGS/FRNGS thermal discharge will not exclude the blue crab from most of the discharge canal throughout the year. Only a small area associated with the maximum delta T of 10 to 13°C (18.0 to 73.4°F) may be unavailable to juveniles and adults during the summer. This area is less than 0.1 percent of the total area of the bay from Cedar Beach to Gulf Point. Historically, neither heat shock nor cold shock mortality have been a problem, and future incidents are expected to be infrequent and of little consequence. Adults secondarily entrained into the upper discharge canal can tolerate the temperatures in this mixing zone and no mortality should occur; losses of larvae from the temperature shock of secondary entrainment are small and will have no effect upon the reproductive success of the blue crab.

3.1.20.2 Life history

The blue crab ranges from Nova Scotia to northern Argentina (Oesterling, 1976). This swimming crab is found primarily from shallow water to 35 m (115 ft) and is a common, year-round resident in New Jersey estuaries. The blue crab is common in Barneget Bay from late March through December but is most abundant from May through August. It burrows into the bottom sediments during winter months. The severe winter of 1976-77 caused substantial mortality of immature blue crab.

The blue crab is important to both the sport and commercial fisheries in Barnegat Bay. From September 1975 through August 1976, some 73,137 kg (161,267 lbs) were harvested by crab pot from spring through fall and by dredge during winter. The blue crab was the most common species caught by sport fishermen from December 1971 through November 1972 (65.3 percent of total catch; Halgren, 1973) and from September 1975 through August 1976 (82.0 percent). In one year, Halgren (1973) estimated that 457,444 individuals were taken by sport fisherman in upper Barneget Bay.

Although some individuals may mature during their first summer of life, most mature during their second summer (Anonymous, undated). Females mate only once during their life, usually in the spring, and they can store viable sperm to produce a second spawn without mating again. An adult female may spawn as many as two million eggs. After mating in low salinity water, females migrate toward higher salinity (> 20 ppt) water to spawn, and in July 1976, egg-bearing females were generally more abundant in the high salinity area near Barnegat Inlet (Figure 3.1-54).

Zoeae (first level stage) of the blue crab are found primarily in high salinity (> 20 ppt) areas (Fishler and Walburg, 1962). Most zoeae in Barnegat Bay are collected near Barnegat Inlet (Figures 3.1-55, 56). This larval stage lasts from 31 to 47 days and involves about seven molts before transformation to the second larval (megalopae) stage (Fishler and Walburg, 1962). Megalopae are tolerant of lower salinities, and this stage lasts only six to nine days (Anonymous, undated) before the last molt produces an approximately 3 mm (0.12 in.) crab. Although megalopae are common throughout Barnegat Bay, they are most abundant in the southern bay near the inlet (Figures 3.1-57, 58).

Young blue crab migrate throughout Barnegat Bay and use primarily shallow areas as a nursery (Figure 3.1-59). Most blue crab collected in Barnegat Bay (91 percent) and nearby Great Bay (87 percent) were immature. Growth of immature blue crab is rapid, and some individuals may reach a carapace width of about 60 mm (2.4 in.) after their first summer of life. After maturity, males remain primarily in the low salinity areas of the estuary (Figure 3.1-60), while females migrate to higher salinity areas after mating. Both immature crabs and mature males migrate toward somewhat higher salinity areas during the winter months (Miller et al, 1975). Few blue crab live beyond three years.

3.1.20.3 Distribution in relation to water temperature

The blue crab was collected in Barnegat Bay from late March through December at temperatures from 6 to 32°C (42.8 to 89.6°F), and it was common at an ambient temperature above 10°C (50°F). It was tolerant of high temperature and was collected in the discharge canal at a temperature as high as 36°C (96.8°F). The blue crab did not overwinter in the discharge canal.

Zoeae were collected in low numbers from late May through early August at a temperature of 21 to 29°C (69.8 to 84.2°F).

Megalopae occurred from late August through October (bay temperature of 14 to 24°C, 57.2 to 75.2°F) but were most abundant from mid-September through early October (bay temperature of 18 to 25°C (64.4 to 77°F).

3.1.20.4 Analysis of experimental data

3.1.20.4.1 Temperature preference studies

Meldrim and Gift (1971) reported a temperature preference of 24.8°C (76.6°F) for blue crab (carapace width of 35 to 55 mm, 1.4 to 2.2 in.) acclimated to 13.8°C (56.8°F).

3.1.20.4.2 Temperature avoidance studies

Immature blue crab had a slightly higher temperature tolerance than mature crabs. Gift and Westman (1971) observed that adults avoided 34.3°C (93.7°F) when acclimated above 21.0°C (69.8°F); the upper avoidance breakdown temperature was 39.2°C (102.6°F) (WPC, Appendix, Table 17). Juveniles avoided 37.5°C (99.5°F) and had an upper avoidance breakdown temperature of 40.0°C (104°F) when acclimated above 21.0°C (69.8°F). Meldrim (unpublished) observed that blue crab (26 to 76 mmm 1 to 3.0 in.) acclimated at 18.0°C (64.6°F) avoided 31.0 to 34.0°C (87.8 to 93.2°F). Meldrim and Gift (1971) reported that individuals 67 to 92 mm (2.6 to 3.6 in.) in carapace width avoided 34.4°C (93.9°F) when acclimated at 26.0°C (78.8°F). No blue crab were collected in the OCNGS discharge canal at a temperature above 36°C (96.8°F).

3.1.20.4.3 Temperature shock studies

Holland, et al, (1971) observed that blue crab acclimated to a temperature of 15.0°C (59°F) experienced heat shock mortality at a temperature of 33.0°C (91.4°F) (WPC, Appendix, Table 17). Juveniles and adults acclimated to temperatures of about 21 to 30.0°C (69.8 to 86°F) had upper lethal temperatures of 36.9 to 40.8°C (98.4 to 105.4°F) (Gift and Westman, 1971; Tagatz, 1969).

3.1.20.5 Predicted response to the OCNGS and FRNGS thermal plume

The blue crab should prefer most of the discharge canal from late May through December. During July and August at bay temperatures above 26°C (78.8°F), it may avoid the maximum discharge temperature in the immediate vicinity of the OCNGS discharge but not other areas of the discharge canal. The blue crab was collected in the OCNGS discharge canal at a temperature as high as 36°C (96.8°F), and a substantial sport fishery exists in the discharge canal throughout summer.

Blue crab in the discharge canal should not usually experience heat shock mortality during the summer. Tagatz (1969) reported a 48-h upper thermal tolerance limit of 38.7°C (101.7°F) for adults and 39.0°C (102.2°F) for juveniles. These temperatures are predicted only for the immedate area of the OCNGS discharge during summer, and this area should be avoided.

Only two incidents of heat shock mortality have been demonstrated since OCNGS began operation. About 30 to 40 dead individuals were noted in August 1973 when the temperature in the dilution pump discharge (21.1°C, 82.6°F) and at the confluence of the ambient and heated water rapidly increased to 41.1°C (106°F). This rapid increase in temperature was caused by the automatic, unscheduled shutdown of the only dilution pump in operation (M.B. Roche, personal communication).

Several thousand dead blue crab were observed along the shore of the discharge canal on April 21-22, 1976. From April 17-20, the water temperature at the intake to the Cooling Water System increased from 15.6 to 21.1°C (60.1 to 70°F). On April 20 the dilution flow in the discharge canal decreased because one of two dilution pumps was shut off in accordance with OCNGS operational procedure. The observed mortality may be materially attributable to the heat shock that resulted from a combination of rapidly increasing ambient temperature for four days and the sudden decrease in dliution flow.

Blue crab in the discharge canal should not experience substantial mortality from cold shock. The blue crab does not overwinter in the discharge canal and is not common in the bay at temperatures below 10°C (50°F). A total of only seven dead blue crab was noted after OCNGS shutdowns in November and December 1975 and in October 1977. Most specimens taken in the canal immediately after OCNGS shut down were alive.

Zoeae of the blue crab are most numerous in the southern bay near Barnet Inlet, and few were collected in the vicinity of OCNGS. Megalopae should suffer little mortality at temperatures below 38°C (100.4°F) (Chase, 1977), and most megalopae are secondarily entrained through the dilution pumps from mid-September through early October when the temperature in the discharge canal should not exceed 38°C (100.4°F) (Table 3.1-4).

3.1.20.6 Conclusion

In summary, the OCNGS and FRNGS thermal plume will not exclude the blue crab from most of the discharge canal during the year. Only a small area associated with the maximum delta T of 10 to 13°C (18 to 23.4°F) (< 0.1 percent of the bay from Cedar Beach to Gulf Point) may be unavailable to juveniles and adults during the summer. Historically, neither heat shock nor cold shock mortality has been a problem. Two incidents of heat shock mortality have occurred but they were attributed to unusual natural or operating conditions and the magnitude of the losses was insignificant. Future incidents are expected to be infrequent and of little consequence. Adults secondarily entrained into the upper discharge canal can tolerate the temperature in the mixing zone, and no mortality should occur. The blue crab does not overwinter in the thermal discharge, and few individuals have died of cold shock during OCNGS shutdowns in late fall. Losses of larvae from the temperature shock of secondary entrainment should be inconsequential to the reproductive success of the blue crab. Blue crabs spawn near the inlet and in the nearby ocean, and early larvae are uncommon in the bay near OCNGS. Late larvae can survive the temperature increase they experience.

The effect of the OCNGS thermal discharge on the blue crab is insignificant. The only large change noted in the abundance and population structure of this species was due to mortality during the severe winter of 1976-77.

3.1.21 Representative Important Species Summary

The thermal discharge of the OCNGS and the FRNGS can affect RIS populations by (1) excluding them from either a substantial portion of their habitat or a critical area of the bay; (2) causing aberrant growth, disease, or abnormal reproductions; (3) subjecting individuals to sudden changes in temperature; or (4) blocking migration or dispersal of migrant species to spawning or nursery areas. If the thermal discharge does not cause any appreciable effect on the RIS, then it will be concluded that the thermal discharge does not interfere with the protection and propagation of the shellfish and fish community.

The portion of the OCNGS and FRNGS thermal discharge from which the RIS may be excluded will vary seasonally and among species. Most exclusion occurs from June into September. For all species except the young of the winter flounder, the area of exclusion will not exceed 4.4 percent of the central bay. For the young of winter flounder, the area of exclusion measured according to surface temperatures, could be as high as 7.8 percent. However, the young winter flounder prefers the bottom of the bay. Because the plume is a surface phenomenon under most meterological conditions, the effective area of exclusion may be smaller. During some portion of the year from October to June, many species will prefer the warmer water of the thermal discharge.

Thermally tolerant species (i.e., blue crab) will avoid only the immediate area of the undiluted OCNGS discharge during summer. Others will be excluded during the summer from Oyster Creek (equivalent to 0.5 percent of the bay from Cedar Beach to Good Luck Point) and a small portion of the central bay: *N. americana* (4.4 percent), the Atlantic menhaden (2.1 percent), bay anchovy (2.1 percent), bluefish (<1 percent), weakfish (4.4 percent), summer flounder (1.9 percent), young of the winter flounder (7.8 percent), and the northern puffer (2.1 percent).

Many sand shrimp avoid Barnegat Bay during the summer when the temperature exceeds approximately 28°C (82.4°F) and, therefore, few individuals are found there. Few striped bass and young of the northern kingfish are present in Barnegat Bay during summer, and these species are not excluded from any portion of the bay during spring, fall, or winter. The threespine stickleback is primarily associated with vegetation and, therefore, is not likely to be found in Oyster Creek whatever the potential for exclusion may be.

Predicted exclusions may not, however, fully describe the area of the bay useable by the RIS even during peak temperatures. In the summer of 1976, the OCNGS operated below its full-rated capacity, and many of the above fishes occurred in some portion of the discharge canal and Oyster Creek because the temperature there was below the predicted temperature for average summer conditions.

Many RIS utilize the bay as a nursery area. The loss of less than 1 percent to 7.8 percent of the habitat from the central portion of the bay will not have a significant effect on the RIS populations. The reproductive activity of those RIS which spawn in the bay (i.e., sand shrimp, Neomysis americana, blue crab, bay anchovy, threespine stickleback, winter flounder, and northern puffer) will not be affected by the thermal discharge because spawning (1) occurs throughout the bay, and in many cases, also in the ocean; (2) occurs at a time when larvae can withstand the temperature increases they experience; or (3) is located in areas unaffected by the discharge. The similarity in the species composition, seasonal occurrence, and age structure of the fish community in Barnegat Bay to the community in the nearby Mullica River-Great Bay estuary in recent years is evidence that successful reproduction and use of the bay as a nursery area has continued in the bay during the operation of the OCNGS for more than eight years.

At the present time, several fishes (i.e., threespine stickleback, striped bass, northern kingfish, and northern puffer) are not as abundant in the bay as in previous years, but these declines are widespread in New Jersey and along the Atlantic coast and reflect natural fluctuations in abundance rather than operation of the OCNGS.

Although there is concern that disease, abnormal growth, and abnormal reproduction will increase for fish populations in thermal discharges, these phenomena have been uncommon in fish populations in the OCNGS thermal discharge (Section 3.2.4). The low incidence of gas bubble disease and loss of body weight has been restricted to fishes attracted to and residing in the OCNGS thermal discharge, primarily from November through April.

The most visible effect of the OCNGS thermal discharge on organisms is stress or mortality caused by temperature shock. Heat shock has been infrequent because most RIS avoid the thermal discharge at a temperature which is several degrees below their avoidance breakdown temperature.

Only two documented incidents of heat shock mortality have occurred since the OCNGS began operation (Section 3.2.4), and they occurred following a reduction in dilution pump operation. The mortality associated with these two episodes was inconsequential to the fish populations in the bay. Future incidents of heat shock mortality should be rare because two dilution pumps operate during the summer months. A third pump is available should a pump failure occur. The operation of FRNGS should not have an adverse effect on individuals in Oyster Creek since in the summer the temperature of the FRNGS blowdown is less than the temperature of the OCNGS discharge and will slightly reduce the overall discharge temperature.

The heat shock mortality of fish or shellfish secondarily entrained into the discharge canal after surviving either impingement on the traveling screens or passage through the dilution pumps should be minimal. Some mortality will occur to smaller organisms secondarily entrained, but those mortalities should not be significant to the fish and shellfish communities. Organisms are released into the ambient temperature water in the dilution pump discharge rather than directly into the OCNGS discharge, and most organisms can survive the resultant more gradual increase in temperature (2.0 to 7.5°C, 3.6 to 13.5°F) that they experience moving from there into in the mixing zone (Table 3.2-11, Section 3.2.4). Only a few fishes and the sand shrimp are secondarily entrained during summer; the blue crab is common in summer but tolerates the temperature in the mixing zone. Since most organisms survive the temperature increase in this area, heat shock mortality of secondarily entrained organisms and effect on the various populations should be inconsequential. Because, as discussed above, the FRNGS blowdown should reduce temperatures in the canal and Oyster Creek, the operation of FRNGS should reduce the potential for secondary entrainment mortalities.

Some potential exists for cold shock mortality of fishes (i.e., bay anchovy, Atlantic menhaden, striped bass, bluefish, weakfish and northern kingfish) which are attracted to and reside in the thermal discharge from November through March if the OCNGS shuts down when the ambient water temperature is less than 5°C (41°F). Several fish kills have been observed in Oyster Creek since 1972 (Section 3.2.4). The magnitude and species composition of a winter kill will depend on the fishes in the thermal discharge and the physical characteristics associated with each shutdown (e.g., bay temperature, meteorological conditions, duration of shutdown). However, because changes were made in the modes of station operation in November 1975, including the cessation of all dilution pumping immediately after shutdown, both the incidence and severity of cold shock mortalities after OCNGS shutdowns have been reduced substantially. The operation of FRNGS should further reduce the potential for cold-shock mortality since the thermal discharge should help to maintain temperature stability in the discharge canal and Oyster Creek in the event of an OCGNS shutdown.

The loss of some fishes from cold shock mortality is inconsequential to the large populations of these fishes along the Atlantic coast. For most fishes, relatively few individuals overwinter and are susceptible to cold shock mortality. Even the largest losses estimated to have occurred during a winter shutdown (1 million Atlantic menhaden) are very small in relation to the number of these fishes along the coast, and the number harvested by commercial fishermen. Because overwintering RIS are not from local populations, and losses of fishes residing in the discharge canal should have little effect on the number of individuals of these species that will be present in the bay during the following year. In short, such losses will not have significant effect on bay populations because of recruitment from the abundant coastal populations.

The decision criteria in the RIS analysis have been adequately addressed, and this portion of the demonstration is satisfied. Since no evidence exists that the RIS populations will be affected by the thermal discharge of the OCNGS and FRNGS, it is concluded that this discharge will not interfere with the protection and propagation of the balanced, indigenous community of fish and shellfish in Oyster Creek and Barnegat Bay.

References

Abbe, G.R. 1967. An evaluation of the distribution of fish populations of the Delaware River estuary. M.S. Thesis. Univ. Del. 64 pp.

Abell, P.R., and D.T. Burton. 1977. Cold shocks: the effects of rate of thermal decrease on the mortality of juvenile Atlantic menhaden (Brevoortia tyrannus). Presented at a symposium on energy and environmental stress on aquatic systems, Augusta GA., 2-4 Nov. 1977. (Abstr.)

Allen, D.M. 1977. Population dynamics, spatial and temporal distribution of mysid crustaceans in a temperate marsh estuary. Ph.D. Dissertation. Lehigh Univ. 191 pp.

Allen, M.S., and R.H. Carter. 1924. Toxicity of certain compounds on marine woodboring organisms together with some physiological considerations. Page 181-196 _in_ W.G. Atwood, et al., eds. Marine structures, their deterioration and preservation. Washington, D.C., National Research Council.

Altman, P.L., and D.S. Dittmer, (eds.). 1966. Environmental biology. Fed. Amer. Soc. Exper. Biol., Bethesda, MD. 694 pp. (not seen, cited in de Sylva 1969).

Anonymous. Undated. The blue crab (_Callinectes sapidus_). Marine Educ. Leaflet #5. Mar. Educ. Center, Biloxi, MS. 4 pp.

Ansell, A.D., 1968. The rate of growth of the hard clam _Mercenaria mercenaria_ (L) throughout the geographical range: Jour. du Conseil. Conseil International Pour L'Exploration de la Mer., v. 31, pp. 364-409.

Arakawa, K.Y. 1971. Notes on a serious damage to cultured Oyster Crops in Hiroshima caused by a unique and unprecedented outbreak of a Serpulid worm _Hydroides norvegica_ in 1969: Venus Jap. J. Malacol. V. 30 no. 2, pp. 75-82.

Atomic Energy Comm. Staff Report. 1974. Evaluation of the Environmental Impact of the Existing and Alternative Cooling Systems at Oyster Creek. Report prepared by the office of Site Safety - Environmental Specialists' Branch.

Atwood, W.G. and A.A. Johnson. 1924. Marine Structures: Their Deterioration and Preservation. National Research Council, Washington, D.C.

Atwood, W.G. 1934. Severe Marine Borer Attach on the New England Coast. Wood Preserving News, Vol. XII, No. 9, Sept. 1934.

Ballengee, D.W., G.L. Ohori, M.B. Roche and J.J. Vouglitois, 1976, Data report on thermal plume surveys conducted by Jersey Central Power & Light Company at the Oyster Creek Nuclear Generating Station, Barneget Bay, New Jersey: unpublished report.

Bason, W.H. 1971. Ecology and early life history of striped bass, Morone saxatilis, in the Delaware Estuary in Ecological Study of the Delaware River in the vicinity of Artifical Island, Delaware. Progress report for the period January-December 1970. Part IV. Ichthyological Assoc., Ithaxa, NY. Bull. No. 4. 122 pp.

Bean, T.H. 1901. Catalogue of fishes of Long Island. Sixth Ann. Rept. N.Y. Forest, Fish, and Game Comm.: 373-398. (not seen, cited in Schaefer 1965).

Bigelow, H.B., and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. U.S. Fish Wildl. Serv., Fish. Bull. 53: 1-577.

______, and W.W. Welsh. 1925. Fishes of the Gulf of Maine. Bull. U.S. Bur. Fish. 48: 319-343. (not seen, cited in Raney 1952).

Blum, H.F. 1922. On the Effect of Low Salinity on Teredo navalis. Univ. of California Publ. Zool., 22(4) 349-368.

Bordeson, D.P. and G.W. McCammon, 1967. White catfish (Ictalurus catus) of the Scaramento-SanJoaquin Delta: Calif. Fish Game 53(4): 254-263.

Bousfield, E.L., 1973. Shallow-water Gammaridean Amphipoda of New England: Cornell University Press.

Brett, J.R. 1956. Some principles in the thermal requirements of fishes. Quart. Rev. Biol. 31(2): 75-87.

Brett, J.R. 1970. Temperature, Fishes. Pages 515-516 in O. Kinne, ed. Marine Ecology. A comprehensive, integated treatise on life in oceans and coastal waters. Wiley Interscience, N.Y.

Brett, J.R. 1971. Energetic responses of salmon to temperature. A study of some thermal relations and the physiology and freshwater ecology of sockeye salmon Oncorhynchus nerka. Amer. Zool. 11(1): 99-113.

_____, J.E. Shelbourn, and C.T. Schoop. 1969. Growth rate and body composition of fingerling sockeye salmon, Oncorhynchus nerka, in relation to temperature and ration size. J. Fish. Res. Bd. Canada. 26(9): 2363-2394.

Burns and Roe, Inc. 1974. Oyster Creek No. 1 circulating water system study (phase 1). Prepared for General Public Utilities Corp. 131 pp.

Campbell, R., 1965. Effect of the effluent from an atomic power plant on the adjacent portion of Barnegat Bay, New Jersey: Special interim report to the U.S. Department of HEW, Public Health Service, Bureau of State Services, Division of Environmental Engineering and Food Protection, Shellfish Sanitation Branch, Northeast Research Center, Narragansett, Rhode Island.

Campbell, R. 1966. Effect of the effluent from an atomic power plant on the adjacent portion of Barnegat Bay, New Jersey: Special interim report #2 to the U.S. Department of HEW, Public Health Service, Bureau of Station Services, Division of Environmental Engineering and Food Protection, Shellfish Sanitation Branch, Northwest Research Center, Narrangansett, Rhode Island.

Campbell, J.H. 1967. Concentration distribution for material discharged into Barnegat Bay, June 21, 1967. Amendment No. 11 to the Application for Construction Permit and Operating License, Docket No. 50-219, March 26, 1964.

Carriker, M.R. 1961. Interrelation of functional morphology behavior,and autecology in early states of the bivalve Mercenaria mercenaria: Jour. Elisha Mitchell Sci. Soc., v. 77, p. 168-241.

Chase, C.L. 1977. Survival of zooplankton entrained into the cooling water system and supplemental cooling powers of a steam-electric generating station located on Galveston Bay, Texas. M.S. Thesis. Texas A & M Univ. 230 pp.

Chellis, R.D. 1948. Finding and fighting marine borers. Engineering News-Record 140: 334-347, 422-424.

Clapp, W.F. 1923. A New Species of Teredo from Florida. Proc. of the Boston Society of Natural History. Vol. 37, No. 2, pp. 31-38, pl. 3-4.

Clapp, W.F. 1935. Increase of the destruction of timber structures by marine borers in New England waters. Proc. Am. Wood-Preser. Assoc. 31: 167-169.

Clapp. W.F. 1951. Observations on living Teredinidae. William F. Clapp Laboratories, Inc. Duxbury, Massachusetts. Fourth Prog. Rep. No. 7550. pp. 1-9.

Clark, J.R. 1972. Estuarine nursery grounds of coastal migratory fishes. N.J. Nature News, Sept. 1972: 105-112.

_______. 1973. Bluefish. Pages 250-251. in A.L. Packero, Ed. Proc. of a workshop on egg, larval and juvenile stages of fish in Atlantic Coast estuaries. U.S. Dept. of Commerce, Nat. Mar. Fish. Serv. Middle Atlantic Coastal Fish. Center, Tech. Publ. No. 1 (July 1973).

Crawford, G.I., 1937. A review of the amphipod genus Corophium. with notes on the British species: J MAR BIOL ASSN UK 21, 589-630.

Culliney, J.L.., P.J. Boyle and R.D. Turner. 1970. New Approaches and Techniques for Studying Bivalve Larvae. Culture of Marine Invertebrate Animals Plenum Publishing Corp.

Culliney, J.L. 1973. Settling of Larval Shipworms Teredo navalis L. and Bankia gouldi Bartsch, Stimulated by Humic Material (Gelbstoff). Museum of Comparative Zoology, Harvard Univ., Cambridge, Mass.

Daiber, F.C. 1963. Tidal creeks and fish eggs. Estuarine Bull. 7(2-3): 6-14.

______. 1957. The sea trout. Estuarine Bull. 2(5): 1-6. (not seek, cited in Thomas 1971).

Davis, H.C. and A. Calabrese, 1964. Combined effects of temperature and salinity on development of eggs and growth of larvae of M. mercenaria and C. virginica: Fishery Bulletin, v. 63 no. 3.

Davis, H.C. and P.E. Chanley, 1956. Spawning and egg production of oysters and clams: Biol. Bull. Woods Hold, v. 110 pp. 117-128.

Engineering News-Record. 1940. Teredos Cause Collapse of Temporary Trestle. Feb. 1, 1940, p. 51.

Enequist, P., 1949. Studies on the soft-bottom amphipods of the Skagerrak: Zool. Bidrag from Uppsala, 28: 297-492.

Festa, P.J. 1974. A study of the distribution of young and larval summer flounder in New Jersey estuarine waters. Project F-15-R. Misc. Rept. No. 11m (mimeo). N.J. Dept. Envir. Prot., Div. of Fish, Game and Shellfish. Bur. Fish., Nacote Creek Res. Sta. 33 pp.

_____. 1975. Creel census of the summer flounder sport fishery in Great Bay, New Jersey. Project F-15-R. Mimeo Rept. N.J. Dept. Envir. Prot., Div. of Fish, Game, and Shellfish. Bur. Fish., Nacote Creek Res. Sta. 27 pp.

Figley, W. 1977. New Jersey's sport fishery. N.J. Outdoors 4(5): 20-21.

Fischler, K.J., and C.H. Walburg. 1962. Blue crab movement in coastal South Carolina, 1958-59. Trans. Amer. Fish. Soc. 91-(3): 275-278. (not seen, cited in Oseterling 1976).

Freeman, B.L., 1977. Notes on Striped Bass migration. Underwater Nat. 10(4): 13-19.

Freeman, B.L., and S.C. Turner. 1976. The effects of anoxic water on the bluefish (Pomatomus saltatrix), and actively swimming fish. Pages 431-450 in Oxygen depletion and associated environmental disturbances in the Middle Atlantic Bight in 1976. A report on a series of interagency workshops held in November and December 1976.

Fry, F.E.J. 1947. Effects on the environment on animal activity. Univ. of Toronto Studies. Biol. Series No. 55., Publ. Ont. Fish. Res. Lab. 68: 1-62.

_____. 1064. Animals in aquatic environments: Fishes. Pages 715-728 in D.B. Dill, ed. Handbook on Physiology. Amer. Physiol. Soc., Wash., DC.

_____. 1967. Responses of vergebrate poikilotherms to temperature. Pages 375-409 in A.H. Rose, ed. Thermobiology. Academic Press, New York, NY.

Gamble, J.C., 1970. Anerobic survival of the crustaceans Corophium volutator, C. arenaruim and Tanais chevreauxi: J MAR BIOL ASSN UK 59(3): 657-671.

Gift, J.J., and J.R. Westman. 1971. Responses of some estuarine fishes to increasing thermal gradients. Privately published monograph, June 1971. 154 pp.

Goss-Custard, J.D., 1969. The winter feeding ecology of the redshank, Tringa totanus: IBIS 111(3): 338-355.

Grave, B.H. 1928. Natural history of the shipworm, Teredo navalis, at Woods Hole, Massachusetts. Biol. Bull. (Woods Hole) 55(4): 260-282. (Abstract.

Grave, B.H., 1933, Rate of growth, age at sexual maturity, and duration of life of certain sessile organisms, at Woods Hole, Massachusetts: Biol. Bull. Woods Hole, V. LXV, no. 3, pp. 375-386.

Grave, B.H. 1937. Rearing Teredo navalis. Pages 545-546 in P.S. Galtsoff, et al., eds. Culture methods for invertebrate animals. Ithaca, New York. (Abstract).

Greenfield, L.J. 1952. The distribution of marine borers in the Miami area in relation to ecological conditions. Bull. Mar. Sci. Gulf Cariff. 2(2): 448-464.

______. 1953. Observations on the nitrogen and glycogen content of Teredo (Lyrodus) pedicellata De Quatrefages at Miami, Florida. Bull. Mar. Sci. Gulf Caribb. 2(3): 486-496.

Haderlie, E.C., and J.C. Mellor. 1972. Settlement, growth rates and depth preference of the shipwork Bankia setacea (Tyron) in Monterey Bay. The Veliger 15(4): 265-286.

Haefner, P.A., Jr. 1972. The biology of the sand shiprm Crangon septemspinosa, at Lamonine, Maine. J. Elisha Mitchell Sci. Soc. 88(1): 36-42.

______. 1976. Seasonal distribution and abundance of sand shrimp Crangan septemspinosa in the York River-Chesapeake Bay Estuary. Chesapeake Sci. 17(2): 131-134.

Halgren, B.A. (1973). Phase III - use studies. Pages 175-224 in Studies of the upper Barnegat System. Misc. Rept. No. 10m (mimeo). N.J. Dept. of Envir. Prot., Div. of Fish, Game, and Shellfish. Bur. Fish., Nacote Creek Res. Sta.

Heard, R.W., III and W.B. Silora, 1972. A new species of Corophium Crustacea, Amphipoda from Georgia brackfish waters with some ecological notes. Proc. Biol. Soc. Wash. 84(55): 467-476.

Higham, J.R., and W.R. Nicholson. 1964. Sexual maturation and spawning of Atlantic menhaden. Fish. Bull. 63(2): 255-271.

Hildebrand, S.F., L.E. Cable. 1934. Reproduction and development of whitings or kingfishes, frums, spots, croakers, and weakfish or sea trouts, Faimly Sciaenidae, of the Atlantic coast of the United States. Bull. U.S. Bur. Fish. 68(16): 41-117.

Hildebrand, S.F. 1963. Family Clupeidae. Pages 257-454 in Fishes of the western north Atlantic. Sears Found. Mar. Res., Mem. No. 1, Part 3. Yale Univ., New Haven, CT.

Hill, C.L. 1922. Service record section, warf construction section, protection section, chemical, specification section. Pages 353-411 in Report of the San Francisco Bay Marine Piling Committee, Proc. Am. Wood Preser. Assoc. Vol. 18.

Hoagland, K.E., R.D. Turner and M. Rochester, 1976. Analysis of populations of boring and fouling organisms in the vicinity of the Oyster Creek Nuclear Generating Station with discussion of relevant physical parameters over the period Dec. 1, 1976-Feb. 28. 1977 (Second Quarterly Report). Wetlands Institute (Lehigh University) Stone Harbor, New Jersey; Harvard University, Cambridge, Mass.

Hoagland, KE., R.D. Turner and M. Rochester, 1977a. Analysis of populations of boring and fouling organisms in the vicinity of Oyster Creek Nuclear Generating Station with discussion of relevant physical parameters over the period Dec. 1, 1976-Feb. 28, 1977 (Second Quarterly Report). Wetlands Institute (Lehigh University) Stone Harbor, New Jersey; Harward University, Cambridge, Mass.

Hoagland, K.E., R.D. Turner and M. Rochester 1977b. Analysis of populations of boring and fouling organisms in the vicinity of the Oyster Creek Nuclear Generating Station with discussion of relevant physical parameters over the period of March 1-May 31, 1977. Wetlands Institute (Lehigh University) Stone Harbor, New Jersey; Harvard University, Cambridge, Mass.

Hoagland, K.E., L. Crockett and M. Rochester, 1977c. Analysis of populations of boring and fouling organisms in the vicinity of the Oyster Creek Nuclear Generating Station with discussion of relevant physical parameters over the period June 1-August 31, 1977. Wetlands Institute (Lehigh University) Stone Harbor, New Jersey).

Hoagland, K.E., R.D. Turner and M. Rochester, 1977. Analysis of populations of boring and fouling organisms in the vicinity of the Oyster Creek Nuclear Generating Station with discussion of relevant physical parameters over the period Dec. 1, 1976-Feb. 28, 1977 (Second quarterly report): Wetlands Institute (Lehigh University) Stone Harbor, New Jersey.

Hoff, J.H., and J.R. Westman. 1966. The temperature tolerances of three species of marine fishes. J. Mar. Res. 24(2): 141-410.

Holland, J.S., D.V. Aldrich, and K. Strawn. 1971. Effects of temperature and salinity on growth, food conversion, survival and temperature resistance of juvenile blue crabs. Callinectes sapidus, Rathbun. Texas A & M Univ., TAMU-SG-71-222. 165 pp.

Howe, A.B., and P.G. Coates. 1975. Winter flounder movements, growth, and mortality off Massachusetts. Trans. Amer. Fish. Soc. 104(1): 13-29.

Huntsman, A.G., and M.I. Sparks. 1924. Limiting factors for marine animals. 3. Relative resistance to high temperatures. Contrib. Can. Biol. 2: 95-114.

Imai, T., et al. 1950. Breeding of marine timber-borer, Teredo navalis, in tanks and its use for anti-boring test. Tohoku J. of Agric. Res. 1(2): 199-114.

Isham, L.B., H.B. Moore, and F.G. Walton-Smith. 1951. Growth rate measurements of shipworms. Bull. Mar. Sci. Gulf Caribb. 1(2): 136-147.

Isham, L.B. & J.Q. Tierney. 1953. Some aspects of the Larval Development and Metamorphosis of Teredo (Lyrodus) predicellata de Quatrefage. Bulletin of Marine Science of the Gulf and Caribbean. Vol. 2, No. 4 pp. 574-589.

Jeffries, H.P., W.C. Johnson. 1974. Seasonal variations of bottom fishes in the Narragansett Bay area: seven-year variations in the abundance of winter flounder (Pseudopleuronectes americanus). J. Fish. Res. Bd. Canada. 31(6): 1057-1066.

Johnson, S.C., 1967. Hierarchical clustering schemes: Psychometrika V. 32, pp. 241-254.

June, F.C., and J. Chamberlin. 1959. The role of the estuary in the life history and biology of Atlantic menhaden. Proc. Gulf Carib. Fish. Inst., 11th Ann. Sess.: 41-45.

_____, and C.M. Roithmayr. 1960. Determining age of Atlantic menhaden from their scales. U.S. Fish Wildl. Serv., Fish. Bull. 171: 323-342.

Karande, A.A., & S.S. Pendsey. 1968. Field and Laboratory Observations on Teredo furcifera M., a Test Organisms for the Bioassessment of Toxic Compounds. Proceedings of the Indiana Academy of Science. Vol. #70-sec. B pp. 223-231.

Kennish, M.J., 1978. Effects of thermal discharges on mortality of Mercenaria mercenaria in Barnegat Bay, New Jersey: Unpub. Ph.D. dissert., 161 p.

Kennish, M.J., and R.K. Olsson, 1975. Effects of thermal discharges on the microstructural growth of Mercenaria mercenaria: Environ. Geol., v. 1. pp. 41-64.

Kinne, O. 1963. The Effects of Temperature and Salinity on Marine and Brackish Water Animals. Oceanogr. Mar. Biol. Ann. Rev. 1963, 1, pp. 301-340. Harold Barnes, Ed. Publ. George Allen and Unwin Lld., London.

Kroger, R.L., and J.F. Guthrie. 1973. Migration of tagged juvenile Atlantic menhaden. Trans. Amer. Fish. Soc. 102(2): 417-422.

______, _____, and M.H. Judy. 1974. Growth and first annulus formation of tagged and untagged Atlantic menhaden. Trans. Amer. Fish. Soc. 103(2) 292-296.

Kuhl, H., 1970. Investigations on the food of smelt (Osmers eperlanus L.) in the estuary of the River Elbe: ARCH FISCHERIWISS 21(3): 222-231.

Lane, C.E., G.S. Posner and L.J. Greenfield. 1952. The distribution of Glycogen in the shipworm, Teredo (Lyrodus) pedicellata Quatrefages. Bull. Marine Sci. Gulf and Caribbean 2(2): 385-392.

Lane, C.E., J.Q. Tierney and R.E. Hannacy. 1954. The respiration of normal larvae of Teredo bartschi Clapp Biol. Bull. 106(3): 323-327.

Lane, C.E. 1955. Recent biological studies on Teredo - a marine woodboring mollusk. The Scientific Monthly 80: 286-292.

_____. 1959. The nutrition of Teredo. Ann. New York. Acad. Sci. 77: 246-248.

Laroche, J.L., and J. Davis. 1973. Age, growth, and reproduction of the northern puffer, Sphoeroides maculatus. Fish. Bull. 71(4): 955-963.

Lawler, Matusky, and Skelly Engineers. 1978. Simulation of the effluent plumes from the Forked River Nuclear Station. Rept. to Jersey Central Power & Light Co. 71 pp.

Leim, A.H., and W.B. Scott. 1966. Fishes of the Atlantic coast of Canada. Bull. Fish. Res. Bd. Canada 155. 485 pp.

Lewis, R.M., and W.F. Hettler, Jr. 1968. Effect of temperature and salinity on the survival of young Atlantic menhaden, Brevoortia tyrannus. Trans. Amer. Fish. Soc. 97(4): 344-349.

Lippson, A.J., and R.L. Moran. 1974. Manual for identification of early developmental stages of fishes of the Potomac River estuary. Prepared for the Power Plant siting program of the Maryland Dept. of Nat. Res. PPSP-MP-13. 282 pp.

Lobell, M.J. 1939. A biological survey of the salt water of Long Island, 1938. Report on certain fishes. Winter flounder (<u>Pseudopleuronectes americanus</u>). Suppl. 28th Ann. Rept., N.Y. Conserv. Dept., Pt. I: 63-96. (not seen, cited in Howe and Coates 1975).

Long, E.R. 1971. Oceanographic cruise summary 2nd year of marine bio fouling studies off Oahu, Hawaii: Gov. Rep. Announce. 71(7).

Loosanoff, V.L. 1939, Effect of temperature upon shell movement of clams, <u>Venus mercenaria</u> (L.):

Loosanoff, V.L., W.S. Miller and P.B. Smith, 1951. Growth and setting of larvae of <u>Venus mercenaria</u> in relation to temperature: J. Mar. Res. v. 10, pp. 59-81.

Loosanoff, V.L., and H.C. Davis. 1963. Rearing of bivalve mollusks. Adv. Mar. Biol. 1: 1-136.

Loveland, R.E. and E.T. Moul, 1966. The qualitative and quantitative analysis of benthic flora and fauna of Barneget Bay before and after the onset of thermal addition. An Initial Progress Report to Jersey Central Power & Light Company. Contract #27-4656. 33 pp.

Loveland, R.E., E.T. Moul, F.X. Phillips and J.E. Taylor, 1967. The qualitative and quantitative analysis of the benthic flora and faune of Barnegat Bay before and after the onset of thermal addition. Second Progress Report to Jersey Central Power & Light Company. Contract #27-4656. 7 pp.

Loveland, R.E., E.T. Moul, J.E. Taylor, F.X. Phillips and K. Mountford, 1968. Barnegat Bay thermal addition. Progress Report No. 3. Jersey Central Power & Light Company. Contract #27-4656. 123 pp.

Loveland, R.E., E.T. Moul, J.E. Taylor, K. Moundford and F.X. Phillips, 1968. The qualitative and quantitative analysis of the benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition. Fourth Progress Report to Jersey Central Power & Light Company. Contract #27-4656. 17 pp.

Loveland, R.E., E.T. Moul, F.X. Phillips, J.E. Taylor, and K. Mountford, 1969. The qualitative and quantitative analysis of the benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition. Fifth Progress Report to Jersey Central Power & Light Company. Contract #27-4656. 115 pp.

Loveland, R.E., E.T. Moul, K. Mountford, P. Sandine, D. Busch, E. Cohen, N. Kirk, M. Moskowitz and C. Messing. 1970. The qualitative and quantitative analysis of the benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition. Sixth Progress Report to Jersey Central Power & Light Company. Contract #27-4656. 30 pp.

Loveland, R.E., K. Mountford, E.T. Moul, D.A. Busch, P.H. Sandine and M. Moskowitz. 1971. The qualitative and quantitative analysis of the benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition. Seventh Progress Report to Jersey Central Power & Light Company. Contract #27-4656. 49 pp.

Loveland, R.E., E.T. Moul, D.A. Busch, P.H. Sandine, S.A. Shafto, J. McCarty, 1972. The qualitative and quantitative analysis of the benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition. Eighth Progress Report to Jersey Central Power & Light Company. Contract #27-4656. 81 pp.

Loveland, R.E., P. Edwards, J.J. Vouglitois and D. Palumbo, 1974. The qualitative and quantitative analysis of the benthic flora and fauna of Barneget Bay before and after the onset of thermal addition. Ninth Progress Report to Jersey Central Power & Light Company. Contract #27-4656. 78 pp.

Lund, W.A., Jr., and G.C. Maltezos. 1970. Movements and migrations of the bluefish, *Pomatomus saltatrix*, tagged in waters of New York and southern New England. Trans. Amer. Fish. Soc. 99(4): 719-725.

Lux, F.E., and L.R. Porter, Jr. 1966. Length-weight relationship of summer flounder *Paralichthys dentatus* (Linnaeus). U.S. Fish and Wildl. Serv. Spec. Sci. Rept. Fish No. 531. 5 pp. (not seen, cited in Smith 1969).

Mansueti, R.J. 1958. Eggs, larvae, and young of the striped bass, *Roccus saxatilis*. Maryland Dept. Res. and Educ., Chesapeake Biol. Lab., Contr. No. 112. 36 pp.

Mansueti, A.J., and J.D. Hardy, J., 1967. Development of fishes of the Chesapeake Bay region; an atlas of egg, larval, and juvenile stages. Nat. Res. Inst., Univ. Maryland. 202 pp.

Marcellus, K.L... 1972. Fishes of Barnegat Bay, New Jersey with particular reference to seasonal influences and possible effects of thermal discharges. Ph.D. dissertation. Rutgers. Univ. 190 pp.

Maryland State Fisheries Administration. 1974. Summary of 1974 fish kills. Dept. Nat. Res., Annapolis, MD.

______________. 1975. Summary of 1975 fish kills, Dept. Nat. Res., Annapolis, MD.

McClain, J.F. (1973). Phase I- Fish studies. Pages 1-74 in Studies of the upper Barnegat System. Misc. Rept. No. 10m (mimeo). N.J. Dept. of Envir. Prot., Div. of Fish, Game and Shellfish. Bur. Fish., Nacote Creek Res. Sta.

McCraken, F.D. 1963. Seasonal movements of the winter flounder, Pseudopleuronectes americanus (Walbaum), on the Atlantic Coast. J. Fish. Res. Bd. Canada. 20(2):

McHugh, J.L., R.T. Oglesby, and A.L. Pacheco. 1959. Length, weight, and age composition of the menhaden catch in Virginia waters. Lemnol. and Oceanogr. 4(2): 145-162.

McHugh, J.L. 1967. Estuarine nekton. Pages 581-620 in G. Lauf, ed. Estuaries. Amer. Assoc. Adv. Sci., Publ. No. 83. Wash., DC.

_____. 1977. Fisheries and fishery resources of New York Bight. U.S. Dept. Commerce, NOAA Tech. Rept., NMFS Circ. 401. 50 pp.

Meadows, P.S., 1964. Experiments on substrate selection by Corophium species films and bacteria on sand particles: JEXP BIOL 41(3): 499-511.

McLusky, D.S., 1967. Some effects of salinity on the survival, moulting and growth of Corophium volutator: J MAR BIOL ASSN UK 47(3): 607-617.

McLusky, D.S., 1968. Some effects of salinity on the distribution and abundance of Corophium volutator in the Ythan estuary: J MAR BIOL ASSN UK 48(2): 443-454.

Meldrim, J.W. and j.J. Gift. 1971. Temperature preference, avoidance, and shock studies with estuarine fishes. Ichthyological Assoc., Inc., Bull. No. 7. Ichthyological Assoc., Inc., Ithaca, NY. 75 pp.

Meldrim, J.W., N.J. Morrison, III, and L.O. Horseman. 1977. Expected effects of the Deepwater Power Station thermal plume on selected estuarine fishes. Ichthyological Assoc., Inc., Ithaca, NY. 134 pp.

Merriman, D. 1937. Notes on the life history of the striped bass (Roccus lineatus). Copeia (1): 15-36 (not seen, cited in Bigelow and Schroeder 1953).

Merriner, J.V. and J.L... Laroche. 1977. Fecundity of the northern puffer, Sphoeroides maculatus, from Chesapeake Bay. Chesapeake Sci. 18(1): 81-83.

M'Gonigle, R.M. 1926. A further consideration of the relation between distribution of Teredo navalis (Linne) and the temperature and salinity of its environment. Natural Resource Council, Canada. Rep. No. 20, 31 pp.

Mihursky, J.A., and V.S. Kennedy. 1967. Water temperature criteria to protect aquatic life. Spec. Publ. Amer. Fish. Soc. 4: 20-32.

Miller, R.C. 1922. Variations in Teredo navalis in San Francisco Bay. Univ. Calif. Zool. 22: 294-328.

_____. 1926. Ecological relations of marine wood-boring organisms in San Francisco Bay. Ecology 7(3): 247-254.

Miller, R.E., S.D., Sulkin, and R.L. Lippson. 1975. Composition and seasonal abundance of the blue crab, Callinectes sapidus - Rathbun, in the Chesapeake and Delaware Canal and adjacent waters. Chesapeake Sci. 16(1): 27-31.

Miller, R.W. (1978). Marine recreational fishing in Delaware. Del. Div. of Fish and Wildl., Document 40-05/78/01/18. 28 pp.

Milstein, C.B., D.L. Thomas, and Associates. 1976. Ecological studies in the bays and other waterways in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress report for the period January-December 1975. Ichthyological Assoc., Inc., Ithaca, NY. 572 pp.

Milstein, C.B., D.L. Thomas and Associates. 1977. Summary of ecological studies for 1972-1975 in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Ichthyological Assoc., Inc., Ithaca, NY. 757 pp.

Nagabhushanam, R. 1961. Ecological factors related to the distribution of Bankia campanellata in Visakhapatnam Harbor Am. Zool. 3: 377. (Abstract).

Nair, N.B. 1956. The development of the wood-boring pelecypod, Bankia indica Nair. J. Madras Univ. B. 36(2): 303-312.

______. 1962. Ecology of marine fouling and wood-boring organisms of western Norway. Sarsia, No. 8: 1-88.

Nair, B.B., and M. Saraswathy, 1971. The biology of wood-boring teredinid mollusks, Adv. Mar. Biol. 9: 335-509.

National Marine Fisheries Service, P.O. Box 143, Toms River, New Jersey 98743.

Naylor, E., 1965. Biological effects of a heated effluent in docks at Swansea, S. Wales: Proc. Zool. Soc. London 144: 253-268.

Nelson, T.C. 1922. Report of the Department of Biology, Marine Borers. N.J. Agric. Col. Exp. Sta., New Brunswick, N.J. Published by the State, 1923.

______, 1924. Report of the Department of Biology of the New Jersey Agricultural College Experiment Station. Published by the State.

______, 1928. On the distribution of critical temperatures for spawning and for ciliary activity in bivalve mollusks. Science, New York 67(1730): 220-221.

Nelson, J.C., and H.H. Haskin, 1949. On the spawning behavior of oysters and of Venus mercenaria with especial reference to the effects of spermatic hormones: Anat. Rec. v. 105, pp. 484-485 (abstract).

Nicholson, W.R. 1972. Population structure and movement of Atlantic menhaden, Brevoortia tyrannus, as inferred from back-calculated length frequency. Chesapeake Sci. 13(3): 161-174.

Norcross, J.J., S.L. Richardson, W.H. Massman, and E.B. Joseph. 1974. Development of young bluefish (Pomatomus saltatrix) and distribution of eggs and young in Virginian Coastal Waters. Trans. Amer. Fish. Soc. 103(3): 477-497.

Oesterling, M.J. 1976. Reproduction, growth, and migration of blue crabs along Florida's Gulf coast. Florida Sea Grant Publ. SUSF-SG-76-003. 19 pp.

Olla, B.L., R. Wickland, and S. Wilk. 1969. Behavior of winter flounder in a natural habitat. Trans. Amer. Fish. Soc. 98(4): 717-720.

Olla, B.L. and A.C. Studholme. 1971. Daily and seasonal rhythms of activity in the bluefish (Pomatomus saltatrix). Pages 303-326 in H.E. Winn and B.L. Olla, eds. Behavior of marine animals. Vol. 2. Vertebrates. Plenum Publ. Corp., New York, NY.

Percival, E. 1929. A report on the fauna of the estuaries of the river temar and the river Lynher. J. Mar. Biol. Assn. UK 16(1): 8-108.

Perlmutter, A. 1947. The blackback flounder and its fishery in New England and New York. Bull. Bing. Oceanogr. Coll. 11(2): 1-92.

Pesch, G.G., 1972. Protein polymorphisms and population genetics of the hard clam, Mercenaria mercenaria (L.) University of Rhode Island, unpublished Ph.D. dissertation, 49 pp.

Phillips, R.J. 1914. Kingfish at Corson's Inlet, New Jersey. Copeia 1914(9): 3-4. (not seen, cited in Schaefer 1965).

Poole, J.C. 1964. Feeding habits of the summer flounder in Great South Bay. N.Y. Fish Game J. 11(1): 28-34.

_____. 1966. Growth and age of winter flounder in four bays of Long Island. N.Y. Fish Game J. 13(2): 206-220.

Pratt, S.D. 1973. Benthic Fauna, in coastal and offshore environmental inventory, Cape Hatteras to Nantucket Shoals: Marine Publication Series No. 2, University of Rhode Island, Kingston, Rhode Island 02881.

Price, D.B. 1962. Biology of the sand shrimp, Crangon septemspinosa, in the shore zone of the Delaware Bay region. Chesapeake Sci. 3(4): 244-255.

Quayle, D.B. 1956. The British Columbia shipworm. Rep. British Columbia Dept. Fish for 1955.

_____. 1959. The growth rate of Bankia sepacea Tryon. Pages 175-183 in D.L. Ray, ed. Marine boring and fouling organisms. University of Washington Press, Seattle.

Raney, E.C. 1952. The life history of the striped bass, Roccus saxatilis (Walbaum). Bull. Bing. Oceanogr. Coll. 14(1): 5-97.

Regnault, M., and J.D. Costlow. 1970. Influence de la temperature et de la salinite sur le development larvaive de Crangon septemspinosa sayi (Decapoda, Caridea). Vie et milieu, Ser. A. 21 (2-A): 453-466.

Reintjes, J.W. 1969. Synopsis of biological data on the Atlantic menhaden, Brevoortia tyrannus. U.S. Fish and Wildl. Serv., Circ. 320. 30 pp.

______. 1975. Compilation and correlation analysis of published and unpublished environmental data with distribution, abundance, and movements of young menhaden in mid-Atlantic estuaries. Nat. Mar. Fish. Serv. 40 pp.

Richards, B.R., and C.P. Belmore, 1975. Evaluation of the extent and effect of the marine woodborer population In Oyster Creek upon the overall Barnegat Bay marine woodborer populations. Report to Jersey Central Power & Light Company.

______, A.E. Rehm, E.I. Belmore and R.C. Hillman. 1978. Woodborer Study Associates with the Oyster Creek Generating Station - Annual Report for the period June 1, 1976 to November 30, 1977. Report to Jersey Central Power & Light Company.

Richards, 1976. Age, growth, and food of bluefish (Pomatomus saltatrix) from east-central Long Island Sound from July through November 1975. Trans. Amer. Fish. Soc. 105(4): 323-325.

Roch, F. 1926. Xylophagae and the means of combating them. Engineering Progress. 7(6): 161-163.

______. 1931. Marine piling investigation. Second prog. rep. New England Committee. pp. 51-62.

______. 1932. Einige Beobachtungen zue Ckologie and Physiologie von Teredo navalis L. ark. Zool. 24(A.2) No. 5, 48 pp.

Rogers, C.A. 1976. Effects of temperature and salinity on the survival of winter flounder embryos. Fish. Bull. 74(1): 52-58.

Saila, S.B. 1961. The contribution of estuaries to the offshore winter flounder fishery in Rhode Island. Proc. Gulf Carib. Fish. Inst., 14th Ann. Sess.: 95-109.

Sandifer, P.A. 1972. Morphology and ecology of Chesapeake Bay decapod crustacean larvae. Ph.D. dissertation. Univ. Virginia. 531 pp.

Sandine, P.H., V.J. McDermott, and J.H. Chamblin. 1974. Zooplankton. Pages 52-74 in Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress Report for the period January-December 1973. Vol. Three. Ichthylogical Assoc., Inc., Ithaca, NY. 393 pp.

______, and F.A. Swiecicki. 1975. Zooplankton. Pages 72-94 in Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress report for the period January-December 1974. Vol. Two. Ichthyological Assoc., Inc., Ithaca, New York. 467 pp.

Schaefer, R.H. 1965. Age and growth of northern kingfish in New York waters. N.Y. Fish Game J. 12(2): 191-216.

______. 1970. Feeding habits of striped bass, Morone saxatilis, from the surf waters of Long Island. N.Y. Fish Game J. 17(1): 1-17.

Scheltema, R.A. and R.V. Truitt. 1954. Ecological factors to the distribution of Bankia gouldi Bartsch in Chesapeake Bay. Chesapeake Boil. Lab. (Solomons Island, Maryland) Publ. 100. 31 pp. (Absract).

Schuster, C.H., Jr. 1959. A biological evaluation of the Delaware River Estuary. Univ. Del. Mar. Lab. Inf. Ser. Publ. (3): 1-77 (not seen, cited in Hopkins 1965).

Shafto, S.A. 1974. The marine boring and fouling invertebrate community of Barnegat Bay, New Jersey. M.S. thesis, Rutgers Univ. 235 pp.

Shyamasundari, K., 1973. Studies on the tube-building amphipod Corophium triaenonyx Stebbing from Visakhapatham Harbor: Effects of salinity and temperature: BIOL BULL 144(3): 503-510.

Sigerfoos, C.P. 1908. Natural history, organization and late development of the Teredinidae, or shipworms. Bull. U.S. Bur. Fish. 27: 191-221.

Smith, R.W. 1969. An analysis of the summer flounder, Paralichthys dentatus (Linnaeus), population in the Delaware Bay. M.S. Thesis. Univ. Delaware. 71 pp.

Smith, S.I. 1879. The stalk-eyed crustaceans of the Atlantic Coast of North America north of Cape Cod. Trans. Conn. Acad. Arts. Sci. 5: 27-136. (not seen, cited in Hopkins 1965).

Snyder, G.R., D.P. Craddock, and T.H. Blahm. 1970. Thermal effects studies on the Lower Columbia River, 1968-1970. Proc. West. Assoc. Game Fish Commnrs. 15: 65-89.

Squires, H.J. 1965. Decapod crustaceans of Newfoundland, Labrador, and the Canadian eastern Arctic. J. Fish. Res. Bd. Canada Man. Rept. Ser. (Biol.) No. 810, 212 pp. (not seen, cited in Wilcox and Jeffries, 1973).

Stevenson, R.A. 1958. The biology of the anchovies Anchoa mitchilla mitchilla (Cuvier and Valenciennes 1848) and Anchoa hepsetus hepsetus (Linnaeus 1758) in Delaware Bay. M.S. Thesis. Univ. Delaware. 55 pp.

Sullivan, C.M. 1948. Bivalve larvae of Malpeque Bay. P.E.I. Fish. Res. Bd. Canada 77: 1-36.

Tagatz, M.F. 1969. Some relations of temperature acclimation and salinity to the thermal tolerance of the blue crab, Callinectes sapidus. Trans. Amer. Fish. Soc. 98(4): 713-716.

Talbot, G.B. 1966. Estuarine environmental requirements and limiting factors for striped bass. Amer. Fish. Soc., Spec. Publ. No. 3: 37-49. (not seen, cited in Gift and Westman 1971).

Tatham, T.R., D.J. Danila, D.L. Thomas, and Associates, 1977a. Ecological studies for the Oyster Creek Generating Station. Progress report for the period September 1975-August 1976. Vol. One. Fin- and shellfish. Ichthyological Assoc., Inc., Ithaca, NY. 338 pp.

______, P.H. Sandine, R.P. Smith, H.W. Hoffman, K.A. Tighe, and D.L. Thomas. 1977b. Ecological studies for the Oyster Creek generating Station. Progress report for the period September 1975-August 1976. Vol. Two. Plankton. Ichthyological Assoc., Inc., Ithaca, NY. 368 pp.

Tatham, T.R., D.J. Danila, D.L. Thomas, and Associates. 1978a. Preliminary report of ecological studies for the Oyster Creek Generating Station. Progress report for the period September 1976-August 1977. Volume One. Part I. Fin- and shellfish. Ichthyological Assoc., Inc., Ithaca, NY.

_____, P.H. Sandine, R.P. Smith, K.A. Tighe, and F.A. Swiecicki. 1978b. Preliminary report of ecological studies for the Oyster Creek Generating Station. Progress report for the period September 1976-August 1977. Vol. Two. Part I. Plankton. Ichthyological Assoc., Inc., Ithaca, NY.

Terpin, K.M., M.C. Wyllie, and E.R. Holmstrom. 1977. Temperature preference, avoidance, shock and swim speed studies with marine and estuarine organisms from New Jersey. Ichthyological Assoc., Inc. Bull. No. 17. Ichthyological Assoc., Inc., Ithaca NY. 86 pp.

Thomas, D.L. 1971. An ecological study of the Delaware River in the vicinity of Artificial Island - progress report for the period January-December 1970. Part III. The early life history and ecology of six species of drum (Sciaenidae) in the lower Delaware River, a brackish tidal estuary. Ichthyological Assoc., Inc. Bull. No. 3, Ichthyological Assoc., Inc., Ithaca, NY. 247 pp.

_____, and C.B. Milstein. 1973. Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress report for the period January-December 1972. Part One. Ichthyological Assoc., Inc., Ithaca, NY. 666 pp.

_____, _____. 1974. A comparision of fishes collected by trawl along the coast of southern New Jersey from 1929 to 1933 with those taken in the vicinity of Little Egg Inlet in 1972 and 1973. Pages 70-75 in Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress report for the period January-December 1973. Vol. I Fishes. Ichthyological Assoc., Inc., Ithaca, NY.

_____, _____, T.R. Tatham, R.C. Bieder, F.J. Margraf, D.J. Danila, H.K. Hoff, E.A. Illjes, M.M. McCullough, and F.A. Swiecicki. 1974. Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress report for the period January-December 1973. Vol. 1. Fishes. Ichthyological Assoc., Inc., Ithaca, NY. 709 pp.

Thomas, D.L., C.B. Milstein, T.R. Tatham, R.C. Bieder, D.J. Danila, H.K. Hoff, D.P. Swiecicki, R.P. Smith, G.J. Miller, J.J. Gift, and M.C. Wyllie. 1975. Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress report for the period January-December 1974. Vol. 1. Fishes. Ichthyological Assoc., Inc., Ithaca, NY. 490 pp.

_____, _____, _____, E. Van Eps, D.K. Stauble, and H.K. Hoff. 1972. Ecological considerations for ocean sites off New Jersey for proposed nuclear generating station. Vol. One. Part One. Ichthyological Assoc., Inc., Ithaca, NY. January 1972. 115 pp.

Tiller, R.E., J.B. Glude and L.D. Stringer, 1952, Hard-clam fishery of the Atlantic Coast: Comm. Fish. Rev. v. 14, No. 10.

Topp, R.W. 1968. An estimate of fecundity of the winter flounder, <u>Pseudopleuronectes americanus</u>. J. Fish. Res. Bd. Canada 25(6): 1299-1302.

Turner, H.J., 1953. A review of the biology of some commercial mollusks of the east of North America: Sixth Report on Investigations of the Shellfisheries of Massachusetts, Div. Mar. Fish., Dept. of Conservation, Comm. of mass., Bostom: 39-74.

Turner, H.J., Jr., and J.E. Hanks, 1960. Experimental stimulation of gametogenesis in <u>Hydroides dianthus</u> and <u>Pecten irradians</u> during the winter. Biol. Bull. Woods Hole 119(1): 145-152.

Turner, R.D. 1966. A survey and illustrated catalogue of the Teredinidae (Mollusca, bivalvia). Mus. Comp. Zool. (Harv. Univ.). Cambridge, Massachusetts. 265 pp.

_____. 1973. Report on marine borers (Teredinidae) in Oyster Creek, Waretown, New Jersey. Dated April 3, 1973. Xerox copy in files.

_____. 1974a. Report on marine borers (Teredinidae) in Oyster Creek, Waretown, New Jersey. Dated February 25, 1974. Xerox copy in files.

_____. 1974b. Third report on marine borers (Teredinidae) in Oyster Creek, Waretown, New Jersey. Dated March 12, 1974.

Turner, R.D., and A.C. Johnson. 1971. Biology of marine wood-boring mollusks. Pages 259-301 in E.B.G. Jones and S.K. Eltringham, eds. Marine borers, fungi and fouling organisms in wood. O.E.C.D. (Organization for Economic Co-operation and Development), Paris.

Vladykov, V.D., and D.H. Wallace. 1952. Studies of the striped bass, Roccus saxatilis (Walbaum) with special reference to the Chesapeake Bay region during 1936-1938. Bull. Bing. Oceanogr. Coll. 14(1): 132-177.

Vouglitois, J.J., 1976. The benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition - a summary analysis of a ten-year study by Rutgers University: Report to U.S. Nuclear Regulatory Commission, 195 pp.

Welsh, W.W. and C.M. Breder, Jr. 1923. Contributions to life histories of Sciaenidae of the Eastern United States Coast. Bull. U.S. Bur. Fish. 39(1923-24). Bur. Fish. Doc. 945: 141-201. (not seen, cited in Thomas 1971).

W.F. Clapp Laboratories, Inc. 1960. Thirteenth Progress Report on Marine Borer Activity in the Test Boards Operating during 1959. Report No. 11466, March 15, 1960. Supplement to Report No. 6063 on Test Board studies from 1942 to 1947, Report No. 6166 and 6517 on Test Boards operated during 1948, Report No. 7034 on Test Boards operated during 1949, Report No. 7550 on Test Boards operated during 1950, Report No. 8088 on Test Boards operated during 1951, Report No. 8511 on Test Boards operated during 1952, Report No. 9000 on Test Boards operated during 1953, Report No. 9440 on Test Boards operated during 1954, Report No. 9889 on Test Boards operated during 1955, Report No. 10333 on Test Boards operated during 1956, Report No. 10677 on Test Boards operated during 1957 and Report No. 11044 on Test Boards operated during 1958. Compiled by Dorothy Brown Wallour. Department of the Navy, Bureau of Yards and Docks, NBy-17810.

Whiteley, G.C. 1948. The distribution of large planktonic crustacea on Georges Bank. Ecol. Monogr. 18(2): 233-264. (not seen, cited in Haefner 1972).

Wigley, R.L., and B.R. Burns. 1971. Distribution and biology of mysids from the Atlantic coast of United States in NMFS Woods Hole Collections Fish. Bull. 69(4): 7-7-746.

Wilcox, J.R., and H.P. Jeffries. 1973. Growth of the sand shrimp, Crangon septemspinosa, in Rhode Island. Chesapeake Sci. 14(3): 201-205.

Williams, A.B. 1965. Marine decapod crustaceans of the Carolinas. Fish. Bull. U.S. Fish. Wildl. Serv. 65: 1-298.

Williams, A.B. 1972. A ten-year study of meroplankton in North Carolina estuaries: mysid shrimps. Chesapeake Sci. 13(4): 254-262.

Williams, A.B., T.E. Bowman, and D.M. Damkaer. 1974. Distribution, variation, and supplemental description of the opossum shrimp, Neomysis americana (Crustacea: Mysidacea). Fish. Bull. 72(3): 835-842.

Woodward-Clyde Consultants, 1975. The physical behavior of the thermal plume discharged from the Oyster Creek Nuclear Genrating Station: Report to Jersey Central Power & Light Company.

Woodward-Clyde, 1976. Marine woodborers of Barnegat Bay and their relationship of the operation of Oyster Creek Nuclear Generating Station. Final Report of 1974-75 Field and Laboratory Studies for Jersey Central Power & Light Company.

Worth, S.G. 1904. The recent hatching of striped bass and possibilities with other commercial fishes. Trans. Amer. Fish. Soc. 33: 223-236.

Wyllie, M.C., E.R. Holstrom, and R.K. Wallace, 1976. Temperature preference, avoidance, shock , and swim speed studies with marine and estuarine organisms from New Jersey. Ichthyological Assoc., Inc. Bull. No. 15. Ichthyological Assoc., Inc., Ithaca, NY. 76 pp.

Wurtz, C.B. 1971. Shipworms at Oyster Creek, N.J. An investigation made for Jersey Central Power & Light. Report to JCP&L, Dec. 13, 1971.

Young, J.S. and A.B. Frame, 1976. Some effects of power plant effluent on estuarine epibenthic organisms. Int. Revue ges. Hydrobiol. 61(1): 37-61.

Zvorykin, N.P. 1941. Pourezhdeniia i Vosstanovlenic portavykh gidrotakhnicheskikh sooruzhenii. Moskva and Leningrad. 271 pp.

Table 3.1-1 Mean monthly water temperature in the OCGS condenser intake and the condenser discharge and the difference between these temperatures (Δt) from September 1975 through August 1976.

	No. of Observations	Mean Temp. Condenser Intake (C)	Mean Temp. Condenser Discharge (C)	Δt
September 1975	30	20.1	28.9	8.8
October	31	16.4	22.8	6.4
November	30	11.8	21.4	9.6
December	31	4.4	13.7	9.3
January 1976[a]	31	0.6	1.2	0.6
February[a]	29	4.1	4.4	0.3
March	31	8.9	13.8	4.9
April	30	14.3	22.5	8.2
May	31	20.0	28.7	8.7
June	30	25.8	35.4	9.6
July	31	26.7	34.4	7.7
August	31	26.6	36.3	9.7

a. OCGS not in operation; only dilution pumps operating.

Table 3.1-2 Mean monthly water temperature in the OCGS condenser intake and the condenser discharge and the difference between these temperatures (Δ t) from September 1976 through August 1977.

	No. of Observations	Mean Temp. Condenser Intake (C)	Mean Temp. Condenser Discharge (C)	Δ t
September	30	23.3	31.5	8.2
October	31	14.9	23.7	8.8
November	30	6.8	16.6	9.8
December	31	0.1	10.0	9.9
January	31	0.1	10.1	10.0
February	28	2.1	12.2	10.1
March	31	8.5	17.1	8.6
April	30	14.1	20.7	6.6
May	31[a]	18.4	19.8	1.4
June	30[b]	20.2	22.7	2.5
July	31[a]	25.8	27.0	1.2
August	31	26.4	36.3	9.9

[a] OCGS in operation only part of month.
[b] OCGS shutdown.

Table 3.1-3 Species list and experimental studies conducted between January 1975 and October 1977.

Common Name	Scientific Name	Preference		Avoidance	Shock[a]	
		Horizontal	Vertical		Cold	Heat
Atlantic menhaden	*Brevoortia tyrannus*	79	11	83	61	79
Bay anchovy	*Anchoa mitchilli*	39	2	33	70	42
Threespine stickleback	*Gasterosteus aculeatus*	7	1	8	-	-
Striped bass	*Morone saxatilis*	39	4	38	11	-
Bluefish	*Pomatomus saltatrix*	37	3	67	15	23
Weakfish	*Cynoscion regalis*	20	4	17	25	15
Northern kingfish	*Menticirrhus saxatilis*	-	-	-	-	-
Summer flounder	*Paralichthys dentatus*	4	-	18	-	-
Winter flounder	*Pseudopleuronectes americanus*	29	-	30	7	15
Northern puffer	*Sphoeroides maculatus*	5	1	5	-	-
Mysids	*Neomysis americana*	-	-	-	-	-
Blue crab	*Callinectes sapidus*	-	-	-	-	-
Sand shrimp	Crangon septemspinosa	-	-	-	2	9
Total		259	26	299	191	183

[a] Includes heat shock and cold shock tests conducted between December 1971 and August 1977 at the Ichthyological Associates, Inc. Delaware Experimental Laboratory.

Table 3.1-4 Nearfield and farfield temperature in the Oyster Creek Generating Station discharge canal and Barnegat Bay under various operating regimes for the Oyster Creek and Forked River Generating Stations.

Season	Predicted Plume[b]	Month	Bay Temp.(C)[a]	Nearfield Temp. (C)				Farfield Temp. (C), by isotherm								
				A[b]	B	C	D	4.4	3.9	3.3	2.8	2.2	1.7	1.1	0.8	0.6
Non-summer	LMST07	Jan	2.8	10.6	10.2	10.1	10.1	-	6.7	6.1	5.6	5.0	4.5	3.9	3.6	3.4
		Feb	3.9	11.7	11.3	11.2	11.2	-	7.8	7.2	6.7	6.1	5.6	5.0	4.7	4.5
		Mar	6.1	13.9	13.5	13.4	13.4	-	10.0	9.4	8.9	8.3	7.8	7.2	6.9	6.7
		Apr	11.1	18.9	18.5	18.4	18.4	-	15.0	14.4	13.9	13.3	12.8	12.2	11.9	11.7
		May	17.8	25.6	25.2	25.1	25.1	-	21.7	21.1	20.6	20.0	19.5	18.9	18.6	18.4
		Oct	15.5	23.3	22.9	22.8	22.8	-	19.4	18.8	18.3	17.7	17.2	16.6	16.3	16.1
		Nov	10.0	17.8	17.4	17.3	17.3	-	13.9	13.3	12.8	12.2	11.7	11.1	10.8	10.6
		Dec	5.0	12.8	12.4	12.3	12.3	-	8.9	8.3	7.8	7.2	6.7	6.1	5.8	5.6
Summer	LMST06	One dilution pump														
		Jun	23.8	31.1	30.7	30.6	30.6	-	27.2	26.6	26.1	25.5	25.0	24.4	24.1	23.9
		Jul	26.7	34.5	34.1	34.0	34.0	-	30.6	30.0	29.5	28.9	28.4	27.8	27.5	27.3
		Aug	26.7	34.5	34.1	34.0	34.0	-	30.6	30.0	29.5	28.9	28.4	27.8	27.5	27.3
		Sep	22.2	30.2	29.8	29.7	29.7	-	26.1	25.5	25.0	24.4	23.9	23.3	23.0	22.8
	LMST08	Two dilution pumps														
		Jun	23.3	29.8	29.5	29.5	29.4	27.7	27.2	26.6	26.1	25.5	25.0	24.4	24.1	23.9
		Jul	26.7	33.2	32.9	32.9	32.8	31.1	30.6	30.0	29.5	28.9	28.4	27.8	27.5	27.3
		Aug	26.7	33.2	32.9	32.9	32.8	31.1	30.6	30.0	29.5	28.9	28.4	27.8	27.5	27.3
		Sep	22.2	28.7	28.4	28.4	28.3	26.6	26.1	25.5	25.0	24.4	23.9	23.3	23.0	22.8

Season	Predicted Plume[b]	Month	Farfield, Area ($10^6 m^3$) per isotherm								
			4.4	3.9	3.3	2.8	2.2	1.7	1.1	0.8	0.6
Summer	LMST06	One dilution pump									
		Jun	-	0.76	1.37	1.98	3.66	5.64	10.82	16.15	25.45
		Jul	-	0.76	1.37	1.98	3.66	5.64	10.82	16.15	25.45
		Aug	-	0.76	1.37	1.98	3.66	5.64	10.82	16.15	25.45
		Sep	-	0.76	1.37	1.98	3.66	5.64	10.82	16.15	25.45
	LMST08	Two dilution pumps									
		Jun	0.46	1.22	2.29	3.81	4.27	5.79	10.21	14.94	24.08
		Jul	0.46	1.22	2.29	3.81	4.27	5.79	10.21	14.94	24.08
		Aug	0.46	1.22	2.29	3.81	4.27	5.79	10.21	14.94	24.08
		Sep	0.46	1.22	2.29	3.81	4.24	5.79	10.21	14.94	24.08

[a] Average Bay temperature from Burns and Roe, Inc. (1974).

[b] See Lawler, Matusky, and Skelly Engineers (1977).

TABLE 3.1-5. Mean age-height' relationships observed in death assemblages of clams at sites 2, 5, 6, and 9.

	Site 2, N* = 101			Site 5, N* = 74			Site 6, N* = 64			Site 9, N* = 38		
Age	N**	Mean height' (mm)	Std. dev.	N**	Mean height' (mm)	Std. dev.	N**	Mean height' (mm)	Std. dev.	N**	Mean height' (mm)	Std. dev.
1	101	12.39	3.76	74	11.36	4.16	64	7.04	2.71	38	12.72	5.15
2	89	23.00	4.49	68	23.51	4.96	64	17.70	4.24	35	25.61	6.19
3	65	32.91	4.49	63	35.01	4.89	63	29.54	5.22	25	37.30	6.42
4	50	42.36	5.26	44	43.78	4.15	54	39.55	5.23	19	46.97	5.25
5	28	49.37	6.27	19	49.89	3.01	28	47.75	5.81	12	55.58	7.05
6	16	57.61	7.76	9	56.18	3.94	10	55.11	4.05	6	62.13	8.88
7	6	59.52	5.41	6	63.60	1.70	7	63.30	4.56	3	65.80	3.04
8	0	-----	----	4	70.60	1.75	3	69.13	5.95	0	-----	----

N* = number of clams

N** = number of size measurements per age

TABLE 3.1-6. Size (height')-frequency distributions for clams transplanted to the substrate at sites 2 and 5 in June, 1975

Size class (mm)	Frequency of clams transplanted to site 2	Frequency of clams transplanted to site 5
20-25	1	0
25-30	9	10
30-35	103	103
35-40	69	68
40-45	116	117
45-50	115	114
50-55	124	124
55-60	103	103
60-65	66	67
65-70	24	24
70-75	10	10
75-80	3	3
	N* = 743	N* = 743

N* = Total number of clams

TABLE 3.1-7. Size statistics for live and dead clams recovered from the substrate at sites 2 and 5 in June, 1976. Clams transplanted in June, 1975.

Site	No. of clams	Mean height' (mm)	Std. dev.
2 (live clams)	515	50.31	7.99
2 (dead clams)	36	47.72	12.74
5 (live clams)	398	49.77	8.66
5 (dead clams)	48*	53.50	9.23

*three broken valves not included in analysis

TABLE 3.1-8 Death-frequency distributions per season for natural populations of *Mercenaria mercenaria* at sites 2, 5, 6, and 9. Percentage of mortality per season in parentheses.

Site	No. of clams	Season of death: Spring	Summer	Fall	Winter
2	101	12 (11.88%)	33 (32.67%)	25 (24.75%)	31 (30.69%)
5	75	13 (17.33%)	24 (32.00%)	13 (17.33%)	25 (33.33%)
6	64	13 (20.31%)	19 (29.69%)	12 (18.75%)	20 (31.25%)
9	38	9 (23.68%)	16 (42.11%)	7 (18.42%)	6 (15.79%)
all sites	278	47 (16.91%)	92 (33.09%)	57 (20.50%)	82 (29.50%)

TABLE 3.1-9. Temperature ranges and optima for life processes of shipworm species found in Barnegat Bay.

Species and Location	Growth and Survival		Reproduction		Larval Development		Source
	Range	Optimum	Range	Optimum	Range	Optimum	
Bankia gouldi Western Atlantic	5-33°		17.5-30°C 16.0-20.0°C	25°C	10-?°C	25 days at 25°C; 20 days at 30°C	Culliney (1970) Turner (1973, 1974) Scheltema and Truitt (1954)
Teredo furcifera Atlantic (Tropics)	24-33°C					40 days at non-uniform temps.	Karrande (1968) Turner and Johnson (1971)
Indian Ocean		Max. growth at 30.9°C					Nagabushanam (1961)
Teredo navalis Atlantic (Canada)		22.5°C					Anon (1927)
Baltic	5-30°C, -1.4°C periodically	15-25°C					Roch (1932)
Black Sea					18-27°C		Kudinova-Pasternak (1962)
Western Atlantic	2-35°C		13-30°C	14-20°C	10-30°C+	33 days at 22-25°C 24 days at 26-30°C	Culliney (1970) Loosanoff and Davis (1963) M'Gonigle (1926) Turner (1973,1974)
Teredo bartschi	18.6-?°C						Richards et al. (1978)

TABLE 3.1-10. Salinity ranges and optima for life process in shipworm species found in Barnegat Bay.

Species and Location	Growth and Survival Range	Growth and Survival Optimum	Reproduction Range	Reproduction Optimum	Larval Development Range	Larval Development Optimum	Source
Bankia gouldi							
Western Atlantic	9-30 ppt						Scheltema and Truitt (1954)
Western Atlantic	10-35 ppt 14-35 ppt				10-32 ppt	19 ppt	Culliney (1969); Turner (1973) Allen (1924)
Teredo furcifera							
India					6 ppt-?	17 ppt	Nagabushanam (1963)
Teredo navalis							
Eastern Pacific		20-30 ppt					Greenfield (1952)
Eastern Pacific	4 ppt lethal		9 ppt or above				Miller (1926)
Western Atlantic	5-32 ppt				10-30 ppt	15 ppt	Culliney (1969); Turner (1973)
Western Atlantic		21-30 ppt no boring below 10 ppt					Anon (1927)
Teredo bartschi	no information available						

TABLE 3.1-11. Chronological documented occurrence of marine borers in Barnegat Bay through 1974.

Year	Location	Reference
1885	R.R. Bridge south of Toms River	Atwood & Johnson (1924)
1896-97	Manahawkin Bay	
1921-23	Sloop Creek	Nelson, T.C. (1922)
1921	Potters Creek	"
1921-22	Barnegat Creek	"
1922	Cedar Creek	"
1922	Barnegat Lagoon	"
1922	Barnegat Pier	
1922	Barnegat City	Atwood & Johnson (1924)
1922	Beach Haven	
1922	R.R. Bridge south of Toms River	
1922	Manahawkin Bay	"
[1922]	Longport & Somers Point (south of BB)	"
1922-23	Tide Pond Creek	Nelson, T.C. (1922)
1923	Conklin's Island	
[1946]	Manasquan Bridge (just north of Barnegat Bay)	Eng. News Rec. (1940)
1948-67	Barnegat Lifeboat Station	Wm. F. Clapp Labs (1960)
1971	Stouts Creek and Oyster Creek	Wurtz, Chas. B. (1971)
1971-73	Stouts Creek-Waretown	Shafto (1974)
1971-74	Holly Park-Waretown	Turner, R.D. (1973; 1974 a & b)
1973	Waretown	Woodward-Clyde (1976)
1974	12 miles north, to 9 miles south of Oyster Creek	Woodward-Clyde (1976)

Table 3.1-12 Components for the multiple linear regression equation to estimate preference temperatures (C) for Atlantic menhaden, Brevoortia tyrannus. The * indicates significant at $P \leq 0.05$ and N.S. indicates not significant at $P \leq 0.05$.

Constant (a) = 13.227
Standard Error of Estimate = 1.315

F (2,60) = 91.930*
R = 0.868*

N = 63
R^2 = 0.754

Variable (Xi)	Mean (Xi)	Correlation (r) with Y	Regression Coefficient (bi)	Standard Error of bi	Standardized Regression Coefficient
Acclimation Temperature (C)	20.1	0.855*	0.448*	0.033	0.857
Light Level (lux)	241.6	0.141 N.S.	0.003*	0.001	0.033

Table 3.1-13 Linear regression equation and ANOVA to estimate preference temperatures (C) for Atlantic menhaden, Brevoortia tyrannus. The * indicates significant at $P \leq 0.05$.

Preference Temperature (Y) = 13.966 + 0.447 X
where X = acclimation temperature (C)

N = 63
R^2 = 0.730
r = 0.855*

Standard Error of Estimate = 1.365
Standard Error of the slope = 0.035

ANOVA

Source	Df	SS	MS	F
Total	62	421.479		
Regression	1	307.868	307.868	165.343*
Residual	61	113.611	1.862	

95% Confidence Interval $Y \pm 2.73\sqrt{1.02 + \frac{(x - 20.1)^2}{155.00}}$

Table 3.1-14 One-way analysis of variance applied to vertical temperature preference data conducted with Atlantic menhaden, Brevoortia tyrannus. N.S. indicates no significant difference at $P \leq 0.05$.

ANOVA

Source of Variation	Df	SS	MS
Between acclimation temperatures	7	7.86	1.12
Within acclimation temperatures	3	3.45	1.15
Total	10	11.31	

F = 1.12/1.15 = 0.98 N.S.

N = 11

Mean final temperature preferendum = 24.3 C

Table 3.1-15 Components for the multiple linear regression equation to estimate avoidance temperatures (C) for Atlantic menhaden, Brevoortia tyrannus. The * indicates significant at $P \leq 0.05$.

Constant (a) = 27.074
Standard Error of Estimate = 0.956

F (2, 77) = 104.336*
R = 0.854*

N = 80
R^2 = 0.730

Variable (Xi)	Mean ($\bar{X}i$)	Correlation (r) with Y	Regression Coefficient (bi)	Standard Error of bi	Standardized Regression Coefficient
Acclimation Temperature (C)	19.3	0.841*	0.282*	0.021	0.813
Total Length (mm)	137.9	-0.294*	-0.006*	0.002	-0.145

Table 3.1-16 Linear regression equation and ANOVA to estimate avoidance temperatures (C) for Atlantic menhaden, Brevoortia tyrannus. The * indicates significant at $P \leq 0.05$.

Avoidance Temperature (Y) = 26.109 + 0.291 X
where X = acclimation temperature (C)

$N = 80$
$R^2 = 0.707$
$r = 0.841^*$

Standard Error of Estimate = 0.990
Standard Error of the slope = 0.021

ANOVA

Source	Df	SS	MS	F
Total	79	261.199		
Regression	1	184.791	184.791	188.562*
Residual	78	76.408	0.980	

95% Confidence Interval $Y \pm 1.97\sqrt{1.01 + \frac{(x - 19.3)^2}{217.64}}$

Table 3.1-17 Linear regression equation and ANOVA to estimate preference temperatures (C) for bay anchovy, Anchoa mitchilli. The * indicates significant at $P \leq 0.05$.

Preference Temperature (Y) = 19.568 + 0.229 X
where X = acclimation temperature (C)

$N = 37$
$R^2 = 0.173$
$r = 0.416^*$

Standard Error of Estimate = 1.983
Standard Error of the slope = 0.085

ANOVA

Source	Df	SS	MS	F
Total	36	166.410		
Regression	1	28.738	28.738	7.307*
Residual	35	137.672	3.933	

95% Confidence Interval $Y \pm 4.01\sqrt{1.03 + \frac{(x - 16.4)^2}{54.72}}$

Table 3.1-18 Linear regression equation and ANOVA to estimate avoidance temperatures (C) for bay anchovy, <u>Anchoa</u> <u>mitchilli</u>. The * indicates significant at $P \leq 0.05$.

Avoidance Temperature (Y) = 22.362 + 0.413 X
where X = acclimation temperature (C)

N = 25
$R^2 = 0.537$
$r = 0.733^*$

Standard Error of Estimate = 1.046
Standard Error of the slope = 0.080

ANOVA

Source	Df	SS	MS	F
Total	24	54.386		
Regression	1	29.228	29.228	26.717*
Residual	23	25.159	1.094	

95% Confidence Interval $Y \pm 2.16 \sqrt{1.04 + \frac{(x - 18.0)^2}{170.88}}$

Table 3.1-19 Linear regression equation and ANOVA to estimate preference temperatures (C) for striped bass, <u>Morone</u> <u>saxatilis</u>. The * indicates significant at $P \leq 0.05$.

Preference Temperature (Y) = 13.951 + 0.565 X
where X = acclimation temperature (C)

N = 29
$R^2 = 0.556$
$r = 0.746^*$

Standard Error of Estimate = 2.735
Standard Error of the slope = 0.097

ANOVA

Source	Df	SS	MS	F
Total	28	454.928		
Regression	1	252.920	252.920	33.804*
Residual	27	202.009	7.482	

Confidence Interval $Y \pm 5.61 \sqrt{1.03 + \frac{(x - 16.8)^2}{79.16}}$

Table 3.1-20 One-way analysis of variance applied to vertical temperature preference data conducted with striped bass, *Morone saxatilis*. N.S. indicates no significant difference at $P \leq 0.05$.

ANOVA

Source of Variation	Df	SS	MS
Between acclimation temperatures	2	14.11	7.05
Within acclimation temperatures	1	5.12	5.12
Total	3	19.23	

F = 7.05/5.12 = 1.38 N.S.

N = 4

Mean final temperature preferendum = 24.1 C

Table 3.1-21 Linear regression equation and ANOVA to estimate avoidance temperatures (C) for striped bass, *Morone saxatilis*. The * indicates significant at $P \leq 0.05$.

Avoidance Temperature (Y) = 27.969 + 0.210 X
where X = acclimation temperature (C)

N = 38
R^2 = 0.768
r = 0.876*

Standard Error of Estimate = 0.698
Standard Error of the slope = 0.019

ANOVA

Source	Df	SS	MS	F
Total	37	75.526		
Regression	1	58.004	58.004	119.104*
Residual	36	17.521	0.487	

$$95\%\ \text{Confidence Interval}\ Y \pm 1.41\sqrt{1.03 + \frac{(x - 17.9)^2}{131.35}}$$

Table 3.1-22 Linear regression equation and ANOVA to estimate preference temperatures (C) for bluefish, Pomatomus saltatrix. The * indicates significant at $P \leq 0.05$.

Preference Temperature (Y) = 16.815 + 0.344 X
where X = acclimation temperature (C)

N = 35
$R^2 = 0.620$
$r = 0.788^*$

Standard Error of Estimate = 1.110
Standard Error of the slope = 0.047

ANOVA

Source	Df	SS	MS	F
Total	34	107.086		
Regression	1	66.414	66.414	53.907*
Residual	33	40.671	1.232	

95% Confidence Interval $Y \pm 2.25 \sqrt{1.03 + \frac{(x - 20.5)^2}{56.10}}$

Table 3.1-23 Components for the multiple linear regression equation to estimate avoidance temperatures (C) for bluefish, Pomatomus saltatrix. The * indicates significant at $P \leq 0.05$.

Constant (a) = 22.917
Standard Error of Estimate = 1.051

F (2, 60) = 49.601
$R = 0.789^*$

N = 63
$R^2 = 0.623$

Variable (Xi)	Mean ($\bar{X}i$)	Correlation (r) with Y	Regression Coefficient (bi)	Standard Error of bi	Standardized Regression Coefficient
Acclimation Temperature (C)	21.1	0.625*	0.345*	0.043	0.639
Total Length (mm)	122.0	0.466*	0.019*	0.003	0.482

Table 3 1-24 Linear regression equation and ANOVA to estimate preference temperatures (C) for weakfish, <u>Cynoscion regalis</u>. The * indicates significant at $P \leq 0.05$.

Preference Temperature (C) = 13.653 + 0.520 X
where = acclimation temperature (C)

N = 19
R^2 = 0.721
r = 0.849*

Standard Error of Estimate = 1.881
Standard Error of the slope = 0.079

ANOVA

Source	Df	SS	MS	F
Total	18	215.327		
Regression	1	155.186	155.186	43 863*
Residual	17	60.142	3.538	

95% Confidence Interval $Y \pm 3.97\sqrt{1.05 + \frac{(x - 17.7)^2}{57.40}}$

Table 3.1-25 Linear regression equation and ANOVA to estimate avoidance temperatures (C) for weakfish, <u>Cynoscion regalis</u>. The * indicates significant at $P \leq 0.05$.

Avoidance Temperature (Y) = 23.659 + 0.245 X
where X = acclimation temperature (C)

N = 17
R^2 = 0.236
r = 0.486*

Standard Error of Estimate = 1.949
Standard Error of the slope = 0.114

ANOVA

Source	Df	SS	MS	F
Total	16	74.611		
Regression	1	17.643	17.643	4.645*
Residual	15	56.968	3.798	

95% Confidence Interval $Y \pm 4.15$ 1.0

Table 3.1-26 Components for the multiple regression analysis to estimate avoidance temperatures (C) for summer flounder, Paralichthys dentatus. N.S. indicates not significant at $P \leq 0.05$.

Constant (a) = 29.962
Standard Error of Estimate = 1.072

F (3, 13) = 0.287 N.S.
R = 0.249 N.S.

N = 17
$R^2 = 0.062$

Variable (Xi)	Mean (Xi)	Correlation (r) Coefficient	Regression Coefficient (bi)	Standard Error of bi
Acclimation Temperature	18.0	0.211	0.036 N.S.	0.060
Total Length (mm)	284.8	0.003	0.000 N.S.	0.003
Light Level (lux)	203.6	-0.185	-0.003 N.S.	0.006

Table 3.1-27 Regression analysis and ANOVA to estimate avoidance temperatures (C) for summer flounder, Paralichthys dentatus. N.S. indicates not significant at $P \leq 0.05$.

Mean Avoidance Temperature (Y) = 30.0 C

N = 17

$R^2 = 0.044$

r = 0.211 N.S.

ANOVA

Source	Df	SS	MS	F
Total	16	15.945		
Regression	1	0.710	0.710	0.699 N.S.
Residual	15	15.235	1.016	

Table 3.1-28 Lengths of winter flounder taken in Barnegat Bay, New Jersey in 1975-76 as calculated from otolith measurements.

Age	Number Examined	Calculated Lengths Min	Max	Mean	Standard Deviation	Standard Error	95% Confidence Interval
Males							
1	200	87	201	151	19.8	1.4	149 - 154
2	90	162	279	216	24.0	2.5	211 - 221
3	24	195	315	250	28.9	5.9	238 - 262
4	5	225	275	251	20.9	9.4	225 - 277
Females							
1	175	117	228	175	20.9	1.6	172 - 178
2	109	182	315	242	27.3	2.6	237 - 247
3	30	216	343	270	25.8	4.7	261 - 280
4	4	261	328	288	28.6	14.3	242 - 333

Table 3.1-29 Components for the multiple regression equation to estimate avoidance temperatures (C) for winter flounder, Pseudopleuronectes americanus. The * indicates significant at $P \leq 0.05$. N.S. indicates not significant at $P \leq 0.05$.

Constant (a) = 23.624
Standard Error of Estimate = 1.463

$F (2, 14) = 17.777^{*}$
$R = 0.847^{*}$

N = 17
$R^2 = 0.717$

Variable (Xi)	Mean ($\bar{X}$i)	Correlation (r) with Y	Regression Coefficient	Standard Error of bi	Standardized Regression Coefficient
Acclimation Temperature (C)	20.9	0.794*	0.292*	0.073	0.641
Total Length (mm)	100.9	-0.631*	-0.018	0.009	0.327

Table 3.1-30 Linear regression equation and ANOVA to estimate avoidance temperatures (C) for winter flounder, Pseudopleuronectes americanus. The * indicates significant at $P \leq 0.05$.

Avoidance Temperature (Y) = 20.586 + 0.363 X
where X = acclimation temperature (C)

N = 17
$R^2 = 0.631$
$r = 0.794^{*}$

Standard Error of Estimate = 1.616
Standard Error of the slope = 0.072

ANOVA

Source	Df	SS	MS	F
Total	16	106.122		
Regression	1	66.945	66.945	25.630*
Residual	15	39.177	2.612	

95% Confidence Interval $Y \pm 3.44 \sqrt{1.06 + \frac{(x - 20.9)^2}{50.83}}$

FIGURE 3.1-1. Sampling locations for biological collections taken for the OCNGS ecological study from September 1975 through August 1977.

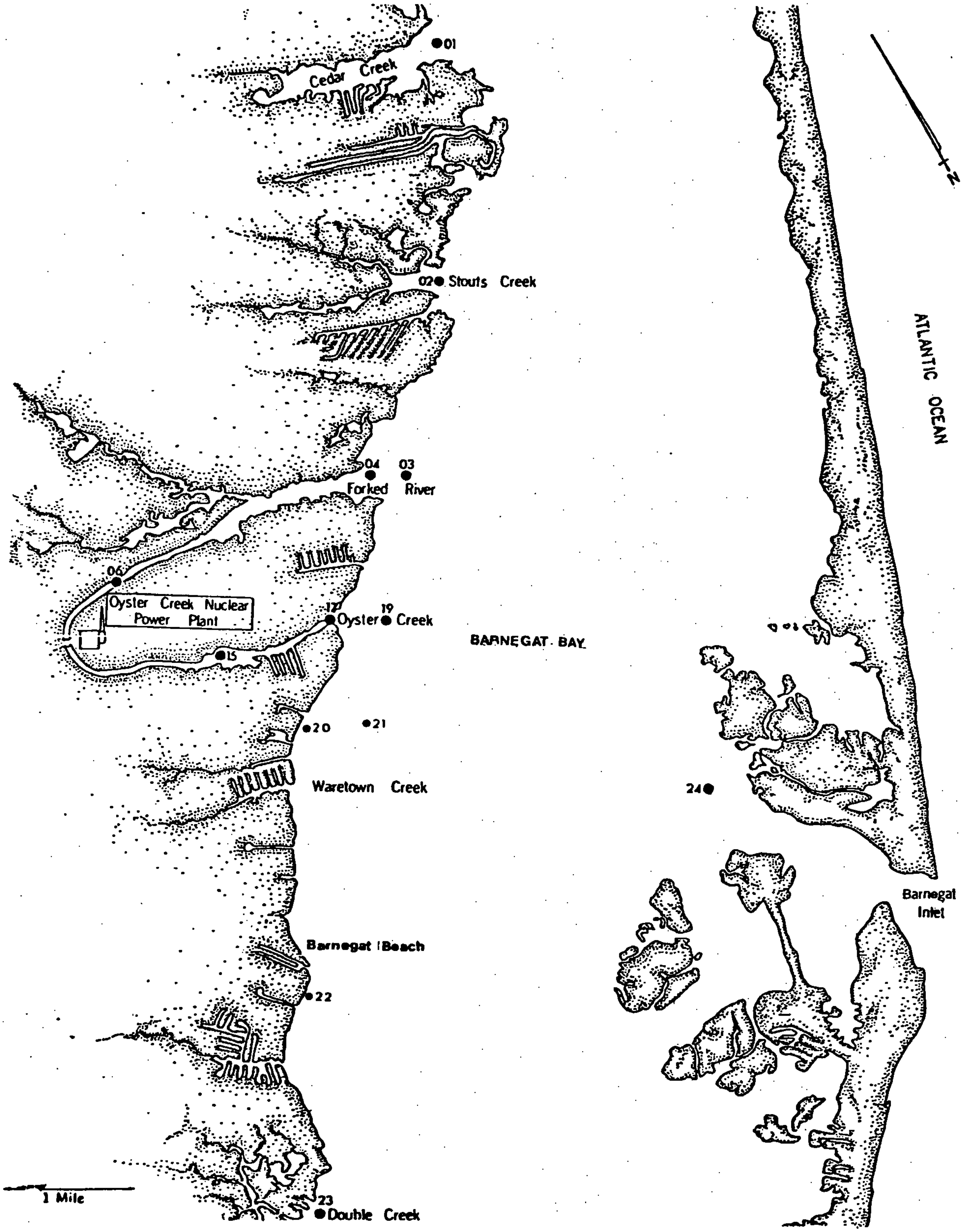

01
Cedar Creek
02 Stouts Creek
04
03
Forked River
06
Oyster Creek Nuclear Power Plant
17
19
Oyster Creek
15
BARNEGAT BAY
20
21
Waretown Creek
Barnegat Beach
22
23
Double Creek
1 Mile
ATLANTIC OCEAN
N
24
Barnegat Inlet

FIGURE 3.1-1

FIGURE 3.1-2. Sampling locations for biological collections for OCNGS thermal effects studies from March 1976 through March 1977.

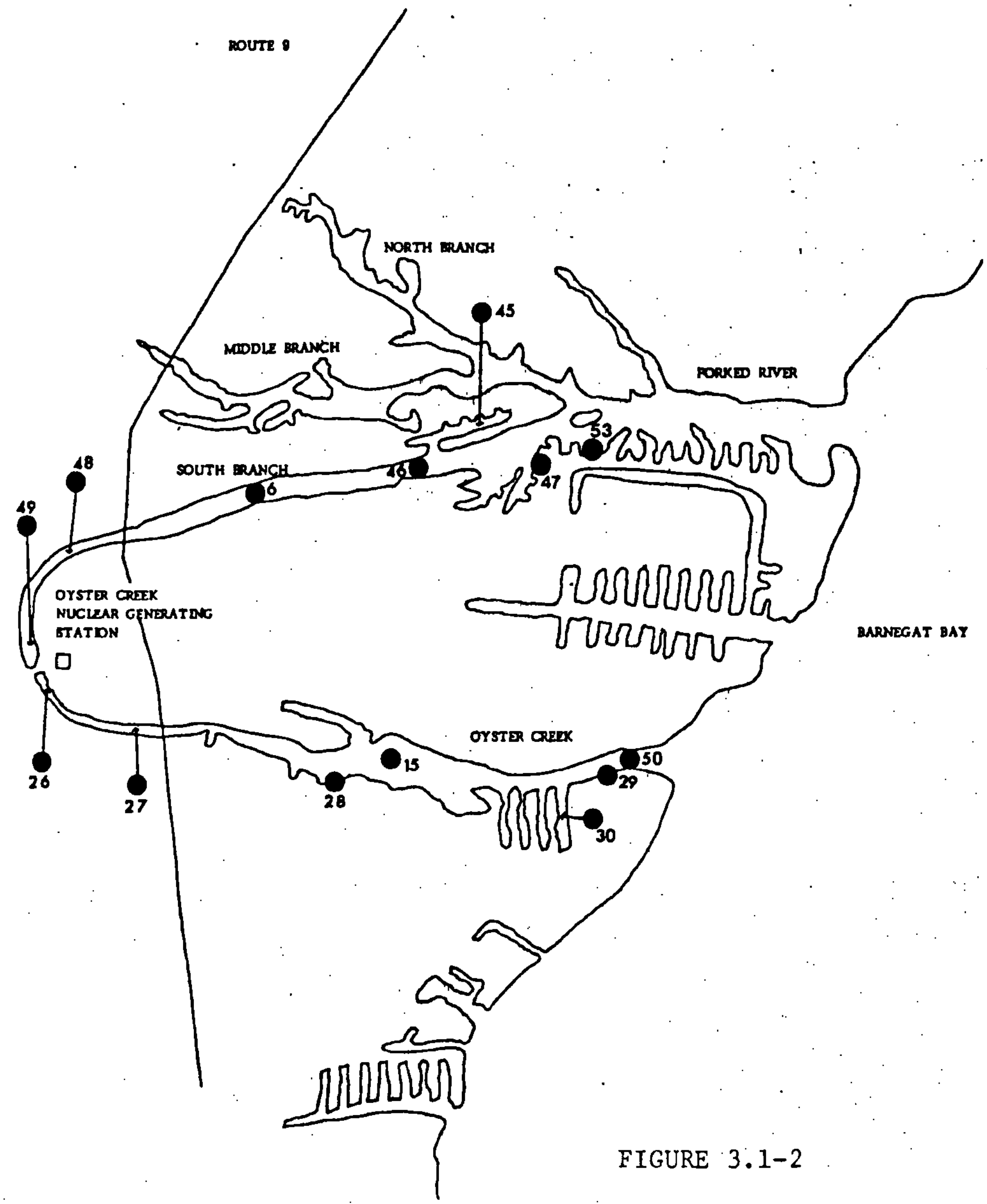

ROUTE 9
NORTH BRANCH
MIDDLE BRANCH
FORKED RIVER
SOUTH BRANCH
OYSTER CREEK NUCLEAR GENERATING STATION
BARNEGAT BAY
OYSTER CREEK
45
53
46
47
6
48
49
26
27
28
15
50
29
30

FIGURE 3.1-2

FIGURE 3.1-3. Sampling stations of Campbell (1969).

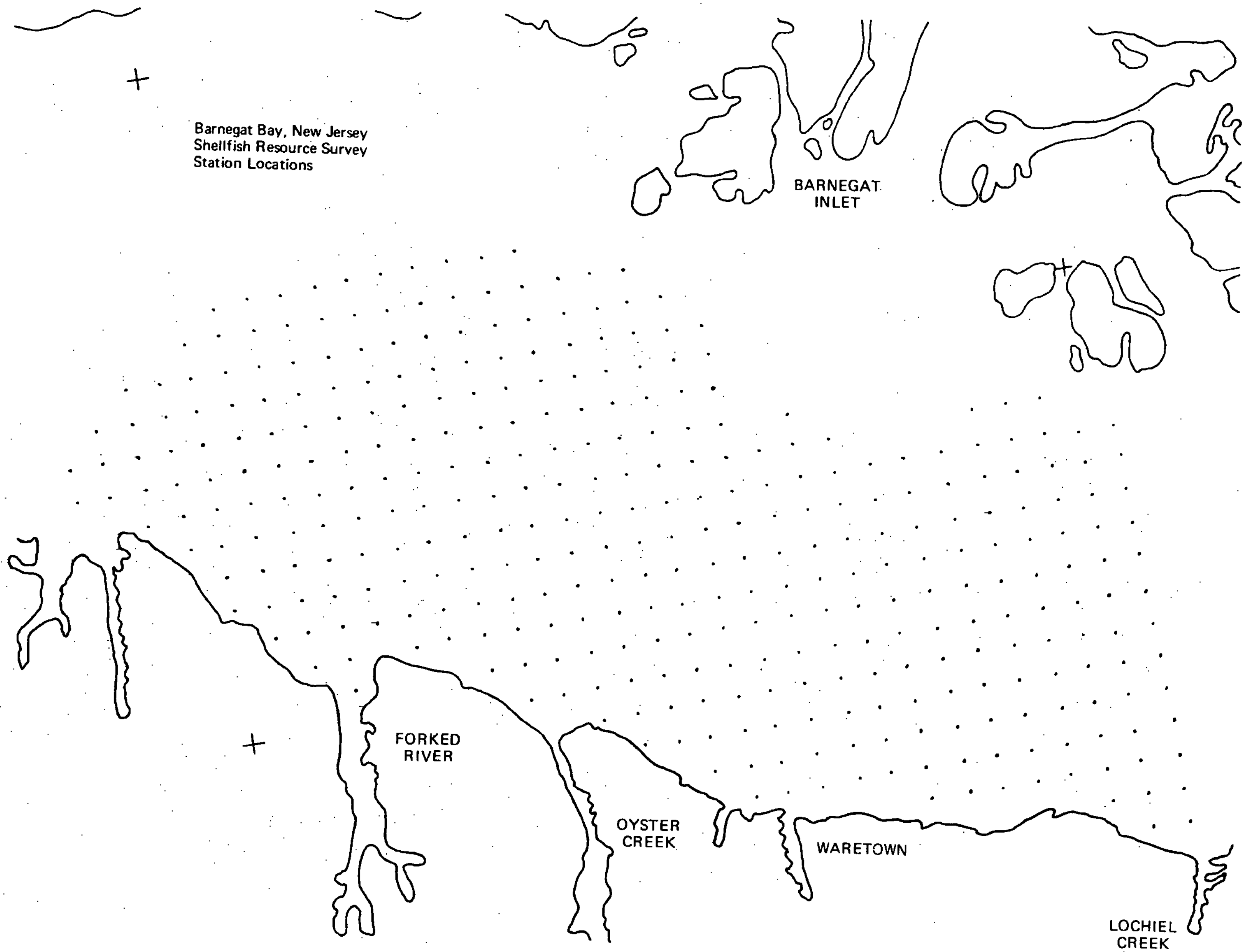

Barnegat Bay, New Jersey
Shellfish Resource Survey
Station Locations
BARNEGAT
INLET
FORKED
RIVER
OYSTER
CREEK
WARETOWN
LOCHIEL
CREEK

FIGURE 3.1-3

FIGURE 3.1-4. Distribution of undersize clams in Barnegat Bay for 1965, 1966, and 1968. After Campbell (1969).

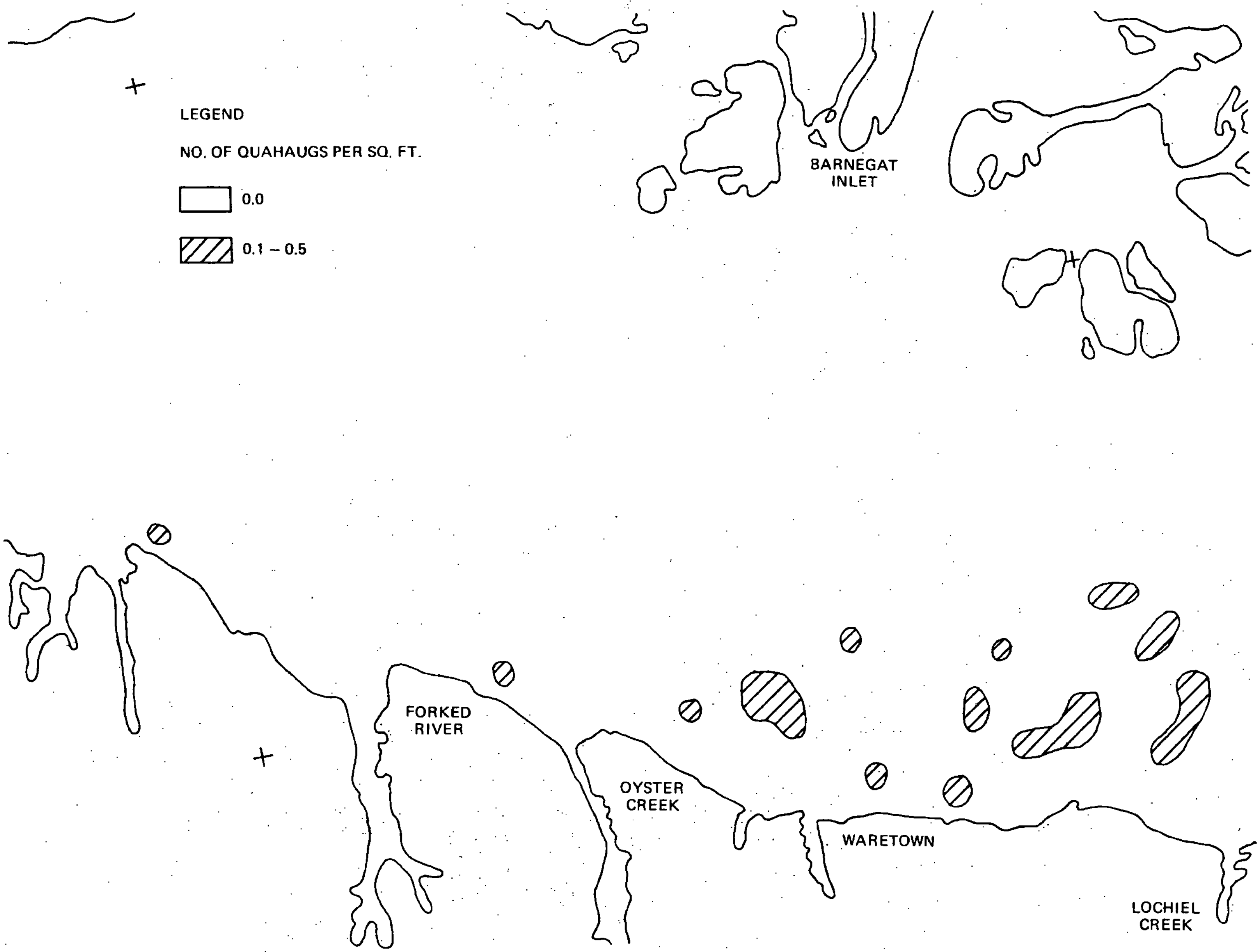

LEGEND
NO. OF QUAHAUGS PER SQ. FT.
0.0
0.1 – 0.5
BARNEGAT INLET
FORKED RIVER
OYSTER CREEK
WARETOWN
LOCHIEL CREEK

FIGURE 3.1-4

FIGURE 3.1-5. Distribution of neck size clams in Barnegat Bay for 1965, 1966, and 1968. After Campbell (1969).

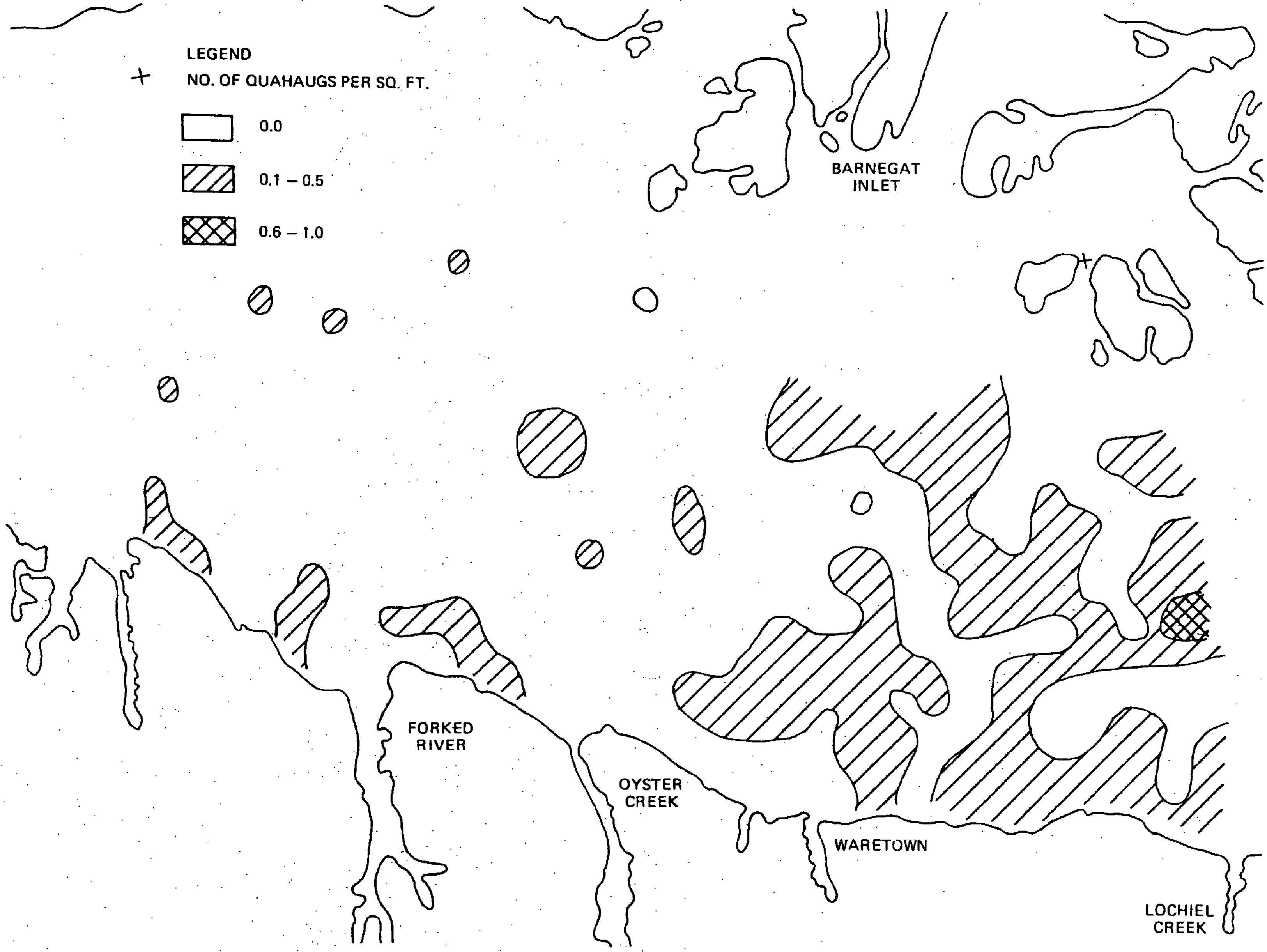

LEGEND
NO. OF QUAHAUGS PER SQ. FT.
0.0
0.1 – 0.5
0.6 – 1.0
BARNEGAT INLET
FORKED RIVER
OYSTER CREEK
WARETOWN
LOCHIEL CREEK

FIGURE 3.1-5

FIGURE 3.1-6. Disbribution of large size clams in Barnegat Bay for 1965, 1966, and 1968. After Campbell (1969).

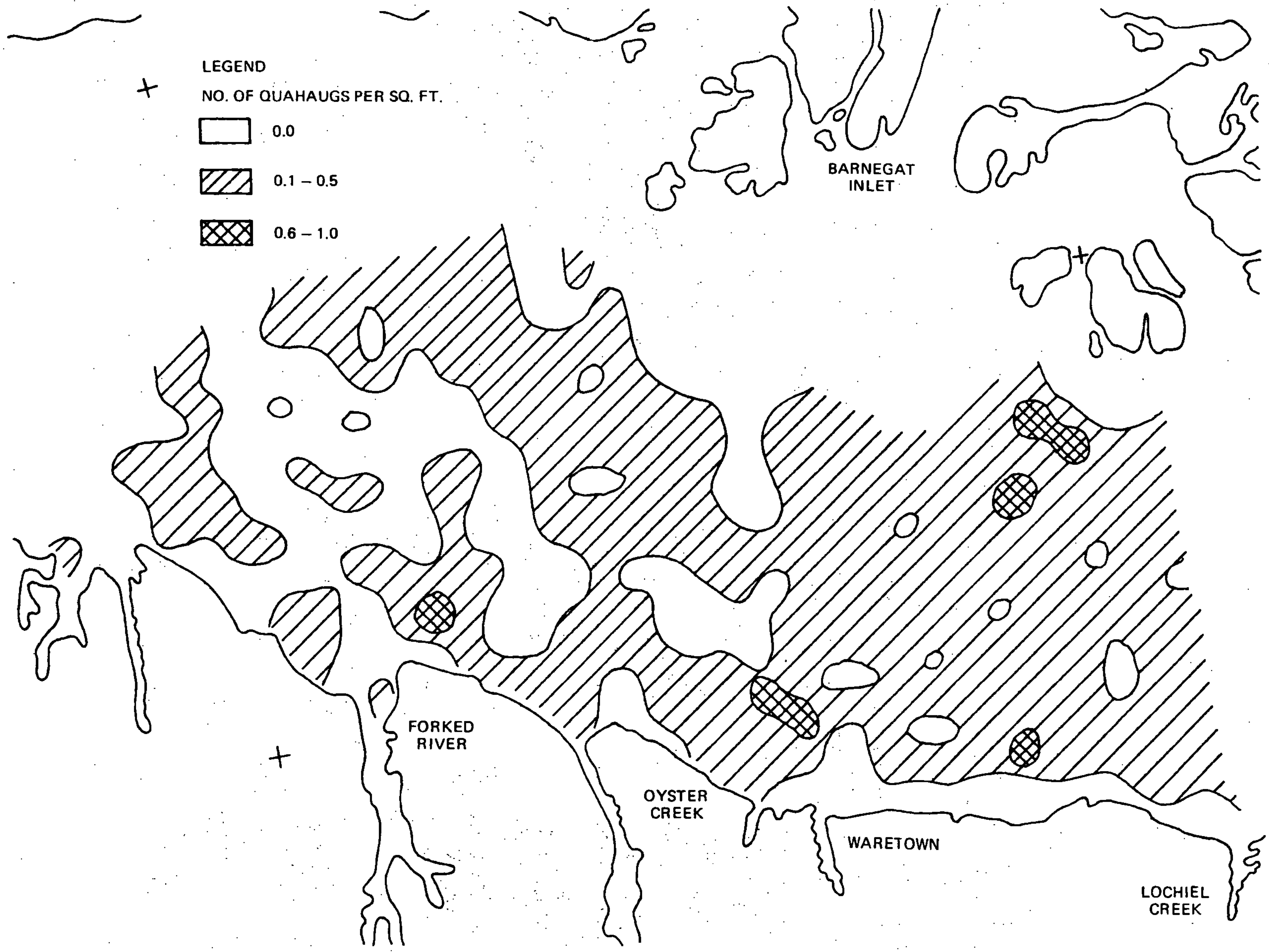
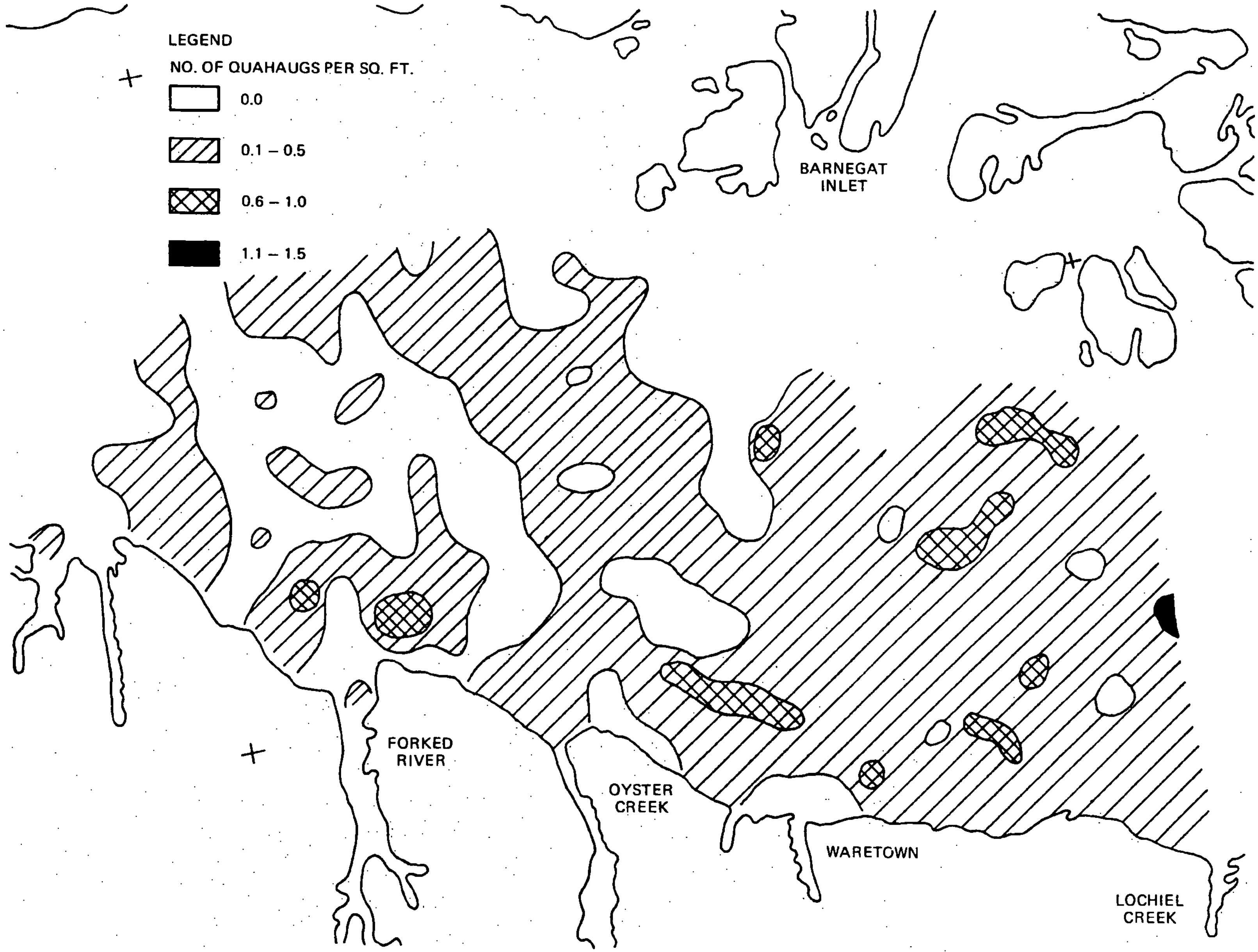

LEGEND
NO. OF QUAHAUGS PER SQ. FT.
0.0
0.1 – 0.5
0.6 – 1.0
BARNEGAT INLET
FORKED RIVER
OYSTER CREEK
WARETOWN
LOCHIEL CREEK

FIGURE 3.1-6

FIGURE 3.1-7. Distribution of all size clams in Barnegat Bay for 1965, 1966, and 1968. After Campbell (1969).


LEGEND
NO. OF QUAHAUGS PER SQ. FT.
0.0
0.1 – 0.5
0.6 – 1.0
1.1 – 1.5
BARNEGAT
INLET
FORKED
RIVER
OYSTER
CREEK
WARETOWN
LOCHIEL
CREEK

IGURE

FIGURE 3.1-8. Sampling localities for _Mercenaria mercenaria_ in Barnegat Bay.

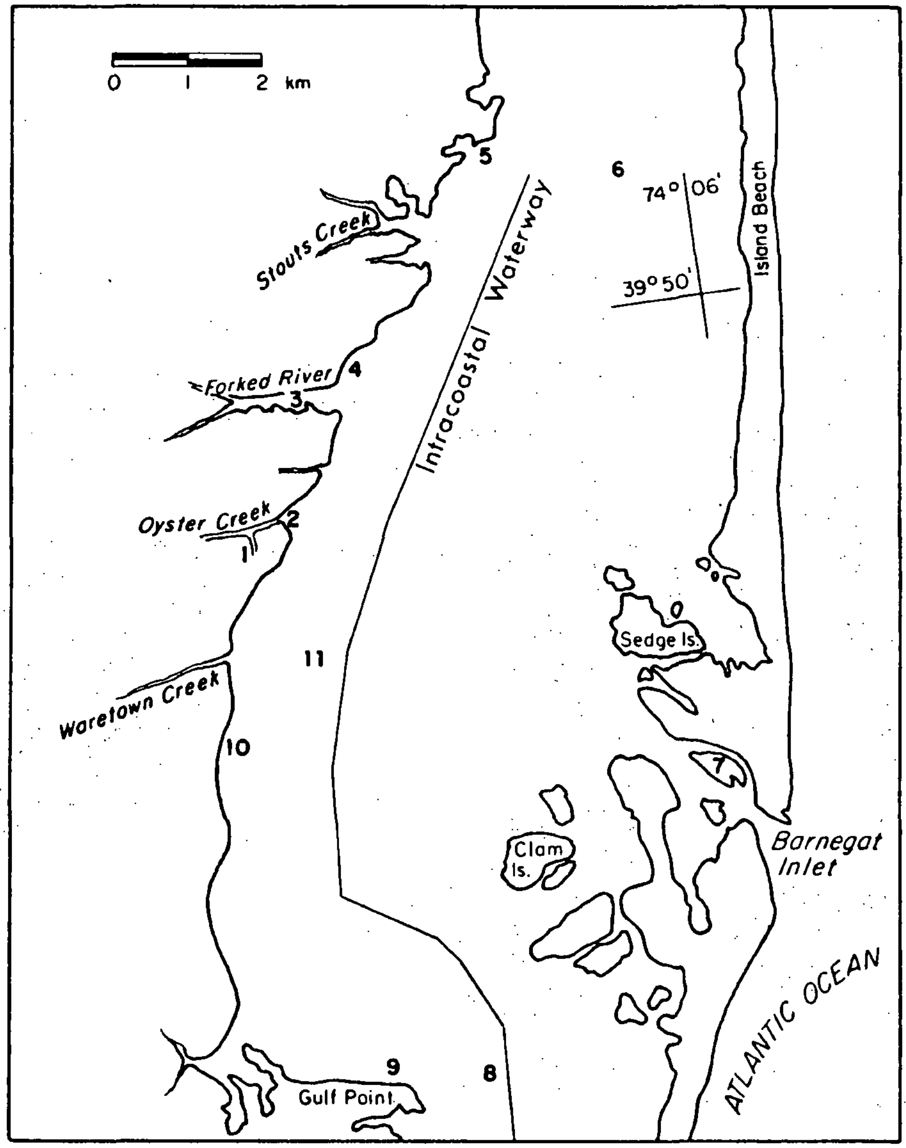

0
1
2 km
5
6
74° 06'
Island Beach
Stouts Creek
Intracoastal Waterway
39° 50'
Forked River
4
3
Oyster Creek
2
1
Sedge Is.
11
Waretown Creek
10
7
Barnegat
Inlet
Clam
Is.
ATLANTIC OCEAN
9
8
Gulf Point

FIGURE 3.1-8

FIGURE 3.1-9 (a-d). Observed and predicted cumulative growth curves for death assemblages of clams at sites 2, 5, 6, and 9.

O = observed growth

L = predicted growth -- logistic model

G = predicted growth -- Gompertz model

M = predicted growth -- monomolecular model

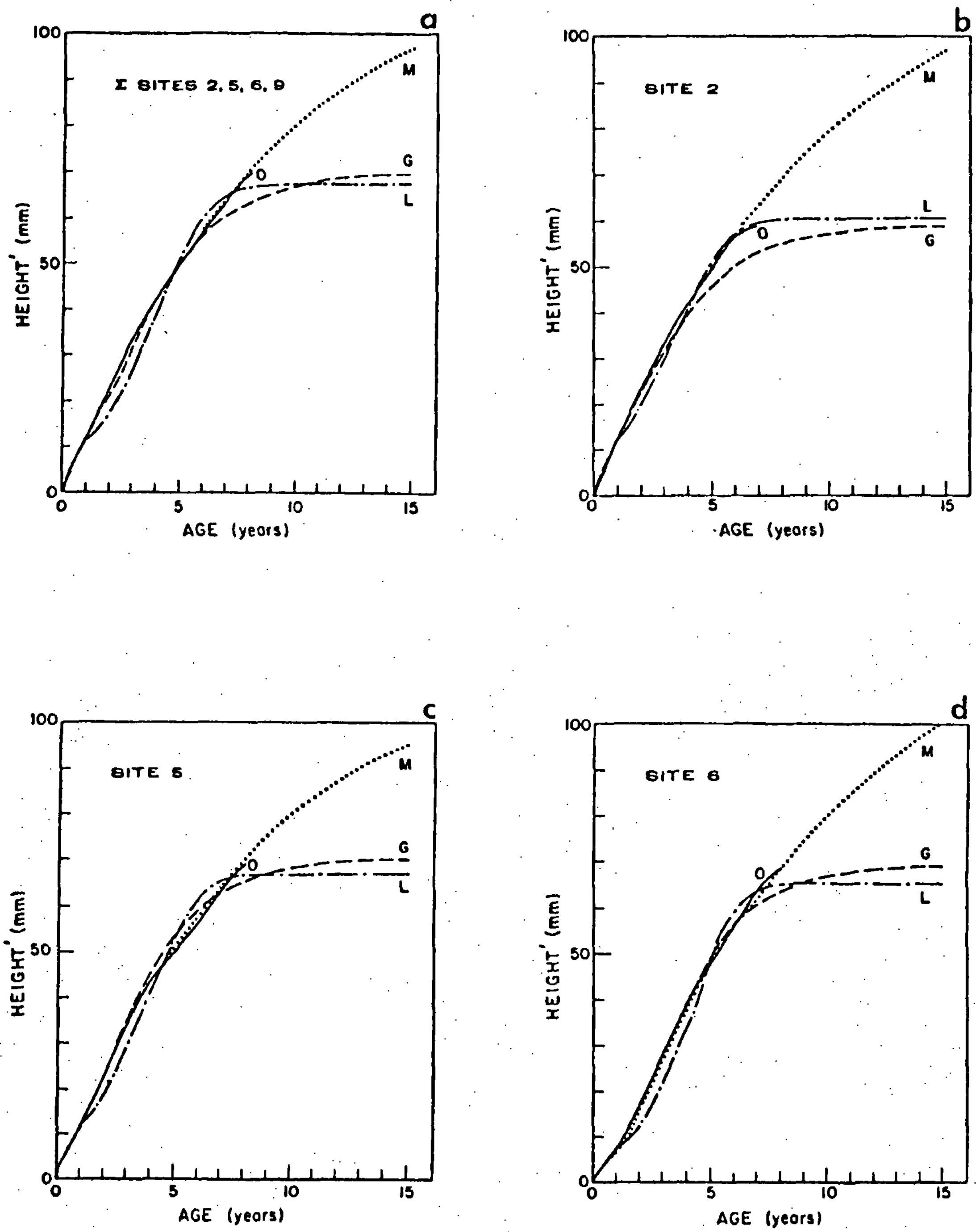


FIGURE 3.1-9(a-d)

FIGURE 3.1-9(e). Observed and predicted cumulative growth curves for death assemblages of clams at site 9.

O = observed growth

L = predicted growth -- logistic model

G = predicted growth -- Gompertz model

M = predicted growth -- monomolecular model

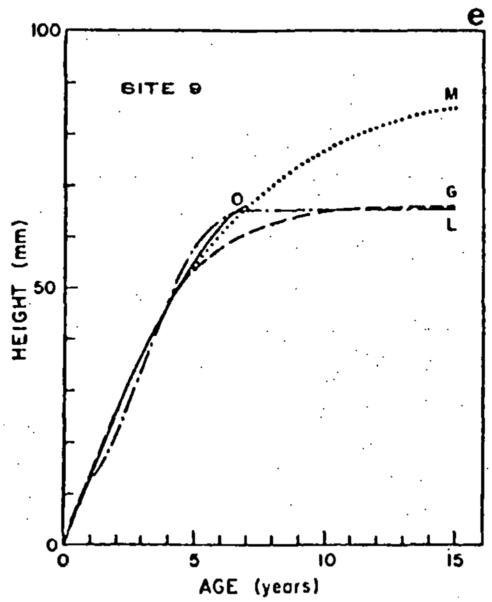


FIGURE 3.1-9(e)

FIGURE 3.1-10. Death-frequency distributions per season for death assemblages of natural populations of *Mercenaria mercenaria* at sites 2, 5, 6, and 9.

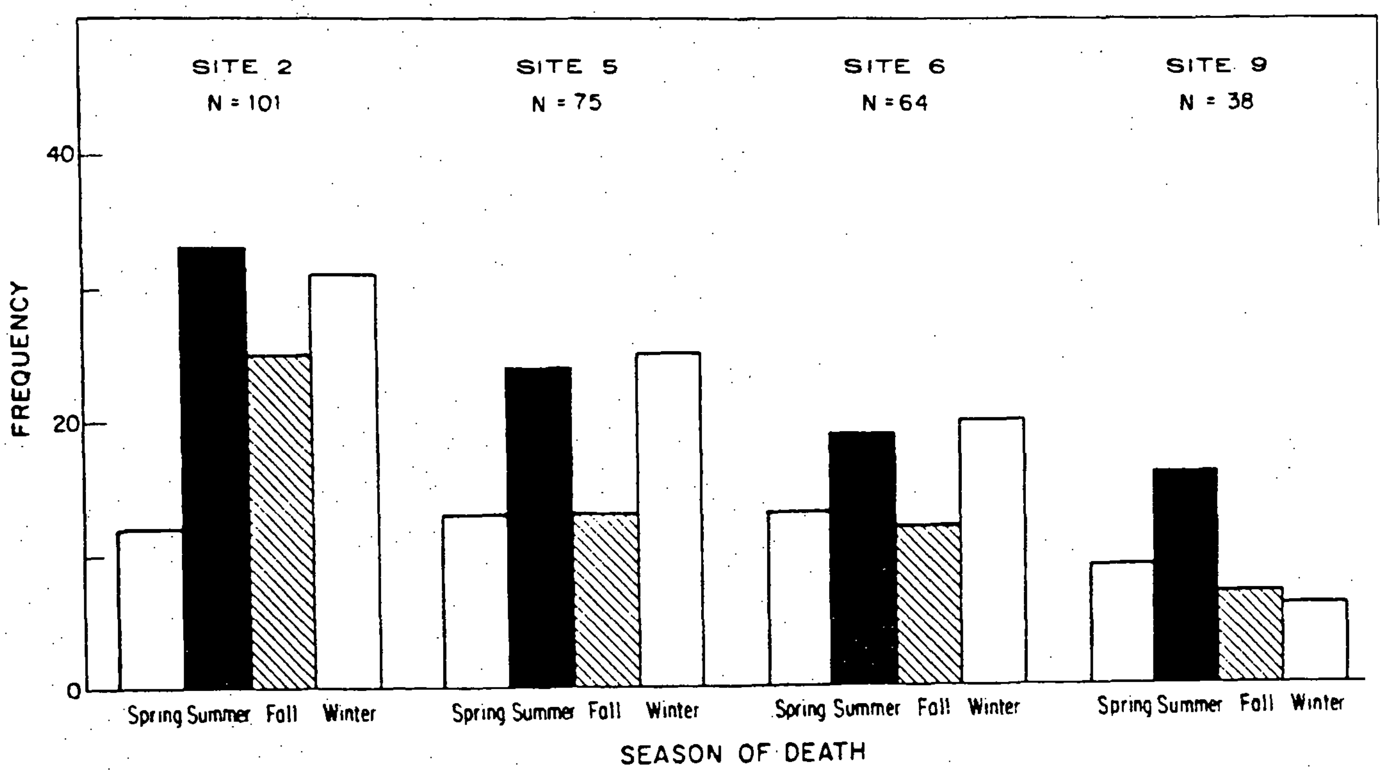

SITE 2
N = 101
SITE 5
N = 75
SITE 6
N = 64
SITE 9
N = 38
40
20
0
FREQUENCY
Spring Summer Fall Winter
Spring Summer Fall Winter
Spring Summer Fall Winter
Spring Summer Fall Winter
SEASON OF DEATH

FIGURE 3.1-10

FIGURE 3.1-11 (a-d). Mortality rate curves for natural populations of *Mercenaria mercenaria* at sites 2, 5, 6, and 9. Data presented as mortality rate per 1,000 for each age interval of 1 year (1,000 q_x), plotted against the start of the interval.

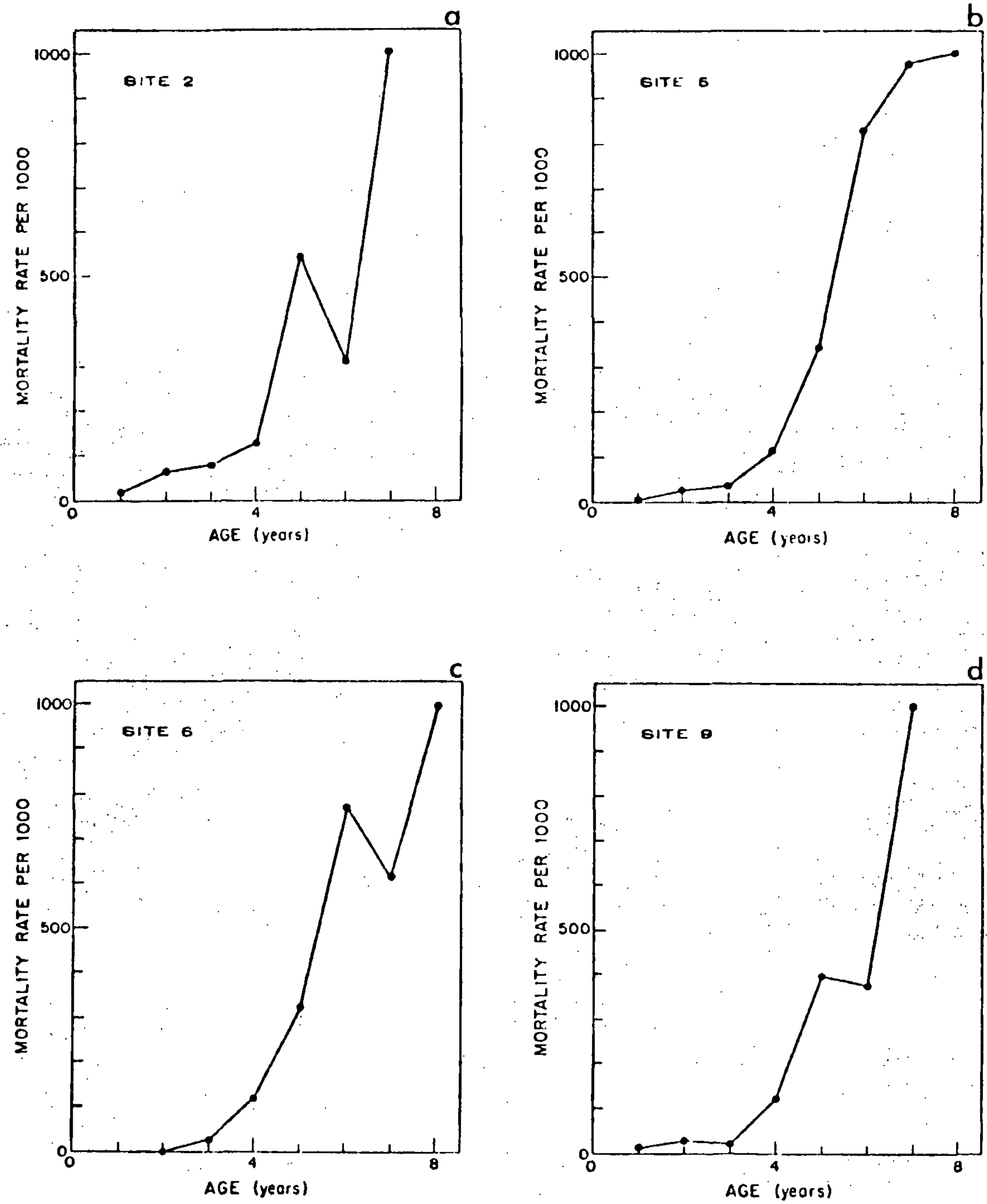


FIGURE 3.1-11(a-d)

FIGURE 3.1-12 (a & b). Survivorship curves for natural populations of *Mercenaria mercenaria* at sites 2 and 5. Data plotted as the number of clams surviving at the beginning of each age interval (l_x) from an initial cohort of 1,000 specimens.

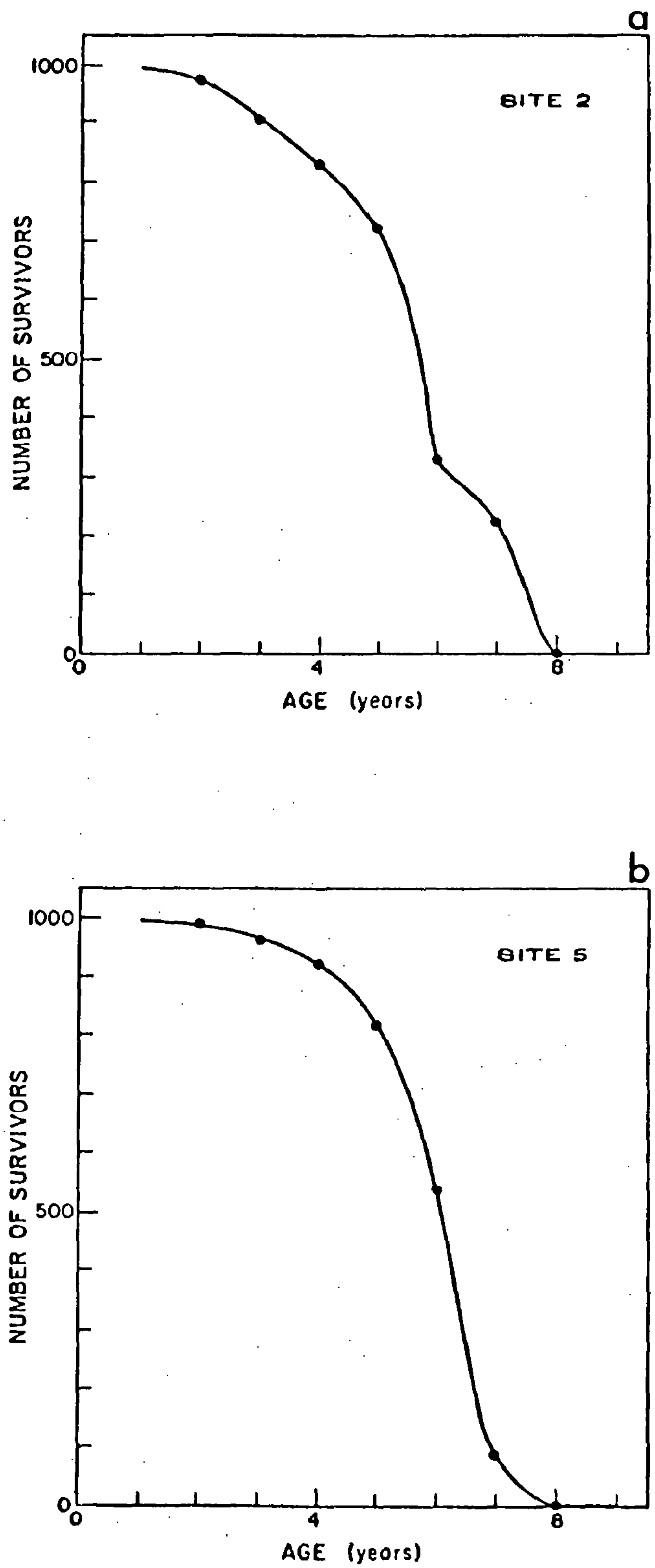
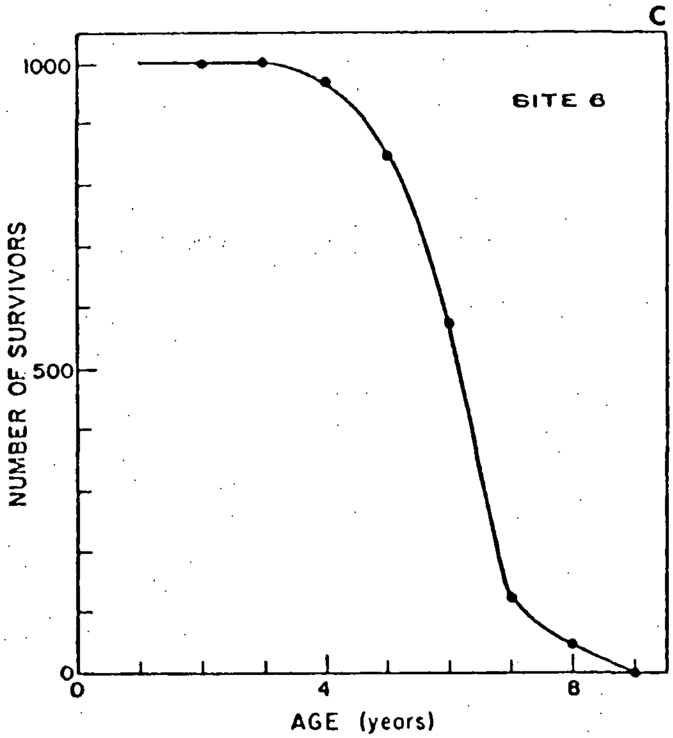


FIGURE 3.1-12(a & b)

FIGURE 3.1-12(c & d). Survivorship curves for natural populations of _Mercenaria mercenaria_ at sites 6 and 9. Data plotted as the number of clams surviving at the beginning of each age interval (l_x) from an initial cohort of 1,000 specimens.



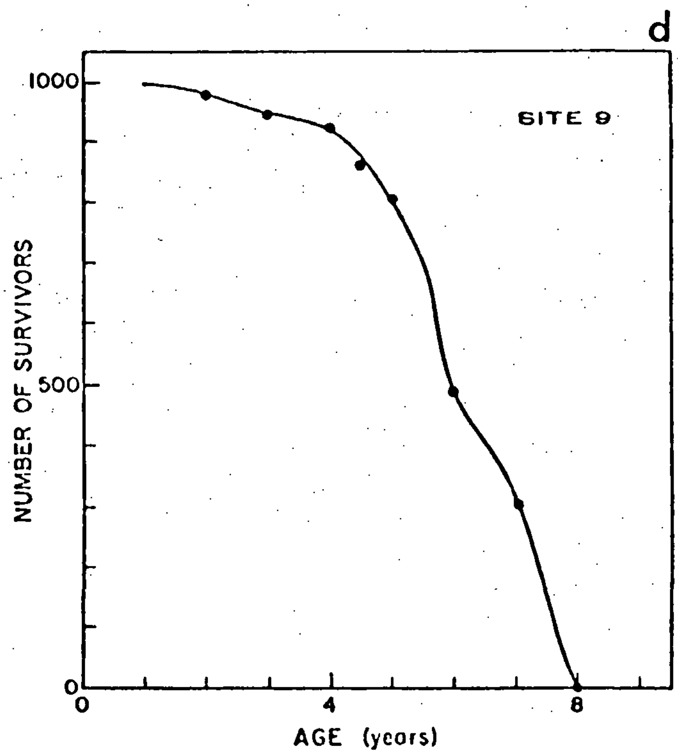
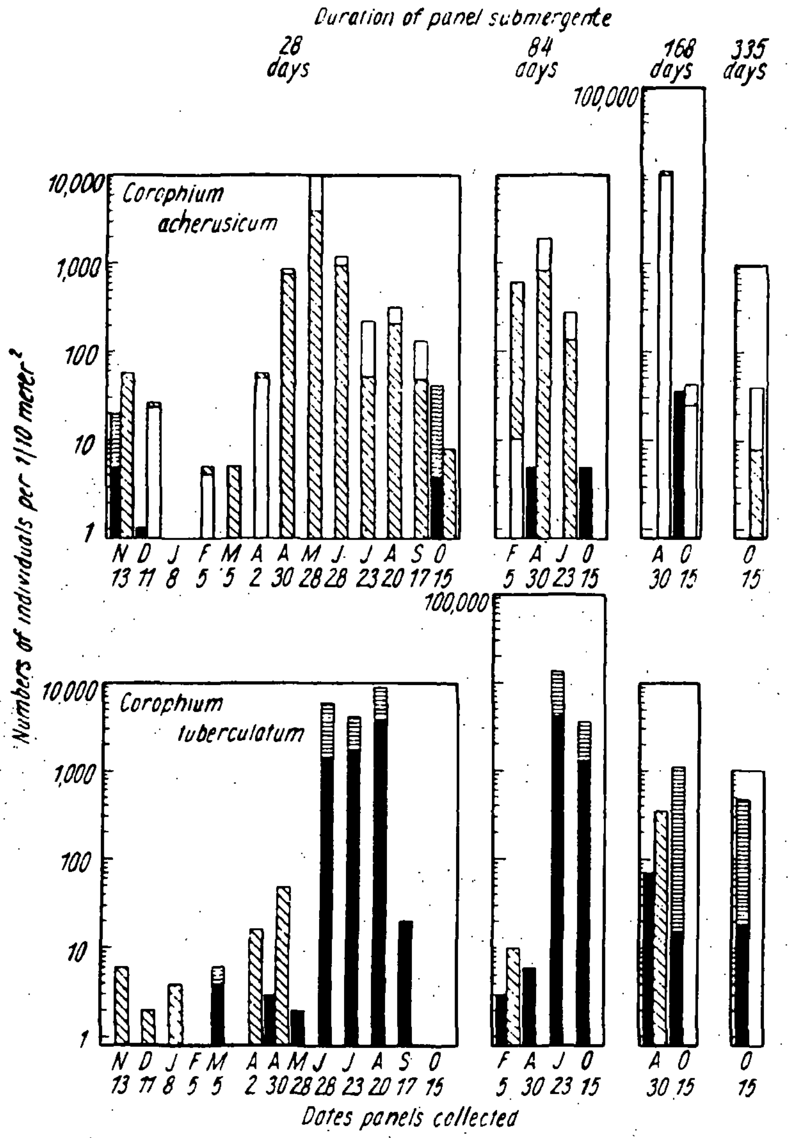


FIGURE 3.1-12(c & d)

FIGURE 3.1-13. Seasonal abundance of *Corophium tuberculatum* and *Corophium acherusicum* which settled on rubber test panels in the intake and discharge canals.



Duration of panel submergence
28 days
84 days
168 days
335 days
Corophium acherusicum
Corophium tuberculatum
Numbers of individuals per 1/10 meter²
Dates panels collected

FIGURE 3.1-13

FIGURE 3.1-14. Sampling stations for boring and fouling animals on wooden test panels. After Shafto (1974).

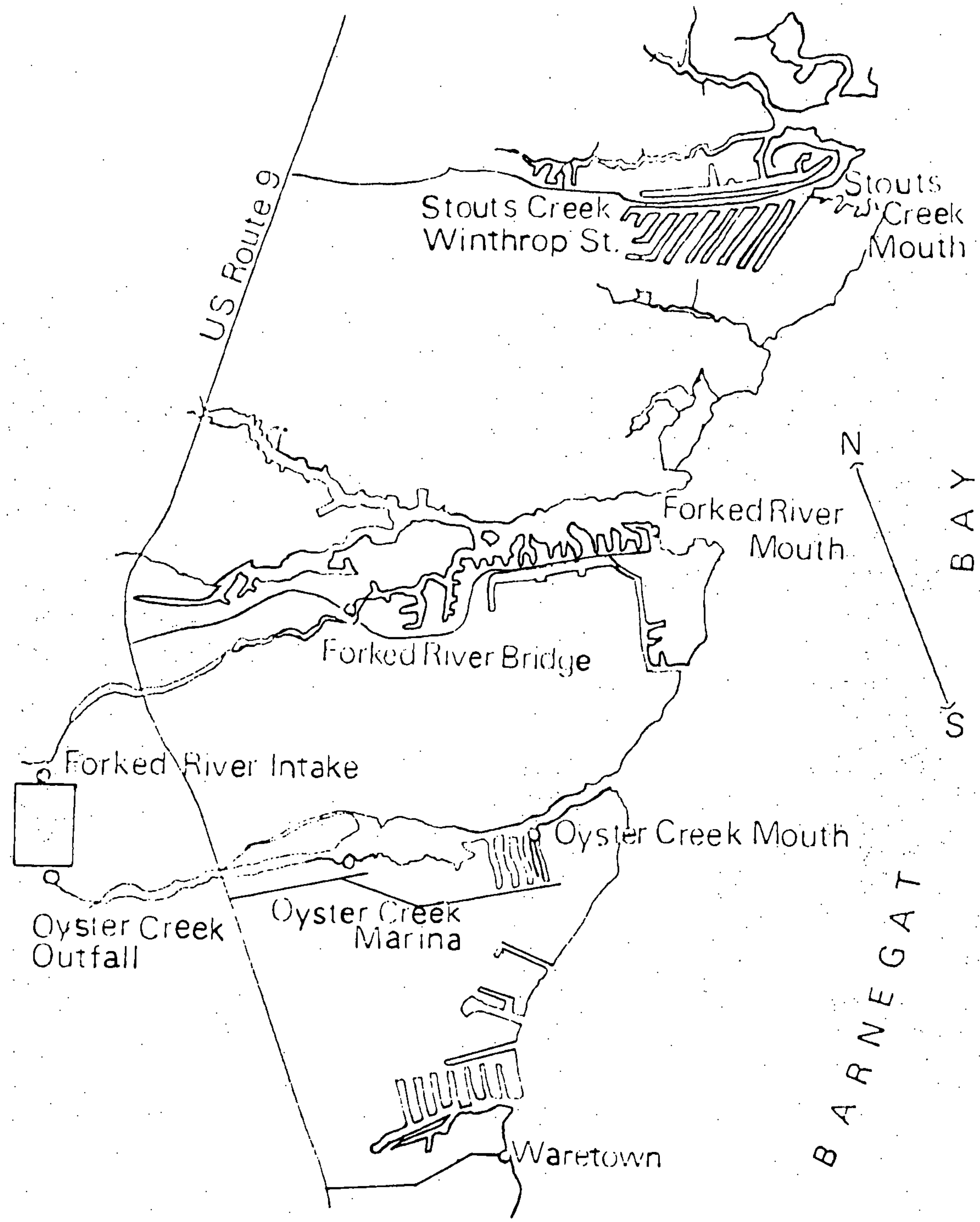

US Route 9
Stouts Creek
Winthrop St.
Stouts
Creek
Mouth
N
S
Forked River
Mouth
Forked River Bridge
Forked River Intake
Oyster Creek Mouth
Oyster Creek
Outfall
Oyster Creek
Marina
Waretown
BARNEGAT BAY

FIGURE 3.1-14

FIGURE 3.1-15. Settling profile of four dominant species of boring and fouling organisms. The total number of individuals of each species which settled at each station from April 1972 through September 1972; the Y-axis gives the number of individuals x 10^3.

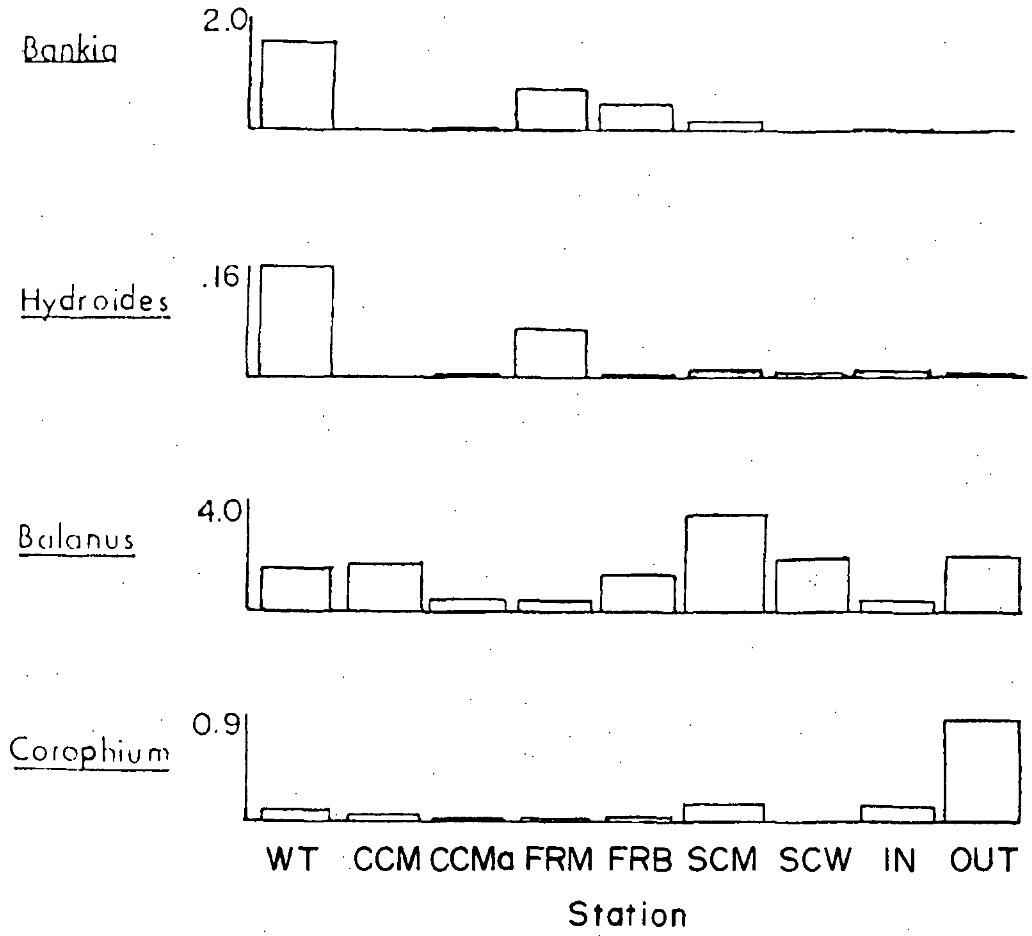

Bankia
2.0
Hydroides
.16
Balanus
4.0
Corophium
0.9
WT
CCM
CCMa
FRM
FRB
SCM
SCW
IN
OUT
Station

FIGURE 3.1-15

FIGURE 3.1-16. Months in which shipworm settlement or gonadal development was reported in Barnegat Bay Area Studies in 1972, 1973, and 1974.

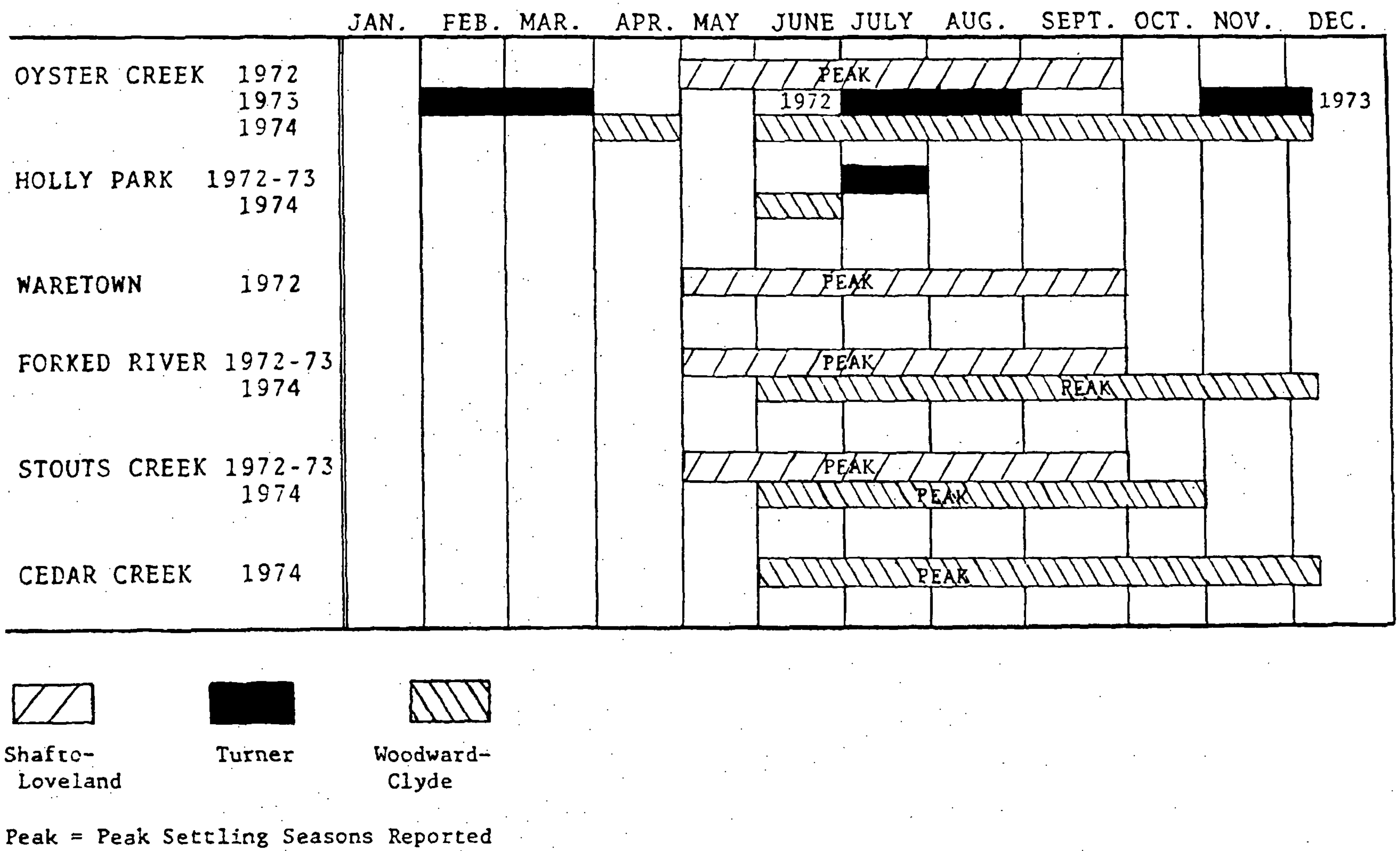

JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.
OYSTER CREEK 1972
1973
1974
PEAK
1972
1973
HOLLY PARK 1972-73
1974
WARETOWN 1972
PEAK
FORKED RIVER 1972-73
1974
PEAK
PEAK
STOUTS CREEK 1972-73
1974
PEAK
PEAK
CEDAR CREEK 1974
PEAK
Shafto-Loveland
Turner
Woodward-Clyde
Peak = Peak Settling Seasons Reported

FIGURE 3.1-16

FIGURE 3.1-17. Outline of Barnegat Bay showing geographical locations of exposure panels and plankton tows for the applicant's wood borer monitoring program conducted by W.F. Clapp Laboratories.

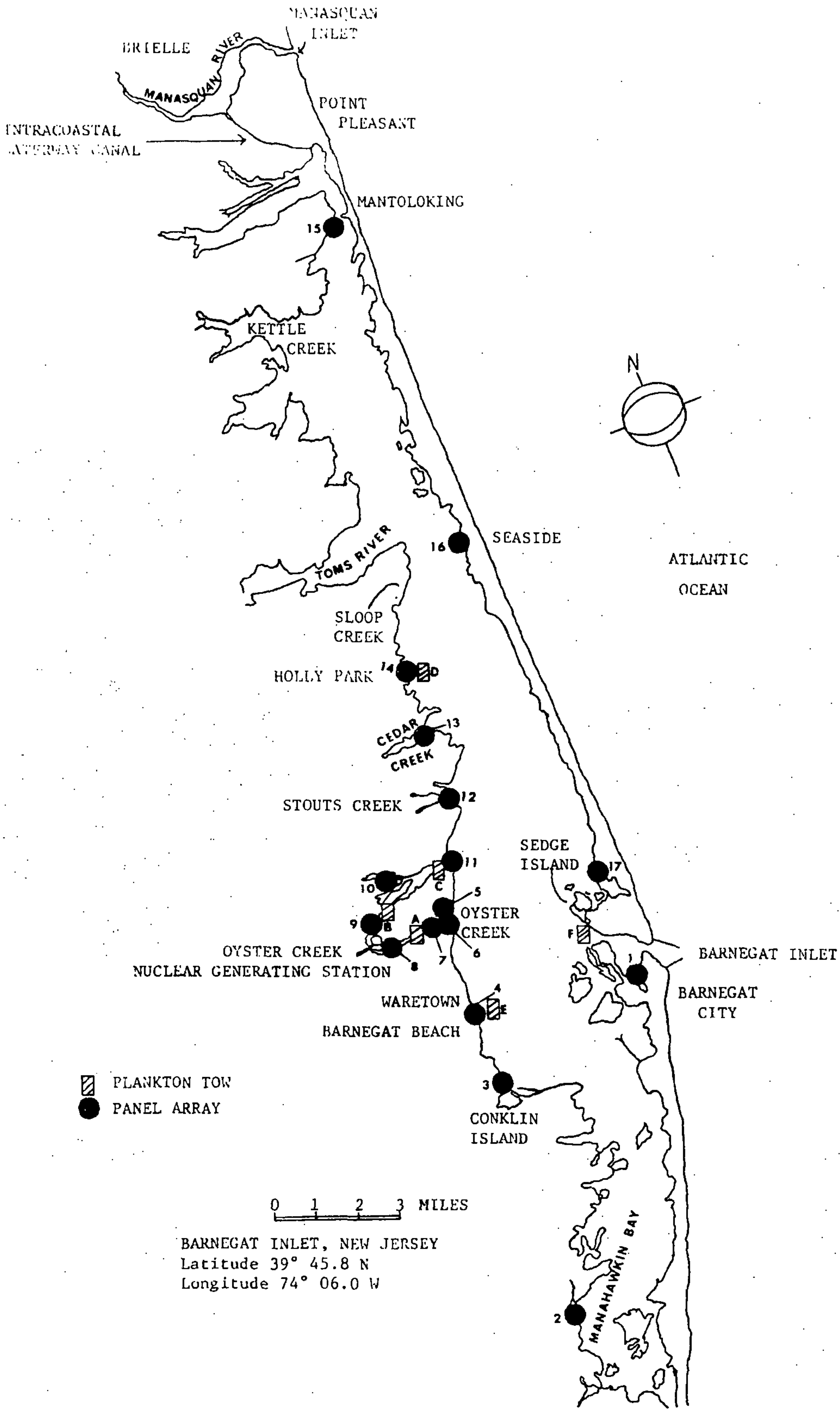

MANASQUAN INLET
BRIELLE
MANASQUAN RIVER
POINT PLEASANT
INTRACOASTAL WATERWAY CANAL
MANTOLOKING
KETTLE CREEK
SEASIDE
ATLANTIC OCEAN
TOMS RIVER
SLOOP CREEK
HOLLY PARK
CEDAR CREEK
STOUTS CREEK
SEDGE ISLAND
OYSTER CREEK
BARNEGAT INLET
OYSTER CREEK NUCLEAR GENERATING STATION
BARNEGAT CITY
WARETOWN
BARNEGAT BEACH
PLANKTON TOW
PANEL ARRAY
CONKLIN ISLAND
0 1 2 3 MILES
BARNEGAT INLET, NEW JERSEY
Latitude 39° 45.8 N
Longitude 74° 06.0 W
MANAHAWKIN BAY

FIGURE 3.1-17

FIGURE 3.1-18. The preferred temperatures of the Atlantic menhaden, *Brevoortia tyrannus*, plotted against their respective acclimation (ambient) temperatures. The regression line is calculated from the regression equation in Table 3.1-13.

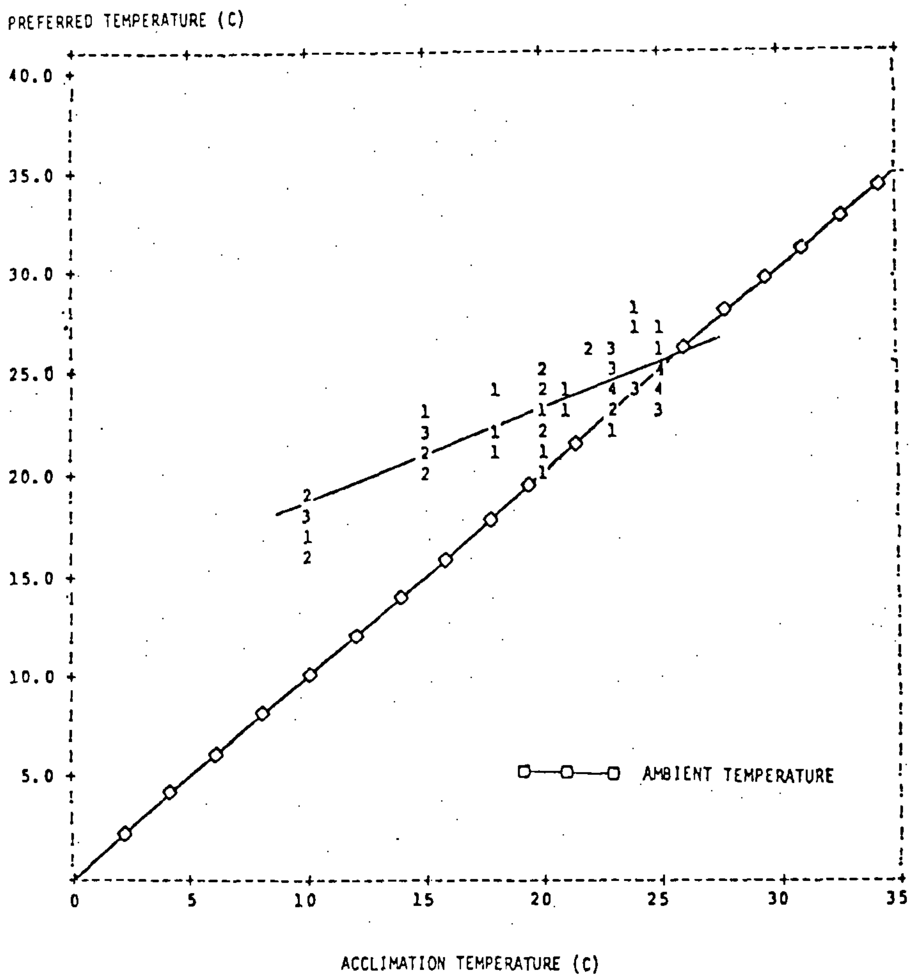
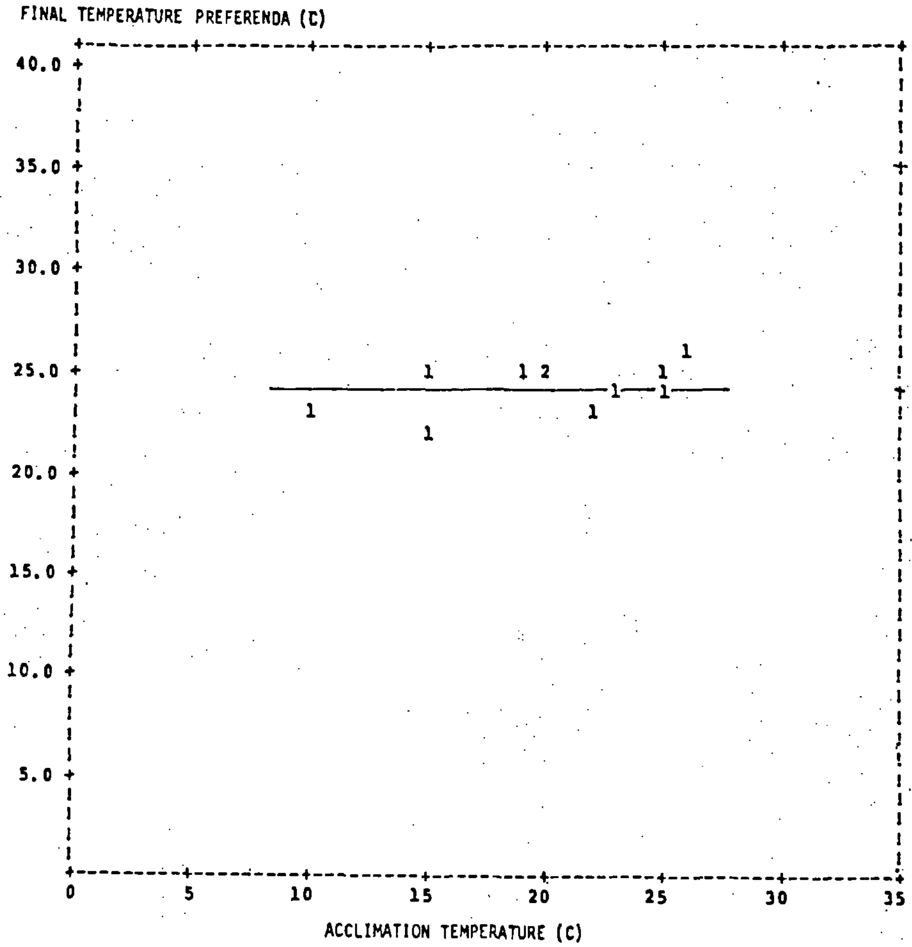

PREFERRED TEMPERATURE (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
5
10
15
20
25
30
35
AMBIENT TEMPERATURE
ACCLIMATION TEMPERATURE (C)

FIGURE 3.1-18

FIGURE 3.1-19. Final temperature preferenda of the Atlantic menhaden, Brevoortia tyrannus, plotted against their respective acclimation (ambient) temperatures. The horizontal line represents the mean final temperature preferendum.



FINAL TEMPERATURE PREFERENDA (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
5
10
15
20
25
30
35
ACCLIMATION TEMPERATURE (C)

FIGURE 3.1-19

FIGURE 3.1-20. The avoidance temperatures of the Atlantic menhaden, Brevoortia tyrannus, plotted against their respective acclimation (ambient) temperatures, and the maximum ΔT of $10.0^{\circ}C$. The regression line is calculated from the regression equation in Table 3.1-16.

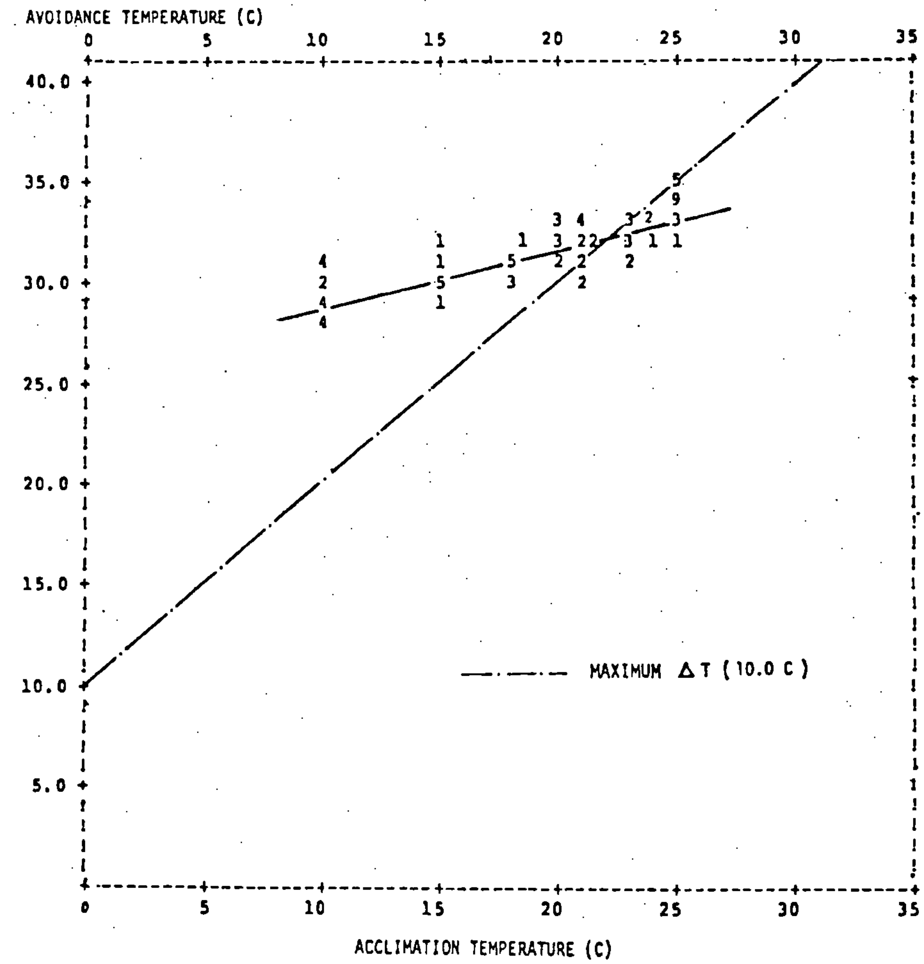

AVOIDANCE TEMPERATURE (C)
MAXIMUM ΔT (10.0 C)
ACCLIMATION TEMPERATURE (C)

FIGURE 3.1-20

FIGURE 3.1-21. Heat shock experimental temperatures which resulted in greater than 30% mortality of Atlantic menhaden, _Brevoortia tyrannus_, during a 48-h exposure plotted against respective acclimation temperatures. The number of data points occurring at respective temperatures is numerically indicated.

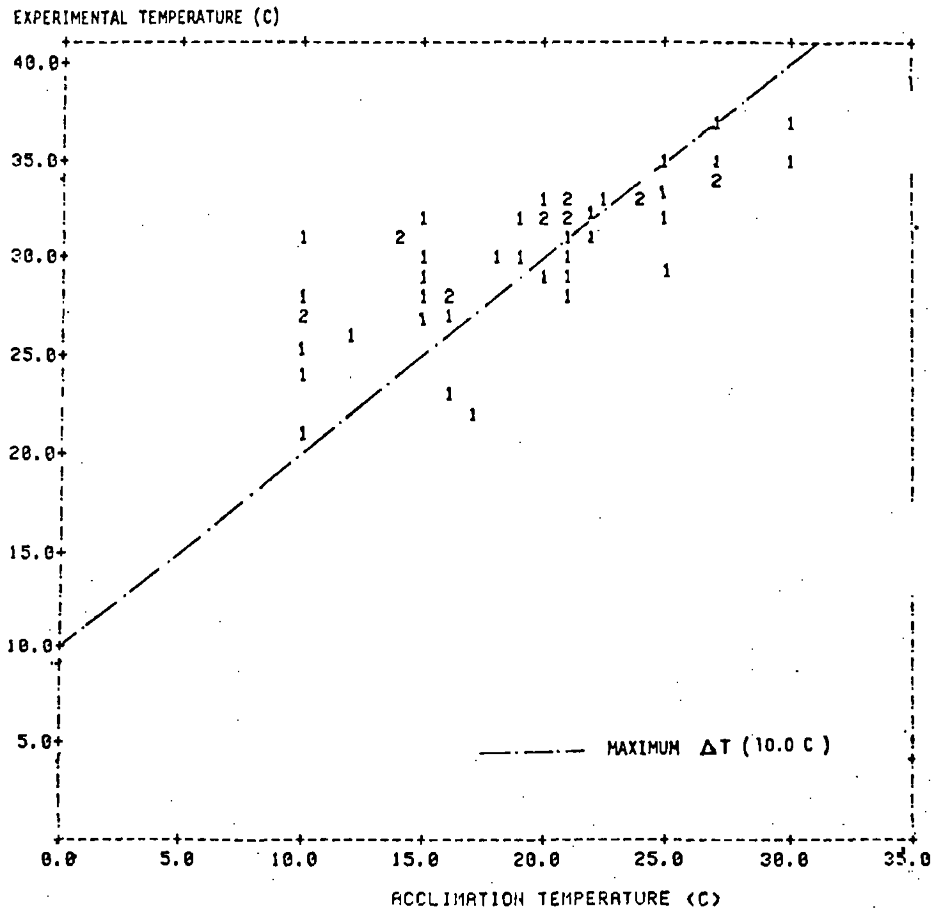

EXPERIMENTAL TEMPERATURE (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
ACCLIMATION TEMPERATURE (C)
MAXIMUM ΔT (10.0 C)

FIGURE 3.1-21

FIGURE 3.1-22. Cold shock experimental temperatures which resulted in greater than 30% mortality of Atlantic menhaden, *Brevoortia tyrannus*, during a 96-h exposure plotted against respective acclimation temperatures. The number of data points occurring at respective temperatures is numerically indicated.

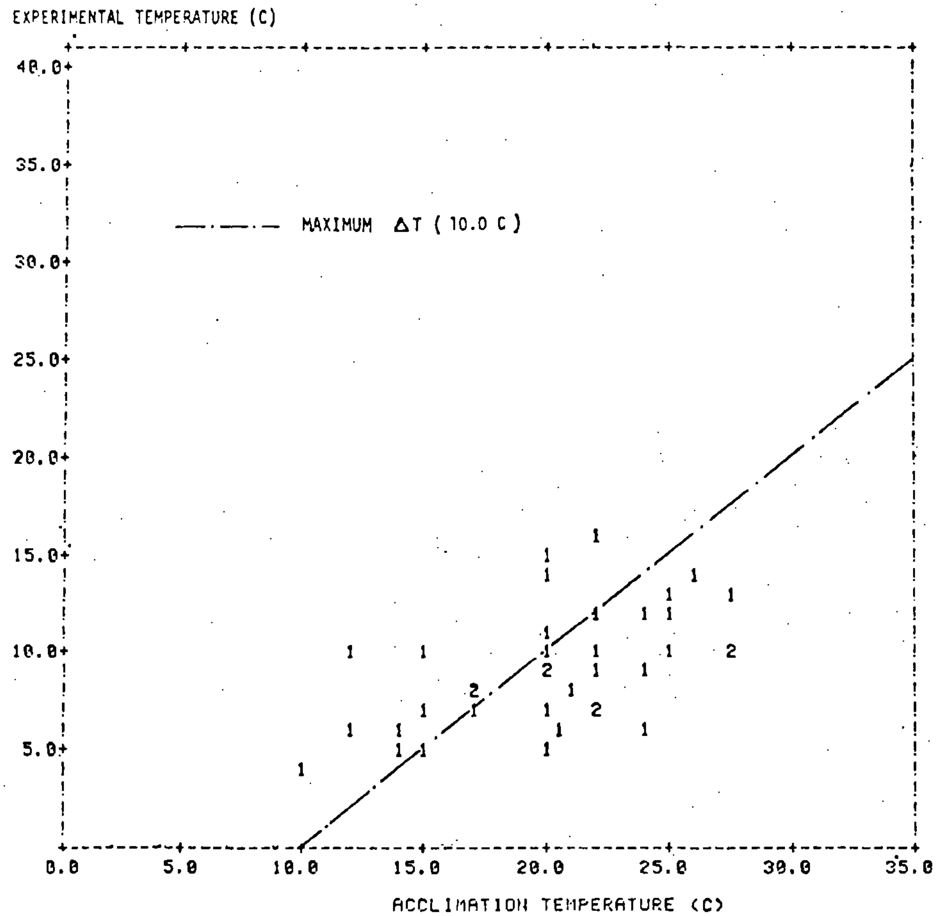

EXPERIMENTAL TEMPERATURE (C)
MAXIMUM ΔT (10.0 C)
ACCLIMATION TEMPERATURE (C)

FIGURE 3.1-22

FIGURE 3.1-23. Area of the OCNGS and FRNGS thermal discharge from which the Atlantic menhaden will be excluded during July and August. The far field temperature distribution was based on LMST 08 (LMS 1977).

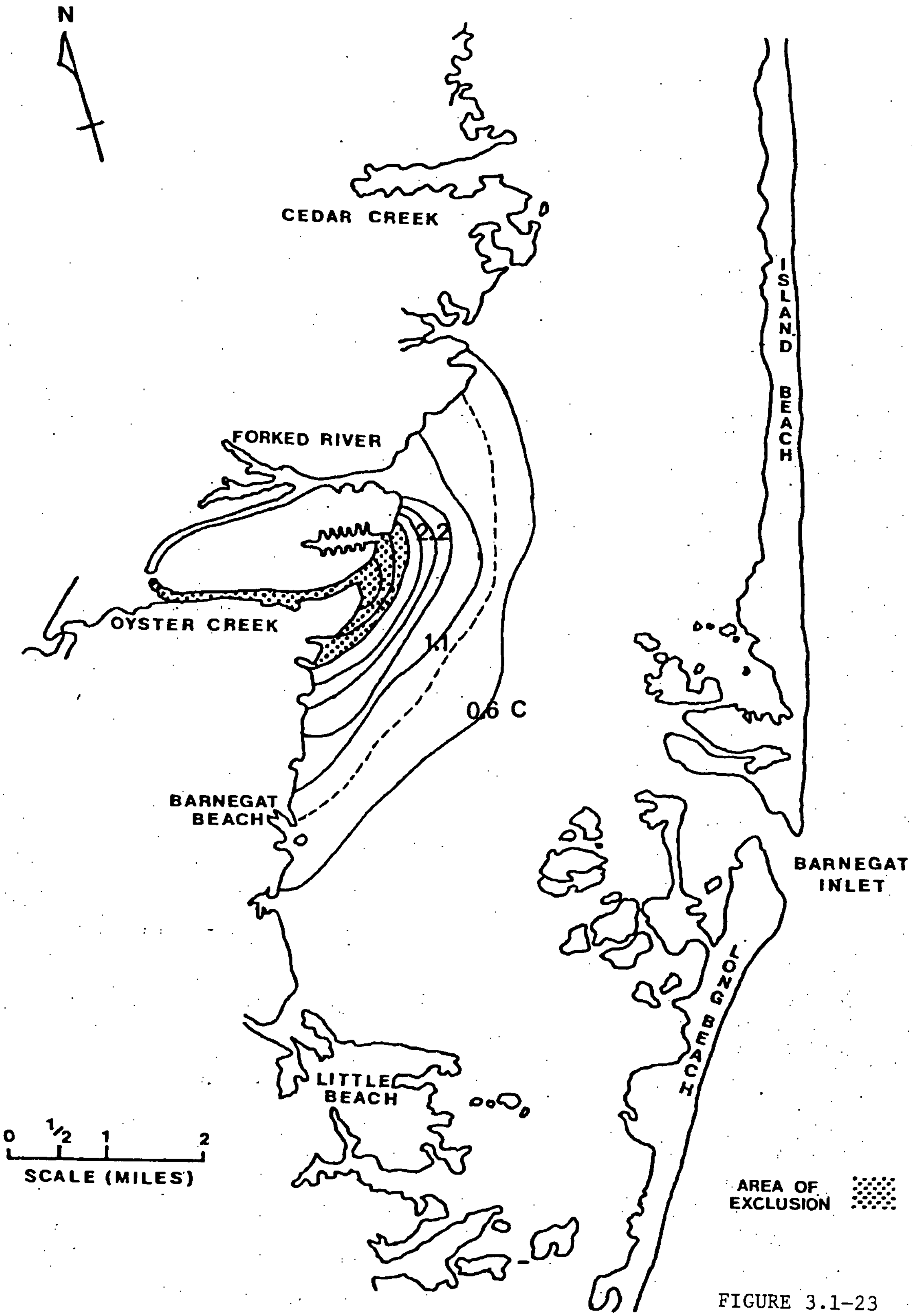

N
CEDAR CREEK
ISLAND BEACH
FORKED RIVER
2.2
OYSTER CREEK
1.1
0.6 C
BARNEGAT BEACH
BARNEGAT INLET
LONG BEACH
LITTLE BEACH
0 1/2 1 2
SCALE (MILES)
AREA OF EXCLUSION

FIGURE 3.1-23

FIGURE 3.1-24. The preferred temperatures of the bay anchovy, *Anchoa mitchilli*, plotted against their respective acclimation (ambient) temperatures. The regression line is calculated from the regression equation in Table 3.1-17.

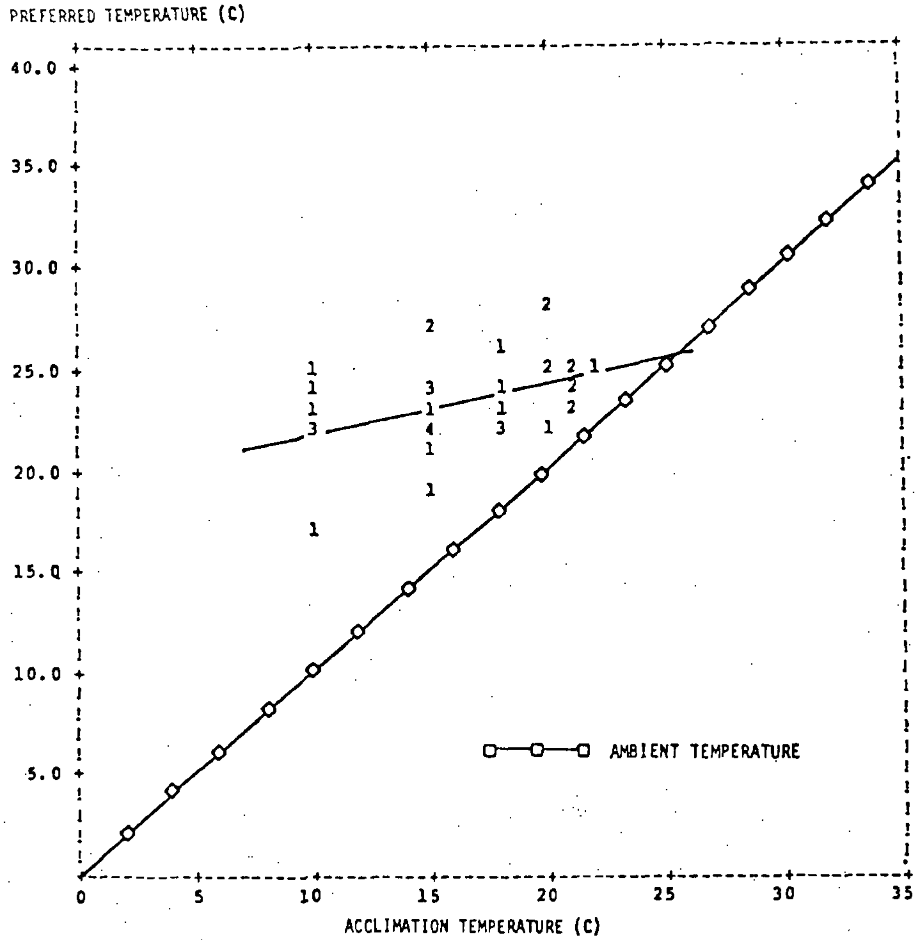

PREFERRED TEMPERATURE (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
5
10
15
20
25
30
35
ACCLIMATION TEMPERATURE (C)
AMBIENT TEMPERATURE

FIGURE 3.1-24

FIGURE 3.1-25. The avoidance temperatures of the bay anchovy, *Anchoa mitchilli*, plotted against their respective acclimation (ambient) temperatures, and the maximum ΔT of 10.0°C. The regression line is calculated from the regression equation in Table 3.1-18.

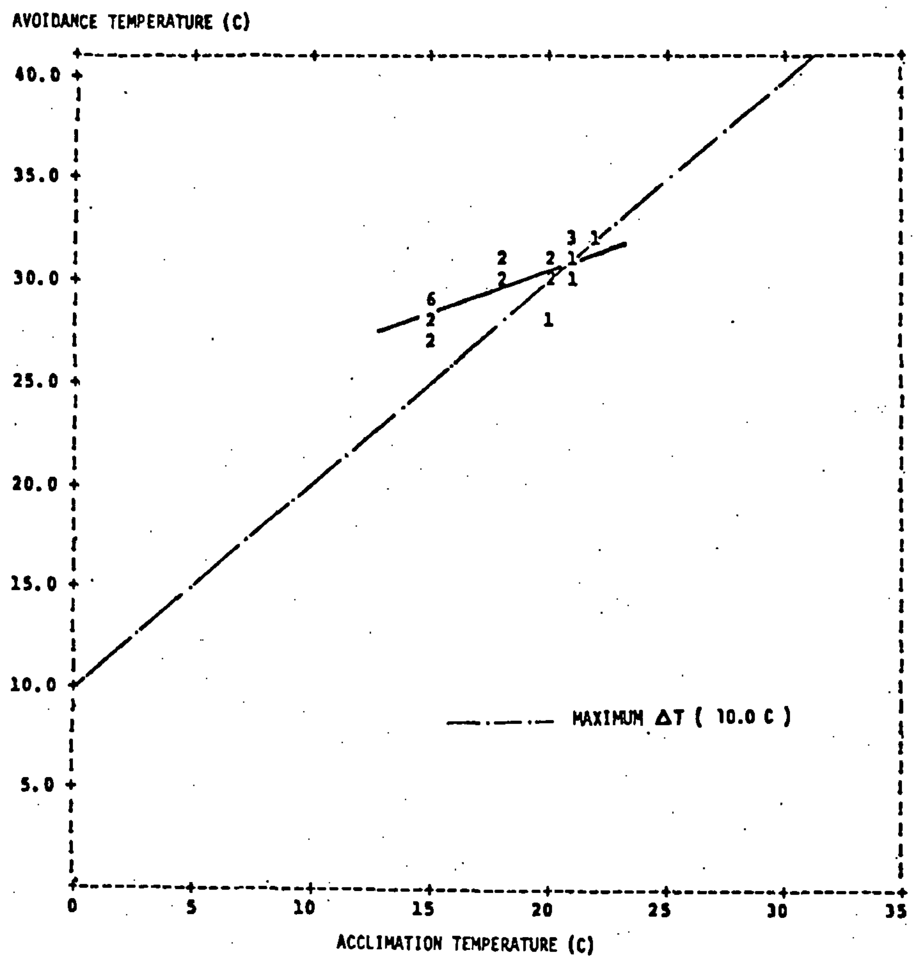

AVOIDANCE TEMPERATURE (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
5
10
15
20
25
30
35
ACCLIMATION TEMPERATURE (C)
MAXIMUM ΔT (10.0 C)

FIGURE 3.1-25

FIGURE 3.1-26. Heat shock experimental temperatures which resulted in greater than 30% mortality of bay anchovy, *Anchoa mitchilli*, during a 48-h exposure plotted against respective acclimation temperatures. The number of data points occurring at respective temperatures is numerically indicated.

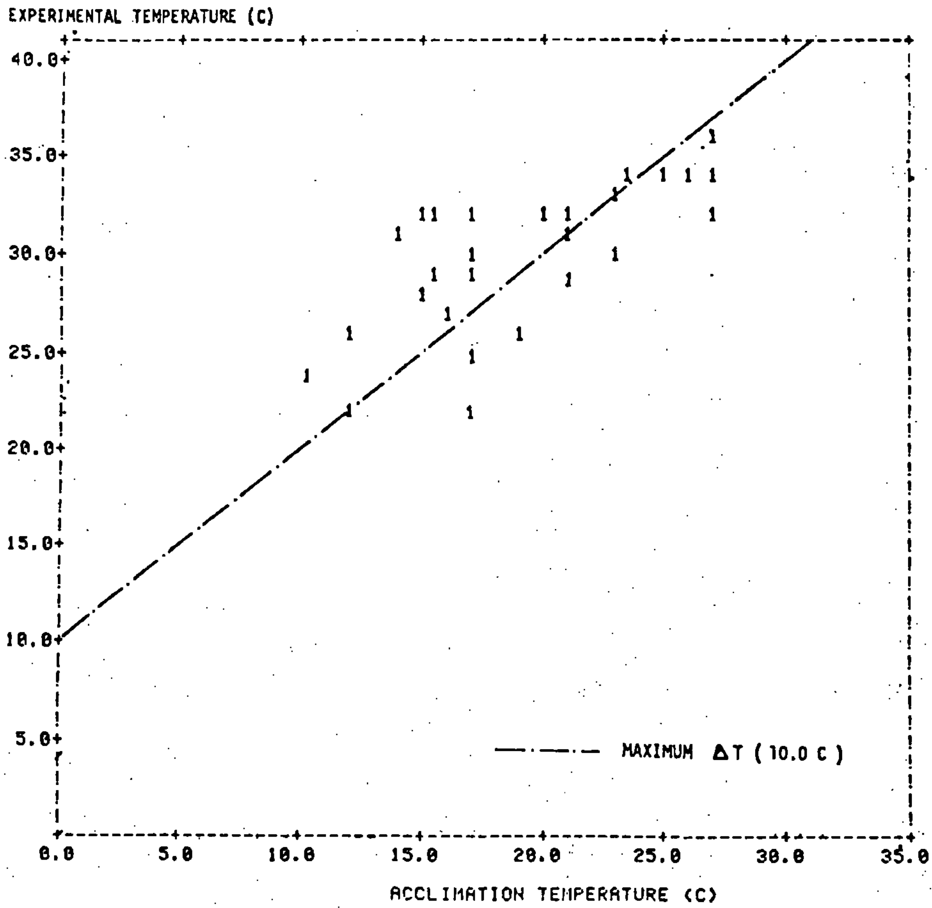

EXPERIMENTAL TEMPERATURE (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
ACCLIMATION TEMPERATURE (C)
MAXIMUM ΔT (10.0 C)

FIGURE 3.1-26

FIGURE 3.1-27. Cold shock experimental temperatures which resulted in greater than 30% mortality of bay anchovy, Anchoa mitchilli, during a 96-h exposure plotted against respective acclimation temperatures. The number of data points occurring at respective temperatures is numerically indicated.

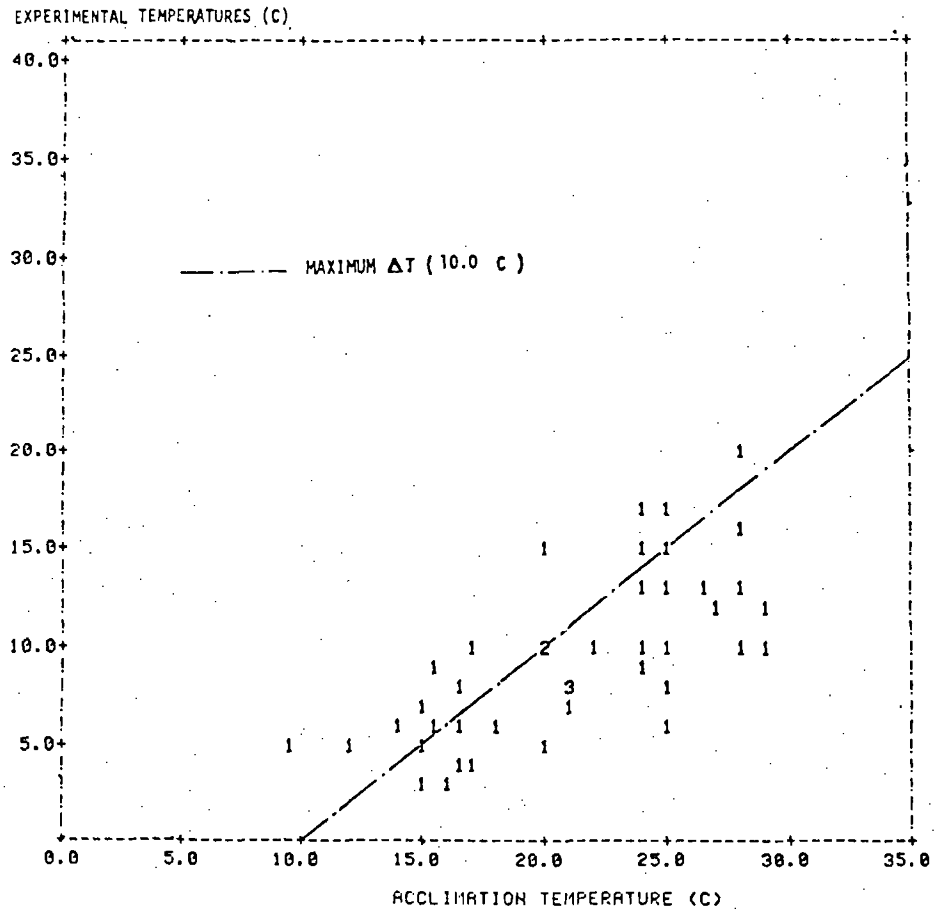

EXPERIMENTAL TEMPERATURES (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
MAXIMUM ΔT (10.0 C)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
ACCLIMATION TEMPERATURE (C)

FIGURE 3.1-27

FIGURE 3.1-28. Area of the OCNGS and FRNGS thermal discharge from which the bay anchovy will be excluded during July and August. The far field temperature distribution was based on LMST 08 (LMS 1977).

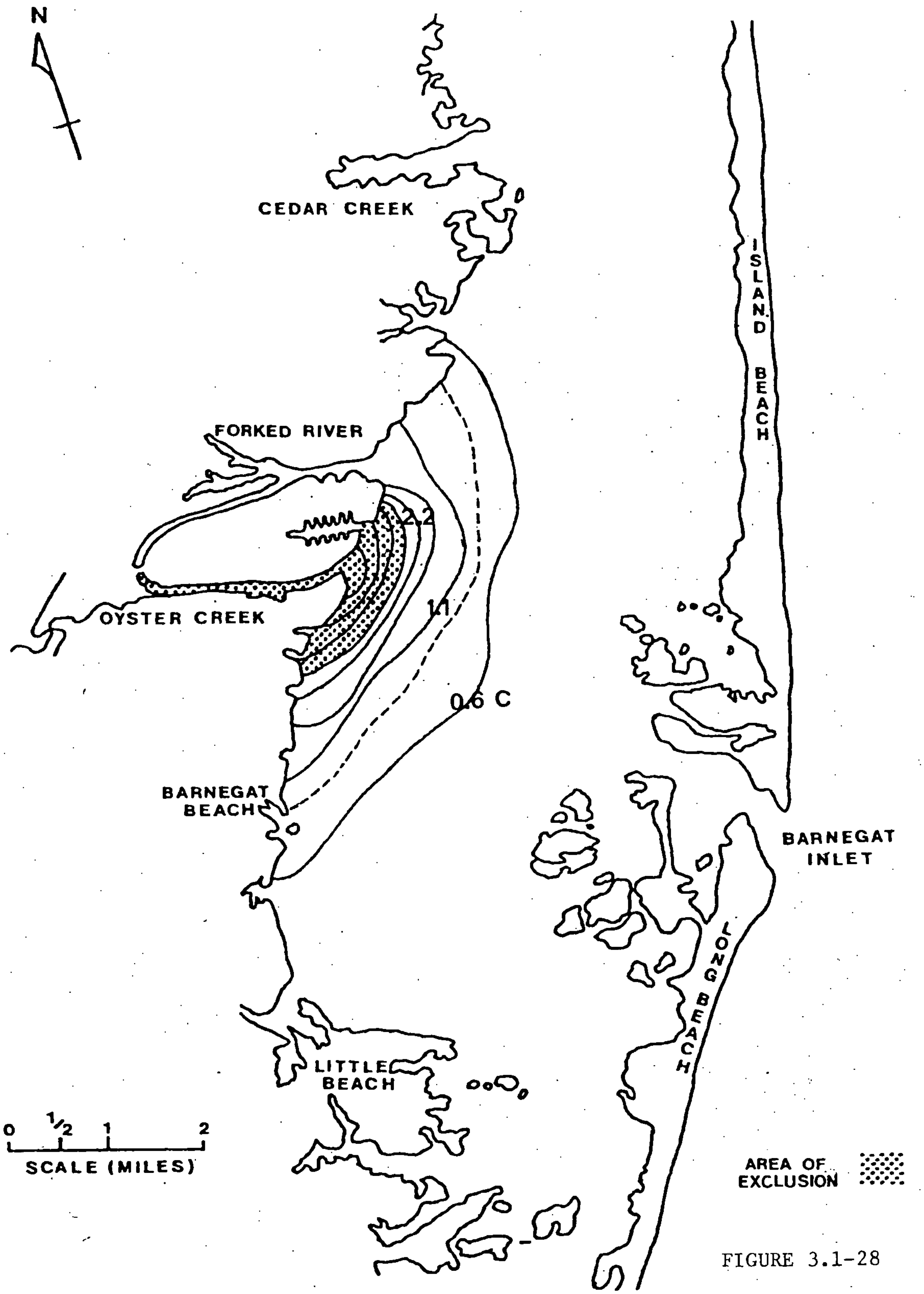

N
CEDAR CREEK
FORKED RIVER
OYSTER CREEK
2.2
1.1
0.6 C
BARNEGAT BEACH
ISLAND BEACH
BARNEGAT INLET
LONG BEACH
LITTLE BEACH
0 1/2 1 2
SCALE (MILES)
AREA OF EXCLUSION

FIGURE 3.1-28

FIGURE 3.1-29. The preferred temperatures of the threespined stickleback, _Gasterosteus acculeatus_, plotted against their respective acclimation (ambient) temperatures.

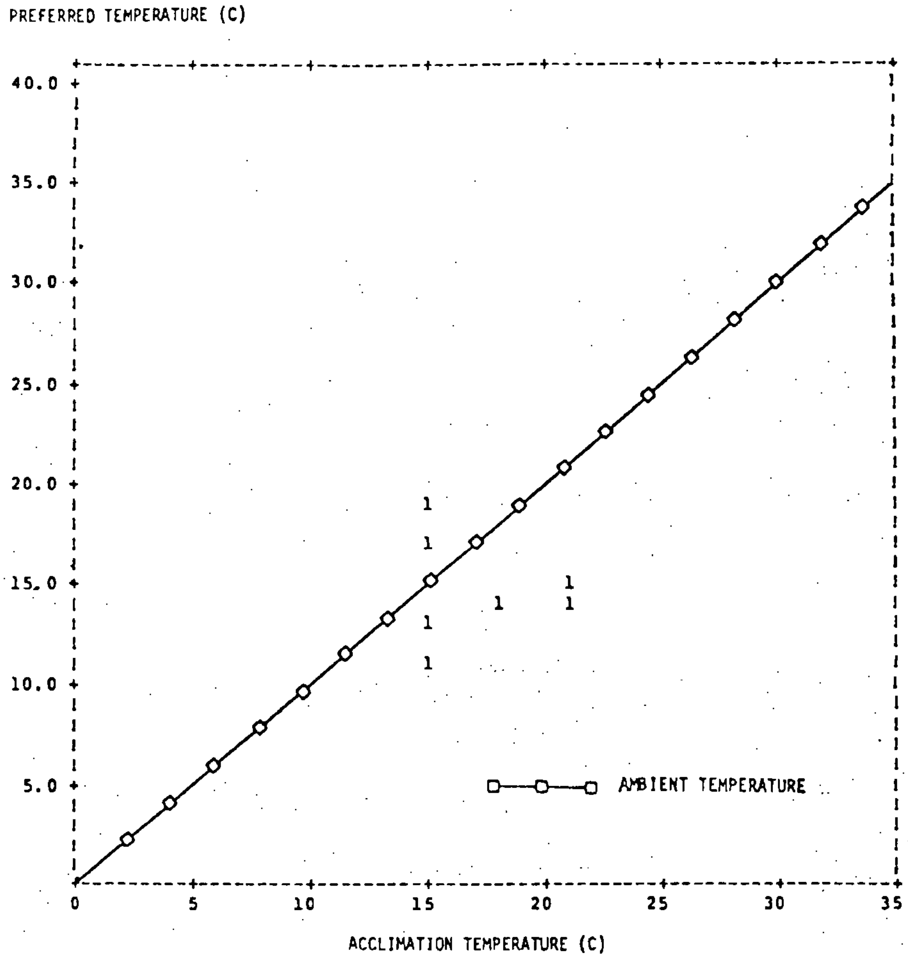

PREFERRED TEMPERATURE (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
5
10
15
20
25
30
35
ACCLIMATION TEMPERATURE (C)
AMBIENT TEMPERATURE

FIGURE 3.1-29

FIGURE 3.1-30. The preferred temperatures of the striped bass, *Morone saxatilis*, plotted against their respective acclimation (ambient) temperatures. The regression line is calculated from the regression equation in Table 3.1-19.

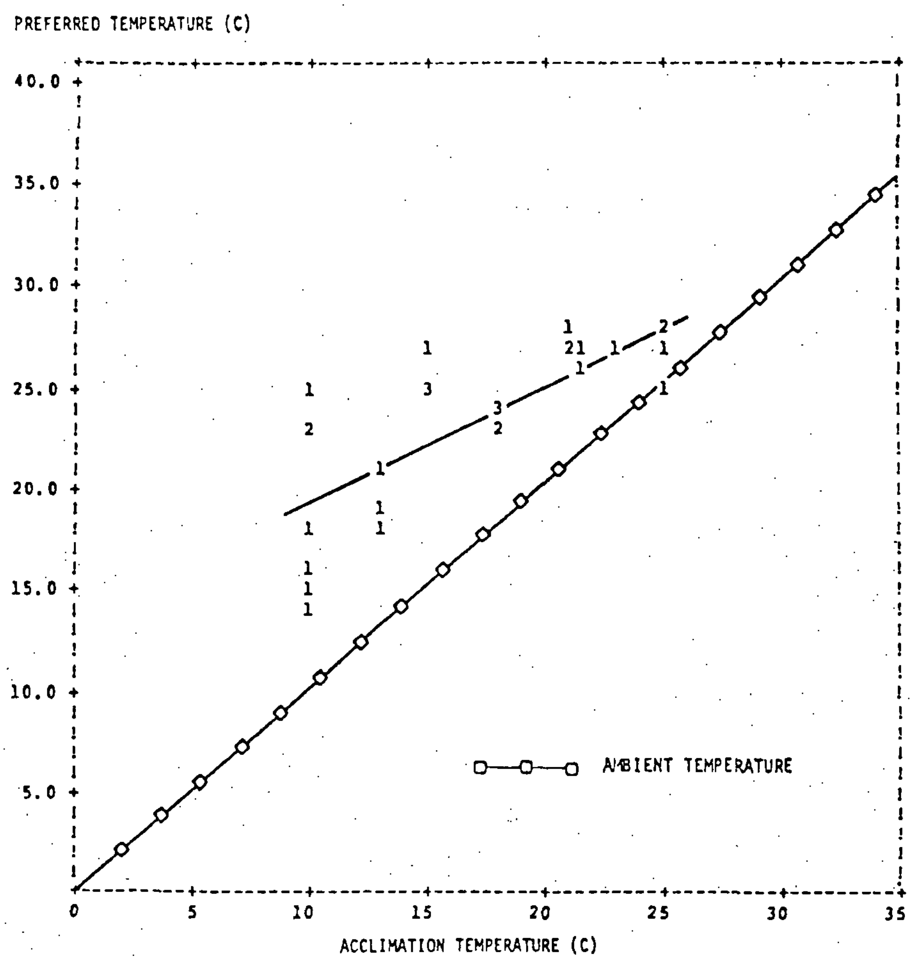

PREFERRED TEMPERATURE (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
5
10
15
20
25
30
35
ACCLIMATION TEMPERATURE (C)
AMBIENT TEMPERATURE

FIGURE 3.1-30

FIGURE 3.1-31. Final temperature preferenda of the striped bass, *Morone saxatilis*, plotted against their respective acclimation (ambient) temperatures. The horizontal line represents the mean final temperature preferendum.

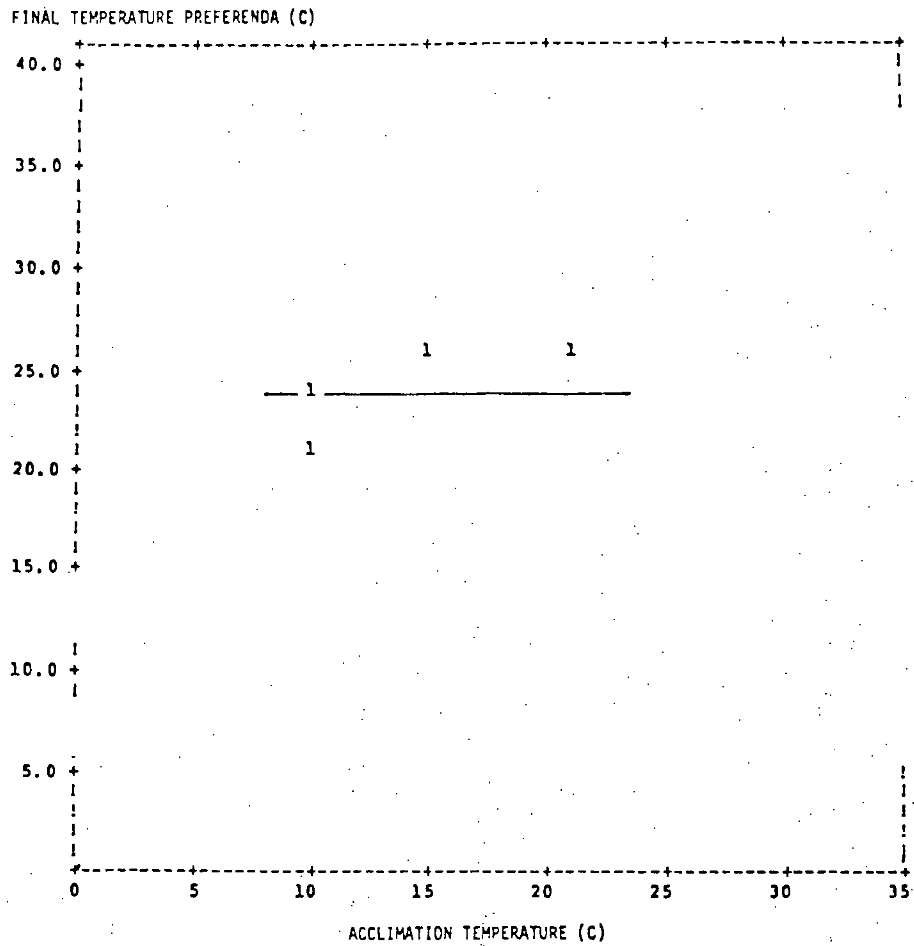

FINAL TEMPERATURE PREFERENDA (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
1
1
1
1
0
5
10
15
20
25
30
35
ACCLIMATION TEMPERATURE (C)

FIGURE 3.1-31

FIGURE 3.1-32. The avoidance temperatures of the striped bass, Morone saxatilis, plotted against their respective acclimation (ambient) temperatures, and the maximum ΔT of 10.0°C. The regression line is calculated from the regression equation in Table 3.1-21.

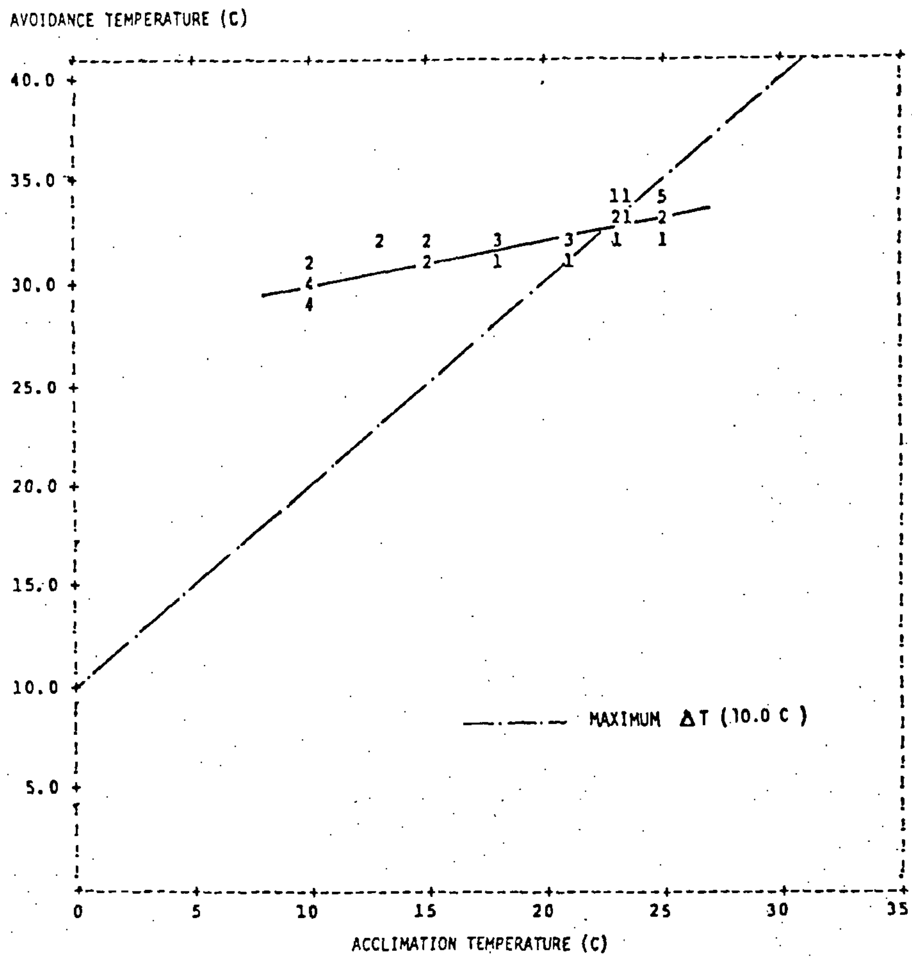

AVOIDANCE TEMPERATURE (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
5
10
15
20
25
30
35
ACCLIMATION TEMPERATURE (C)
MAXIMUM ΔT (10.0 C)

FIGURE 3.1-32

FIGURE 3.1-33. The preferred temperatures of the bluefish, *Pomatomus saltatrix*, plotted against their respective acclimation (ambient) temperatures. The regression line is calculated from the regression equation in Table 3.1-22.

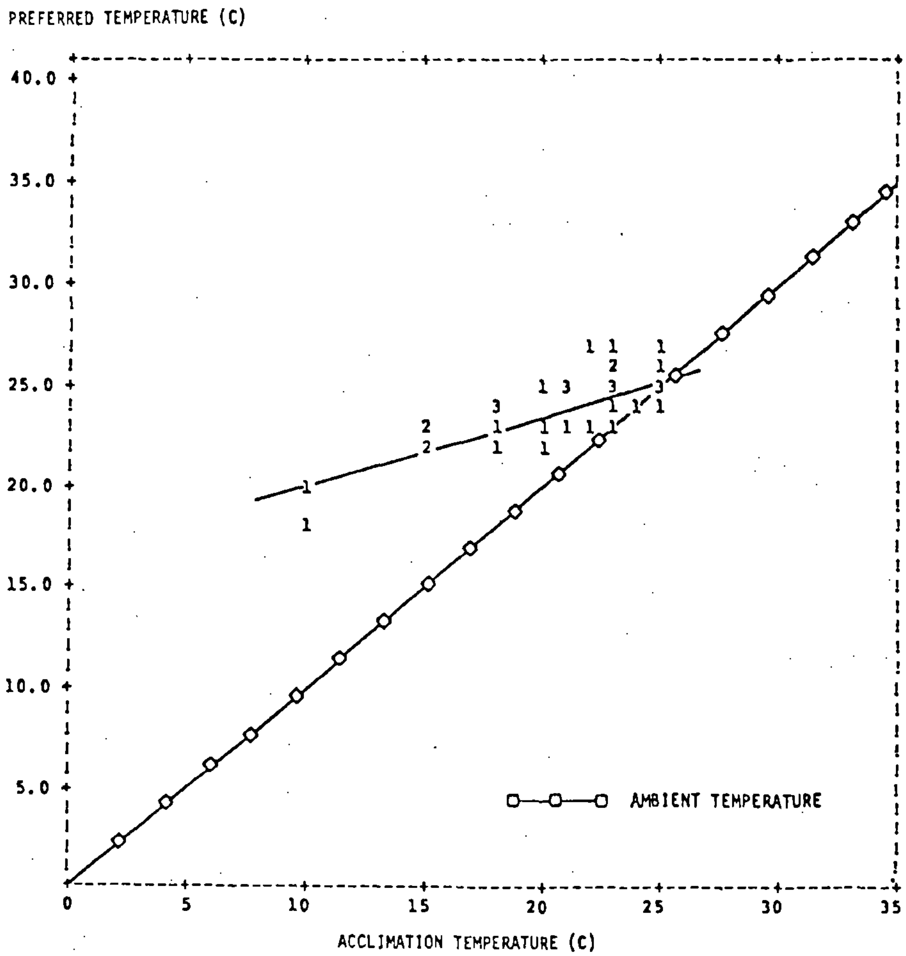
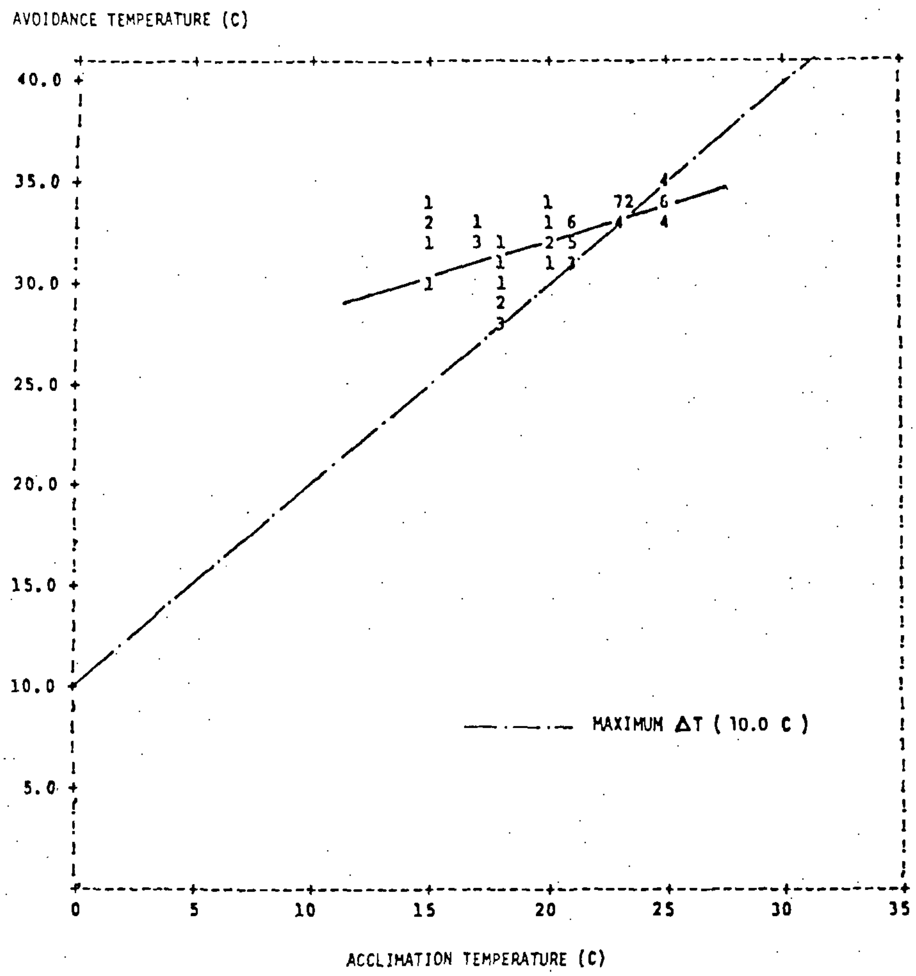

PREFERRED TEMPERATURE (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
5
10
15
20
25
30
35
ACCLIMATION TEMPERATURE (C)
AMBIENT TEMPERATURE

FIGURE 3.1-33

FIGURE 3.1-34. The avoidance temperatures of the bluefish, *Pomatomus saltatrix*, plotted against their respective acclimation (ambient) temperatures, and the maximum ΔT of 10.0°C. The regression line is calculated from the regression equation in Table 3.1-23.



AVOIDANCE TEMPERATURE (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
5
10
15
20
25
30
35
ACCLIMATION TEMPERATURE (C)
MAXIMUM ΔT (10.0 C)

FIGURE 3.1-34

FIGURE 3.1-35. Heat shock experimental temperatures which resulted in greater than 30% mortality of bluefish, *Pomatomus saltatrix*, during a 48-h exposure plotted against respective acclimation temperatures. The number of data points occurring at respective temperatures is numerically indicated.

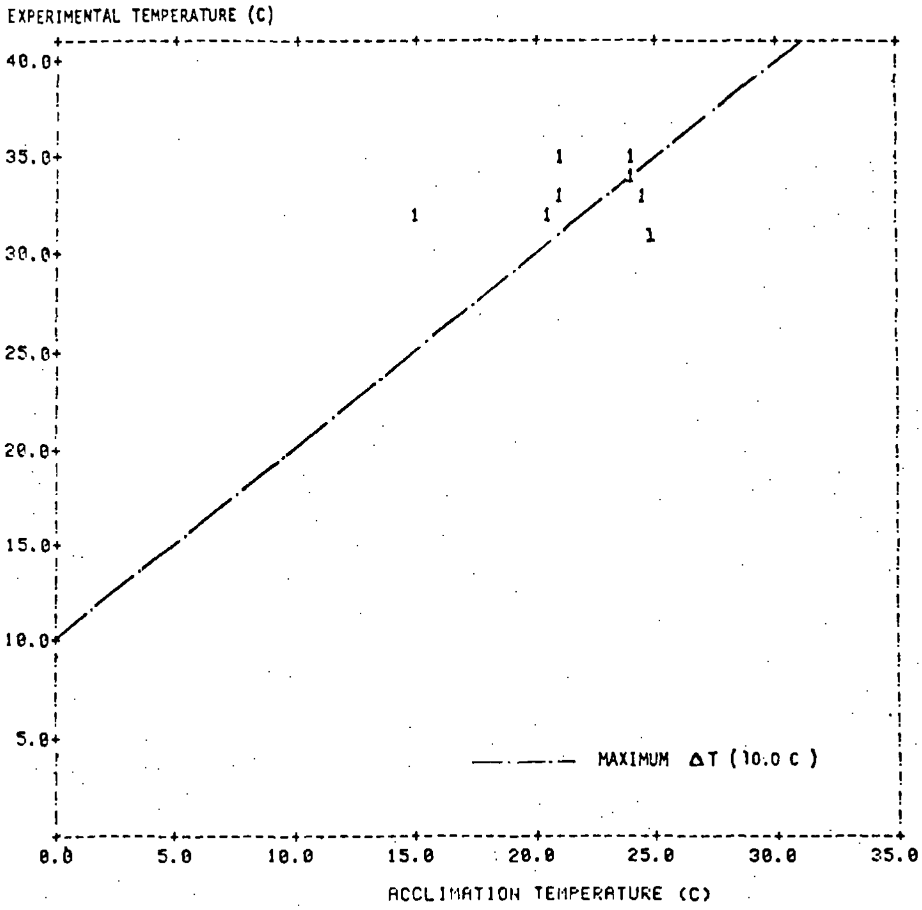

EXPERIMENTAL TEMPERATURE (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
MAXIMUM ΔT (10.0 C)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
ACCLIMATION TEMPERATURE (C)

FIGURE 3.1-35

FIGURE 3.1-36. Cold shock experimental temperatures which resulted in greater than 30% mortality of bluefish, *Pomatomus saltatrix*, during a 96-h exposure plotted against respective acclimation temperatures. The number of data points occurring at respective temperatures is numerically indicated.

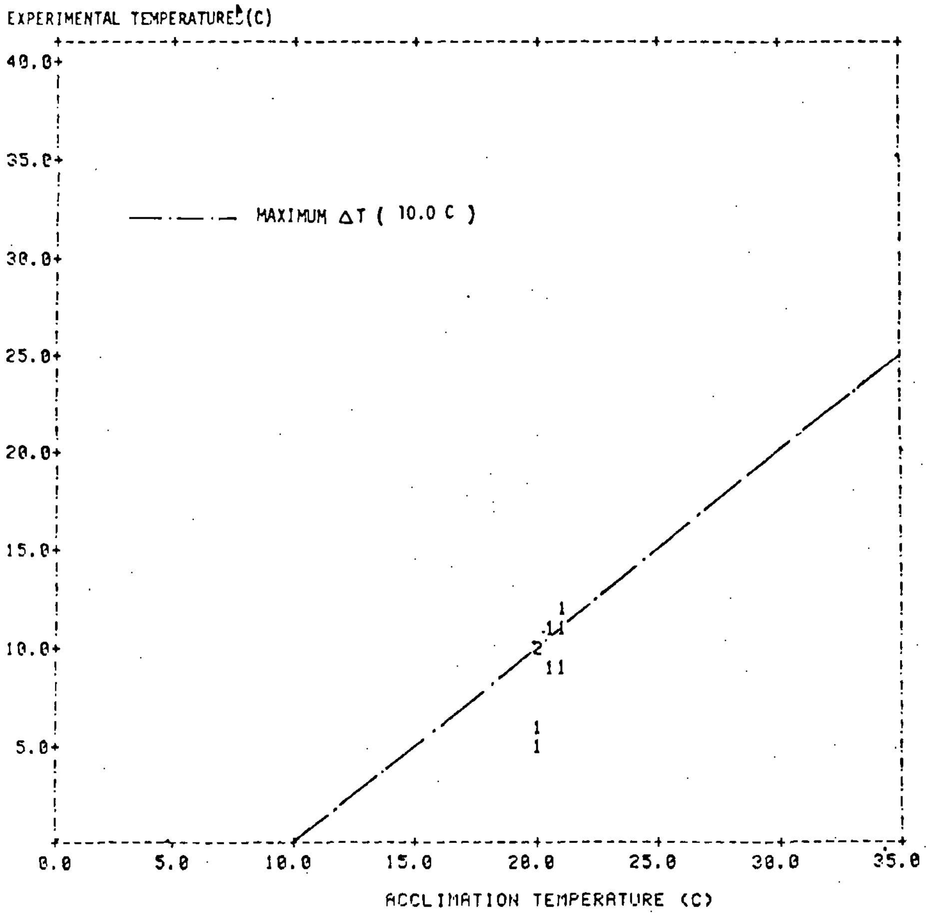

EXPERIMENTAL TEMPERATURE (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
MAXIMUM ΔT (10.0 C)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
ACCLIMATION TEMPERATURE (C)

FIGURE 3.1-36

FIGURE 3.1-37. Area of the OCNGS and FRNGS thermal discharge from which the bluefish will be excluded during July and August. The far field temperature distribution was based on LMST 08 (LMS 1977).

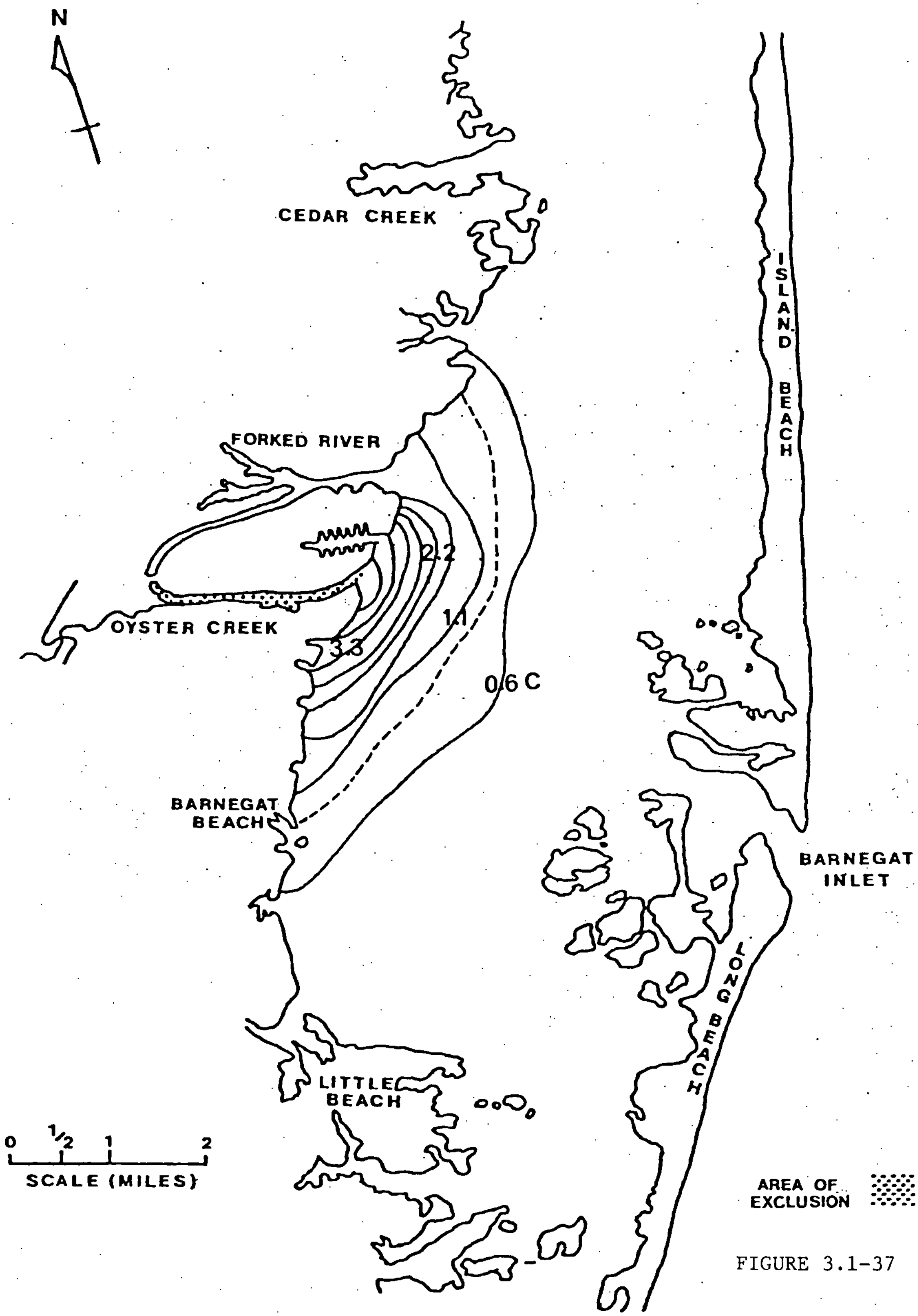

N
CEDAR CREEK
ISLAND BEACH
FORKED RIVER
2.2
OYSTER CREEK
1.1
3.3
0.6 C
BARNEGAT BEACH
BARNEGAT INLET
LONG BEACH
LITTLE BEACH
0 1/2 1 2
SCALE (MILES)
AREA OF EXCLUSION

FIGURE 3.1-37

FIGURE 3.1-38. The preferred temperatures of the weakfish, *Cynoscion regalis*, plotted against their respective acclimation (ambient) temperatures. The regression line is calculated from the regression equation in Table 3.1-24.

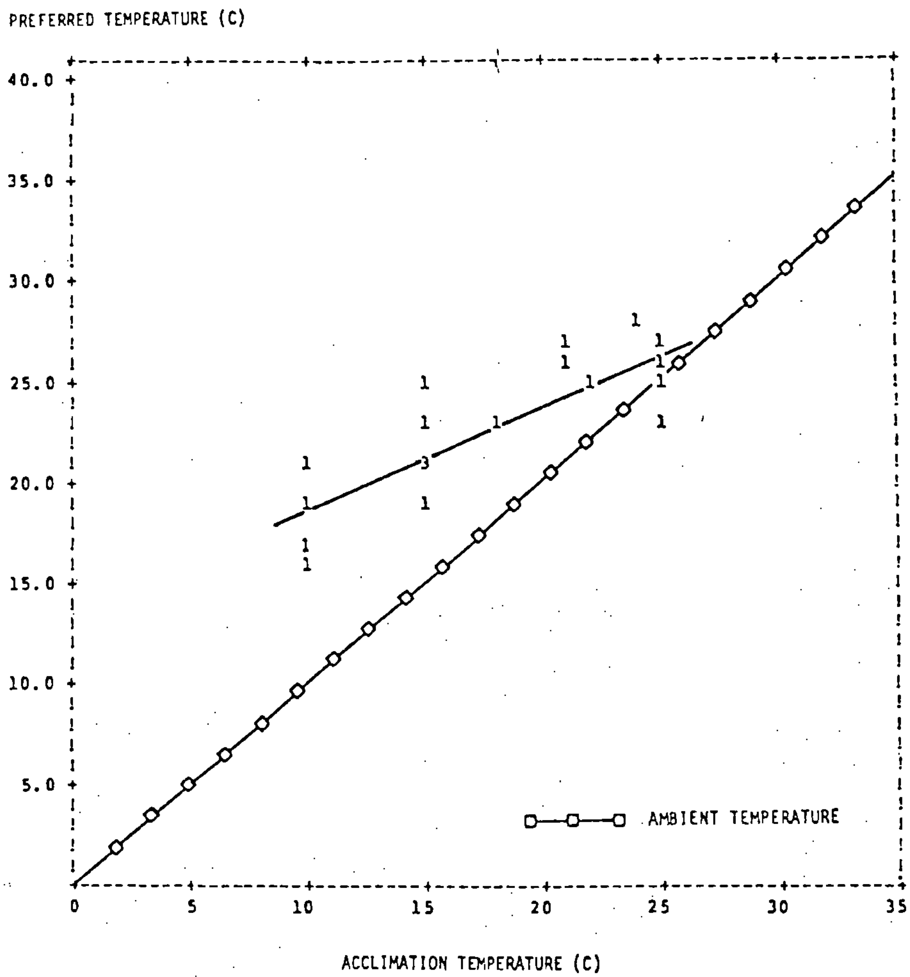

PREFERRED TEMPERATURE (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
5
10
15
20
25
30
35
AMBIENT TEMPERATURE
ACCLIMATION TEMPERATURE (C)

FIGURE 3.1-38

FIGURE 3.1-39. The avoidance temperatures of the weakfish, *Cynoscion regalis*, plotted against their respective acclimation (ambient) temperatures, and the maximum ΔT of $10.0^{\circ}C$. The regression line is calculated from the regression equation in Table 3.1-25.

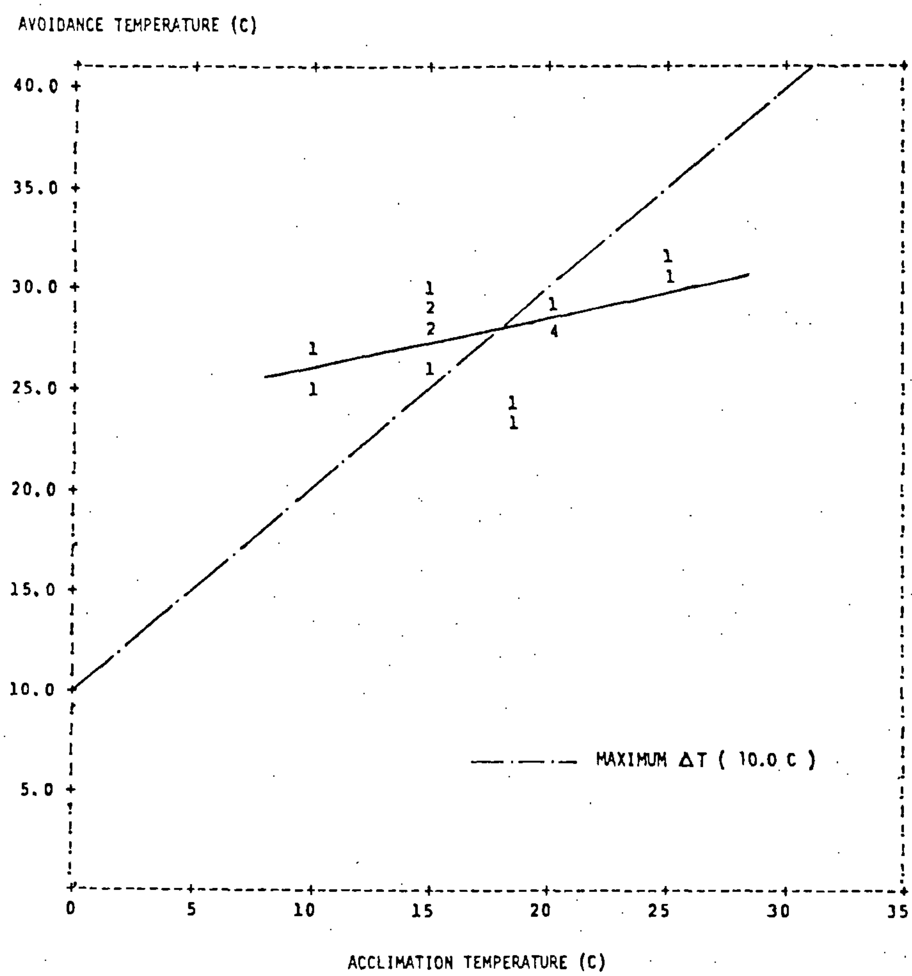

AVOIDANCE TEMPERATURE (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
5
10
15
20
25
30
35
ACCLIMATION TEMPERATURE (C)
MAXIMUM ΔT (10.0 C)

FIGURE 3.1-39

FIGURE 3.1-40. Heat shock experimental temperature which resulted in greater than 30% mortality of weakfish, *Cynoscion regalis*, during a 48-h exposure plotted against respective acclimation temperatures. The number of data points occurring at respective temperatures is numerically indicated.

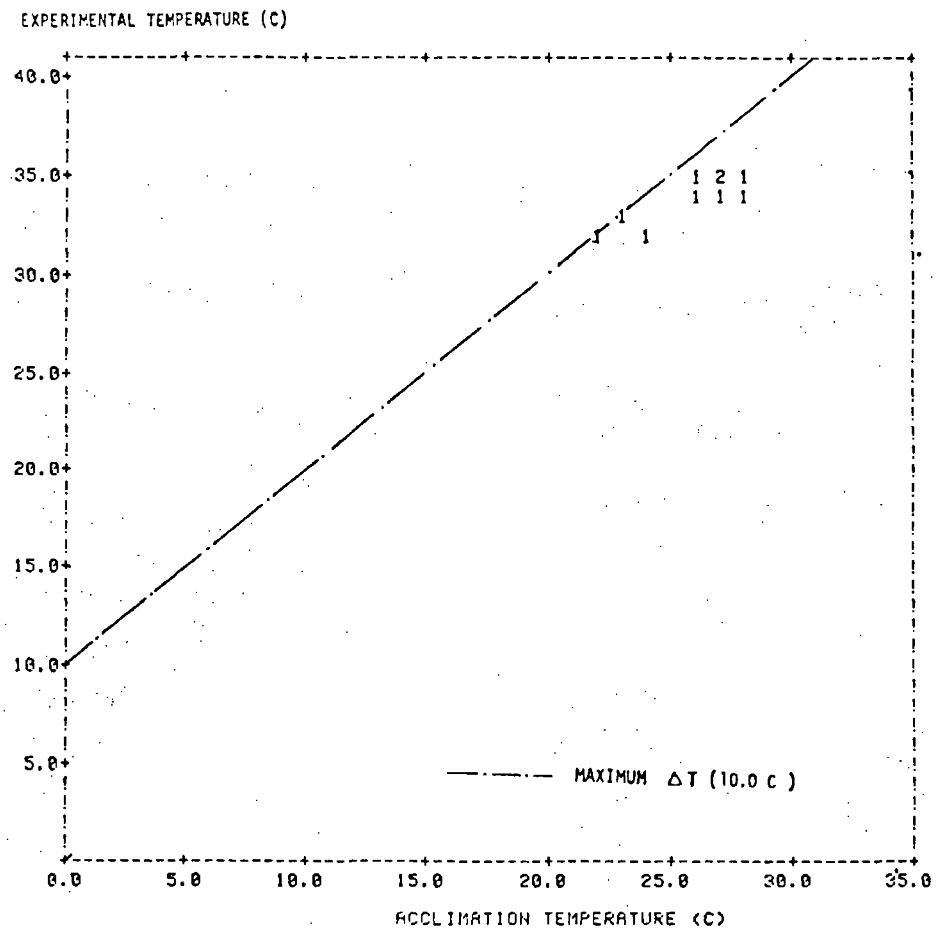

EXPERIMENTAL TEMPERATURE (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
ACCLIMATION TEMPERATURE (C)
MAXIMUM ΔT (10.0 C)

FIGURE 3.1-40

FIGURE

Cold shock experimental temperatures which resulted in greater than 30% mortality of weakfish, Cynoscion regalis, during a 96-h exposure plotted against respective acclimation temperatures. The number of data points occurring at respective temperatures is numerically indicated.

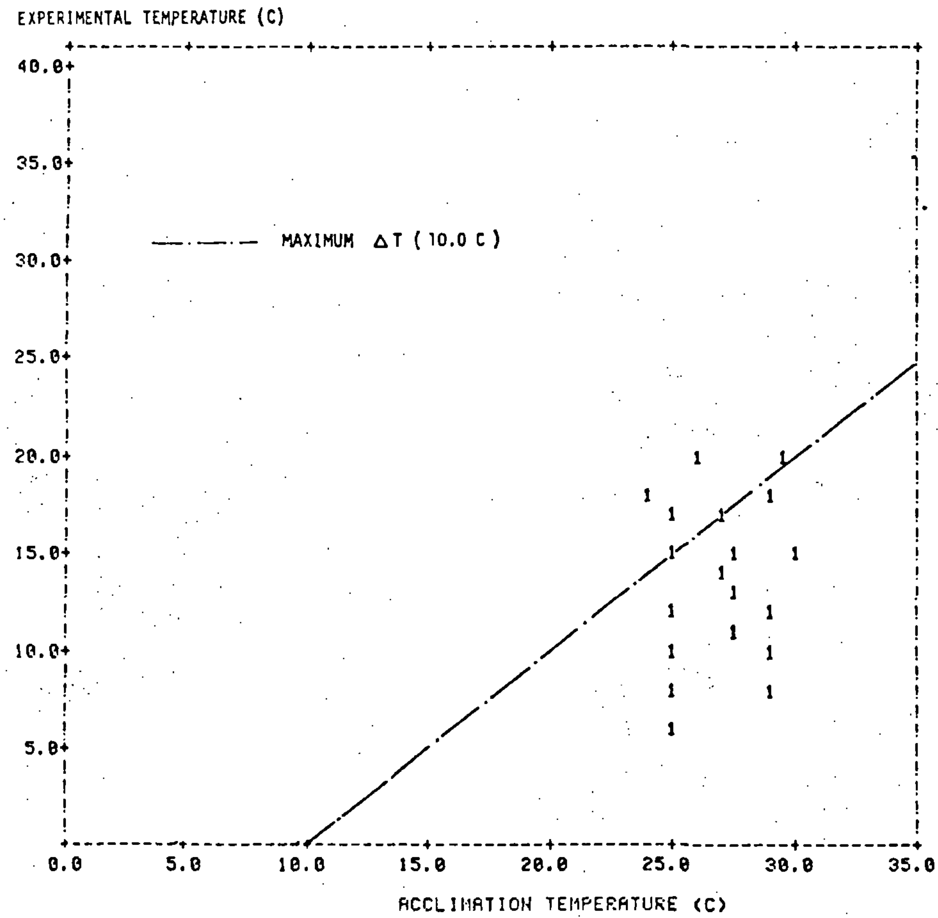

EXPERIMENTAL TEMPERATURE (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
MAXIMUM ΔT (10.0 C)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
ACCLIMATION TEMPERATURE (C)
FIGURE 3.1-41

FIGURE 3.1-42. Area of the OCNGS and FRNGS thermal discharge from which the weakfish will be excluded during July and August. The far field temperature distribution was based on LMST 08 (LMS 1977).

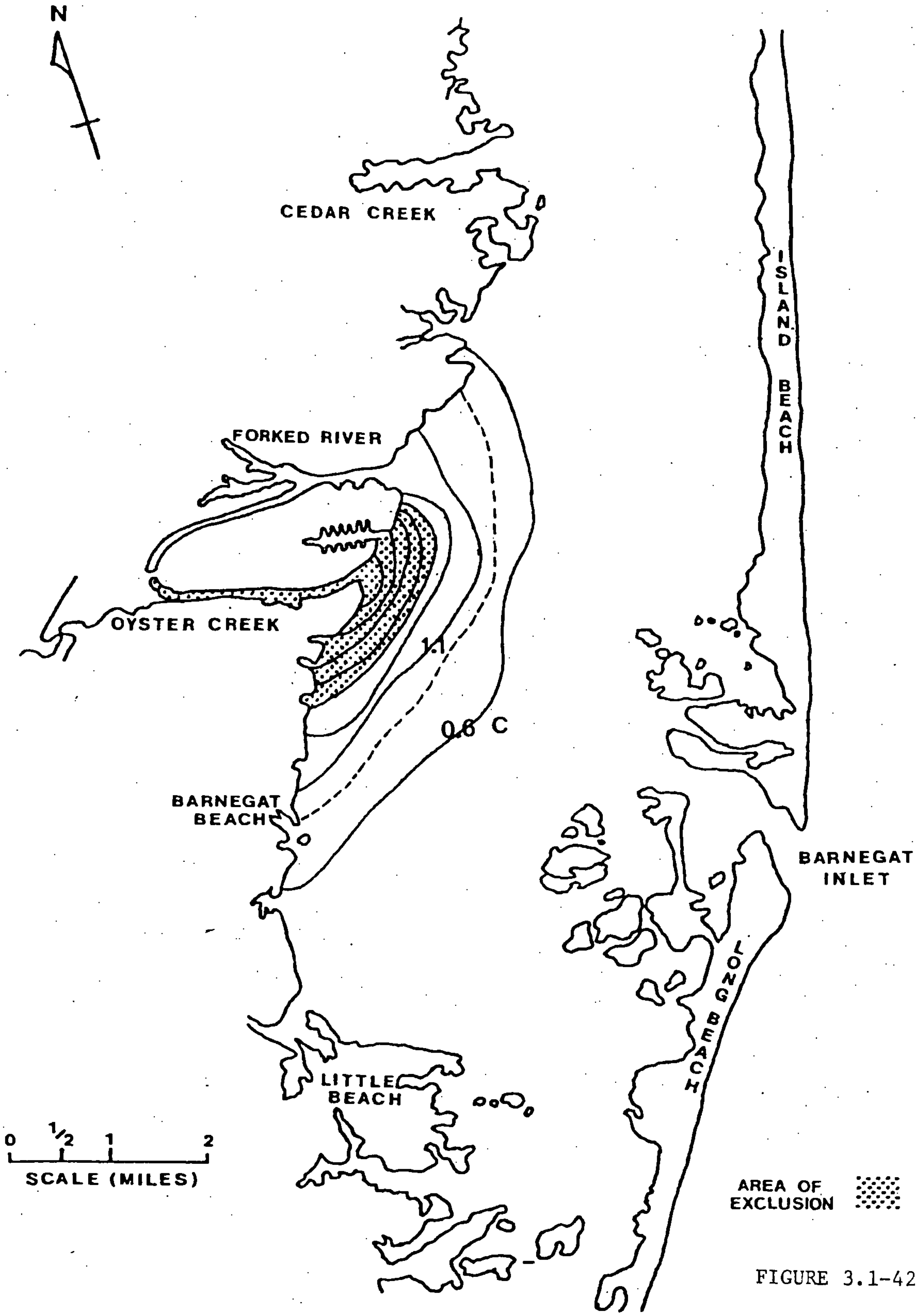

N
CEDAR CREEK
ISLAND BEACH
FORKED RIVER
OYSTER CREEK
1.1
0.6 C
BARNEGAT BEACH
BARNEGAT INLET
LONG BEACH
LITTLE BEACH
0 1/2 1 2
SCALE (MILES)
AREA OF EXCLUSION

FIGURE 3.1-42

FIGURE 3.1-43. Area of the OCNGS and FRNGS thermal discharge from which the northern kingfish will be excluded during July and August. The far field temperature distribution was based on LMST 08 (LMS 1977).

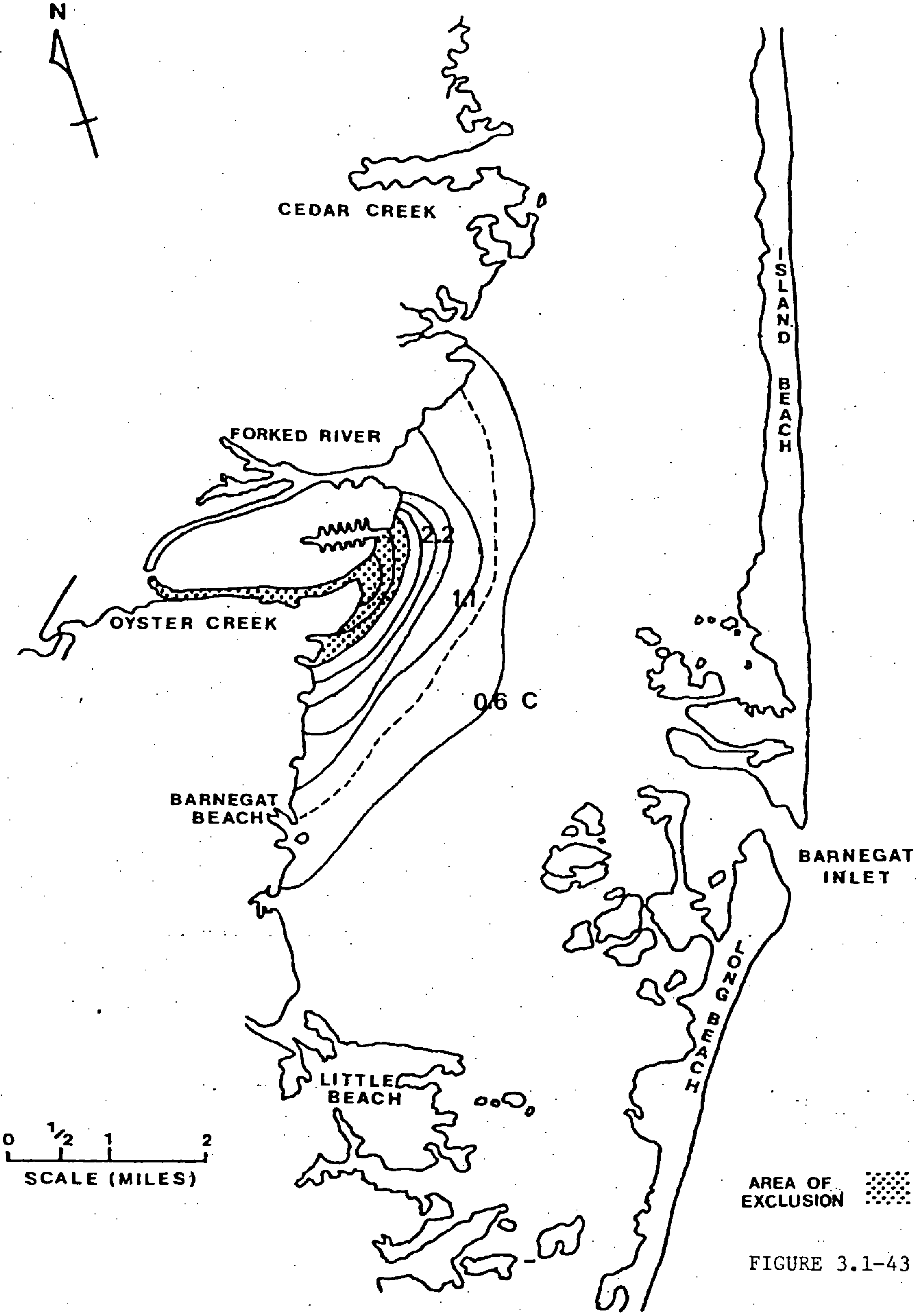

N
CEDAR CREEK
ISLAND BEACH
FORKED RIVER
2.2
1.1
OYSTER CREEK
0.6 C
BARNEGAT BEACH
BARNEGAT INLET
LONG BEACH
LITTLE BEACH
0 1/2 1 2
SCALE (MILES)
AREA OF EXCLUSION

FIGURE 3.1-43

FIGURE 3.1-44. The avoidance temperatures of the summer flounder, _Paralichthys dentatus_, plotted against their respective acclimation (ambient) temperatures and the maximum ΔT of $10.0^{\circ}C$.

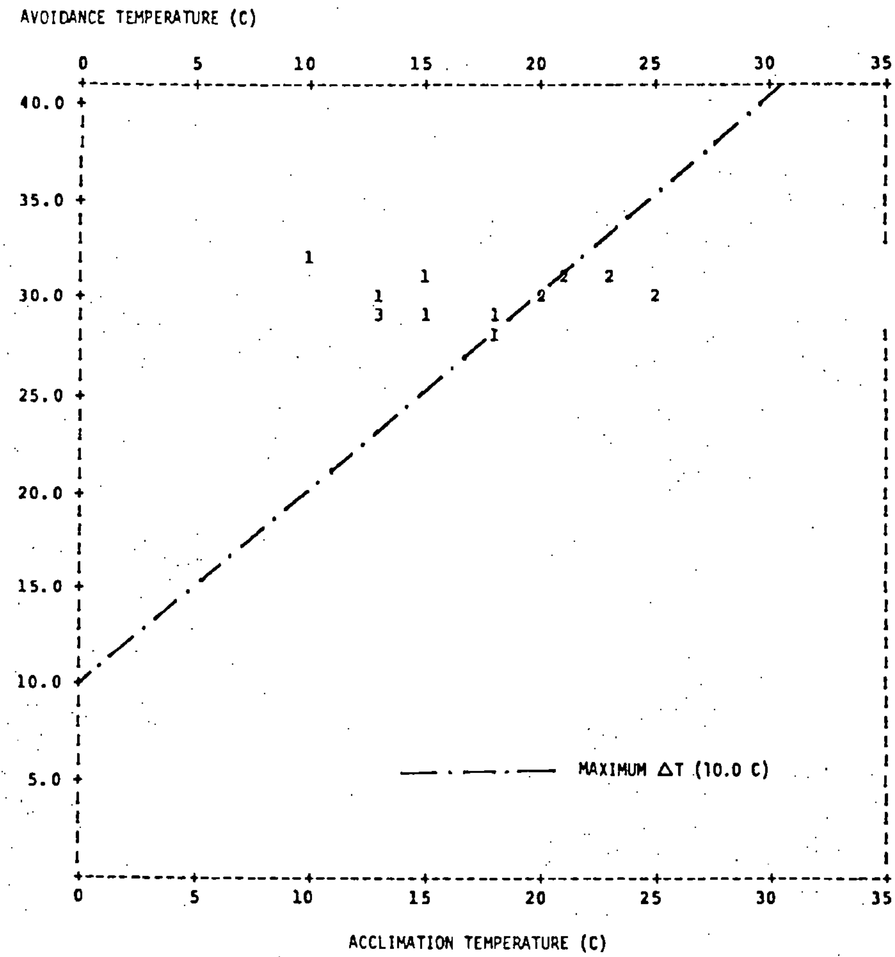

AVOIDANCE TEMPERATURE (C)
0 5 10 15 20 25 30 35
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
MAXIMUM ΔT (10.0 C)
ACCLIMATION TEMPERATURE (C)

FIGURE 3.1-44

FIGURE 3.1-45. Area of the OCNGS and FRNGS thermal discharge from which the summer flounder will be excluded during July and August. The far field temperature distribution was based on LMST 08 (LMS 1977).

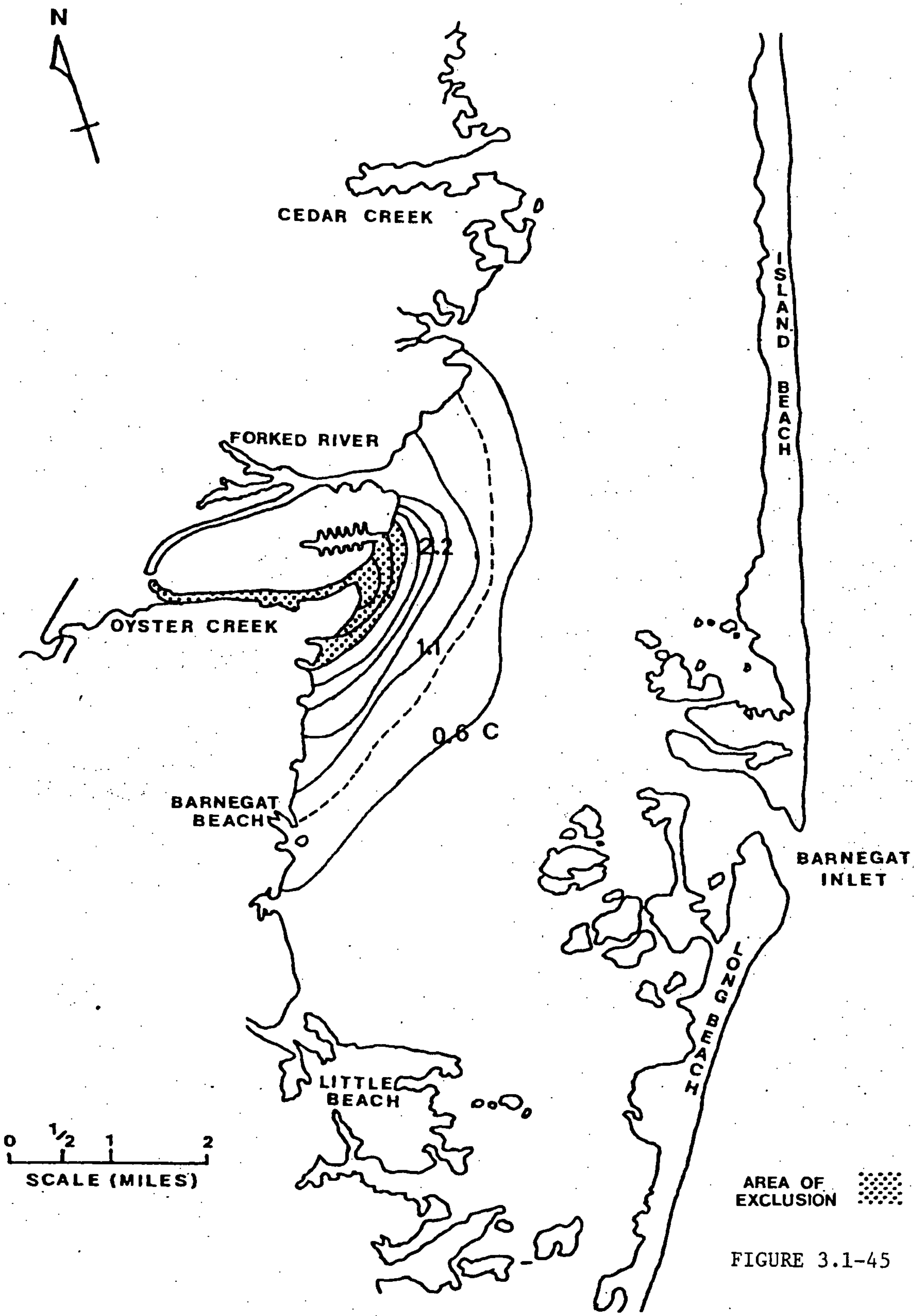

N
CEDAR CREEK
ISLAND BEACH
FORKED RIVER
2.2
OYSTER CREEK
1.1
0.6 C
BARNEGAT BEACH
BARNEGAT INLET
LONG BEACH
LITTLE BEACH
0 1/2 1 2
SCALE (MILES)
AREA OF EXCLUSION

FIGURE 3.1-45

FIGURE 3.1-46. Areas of greatest abundance (///////) of adult winter flounder in Barnegat Bay from February through April based on collections taken in March and April.

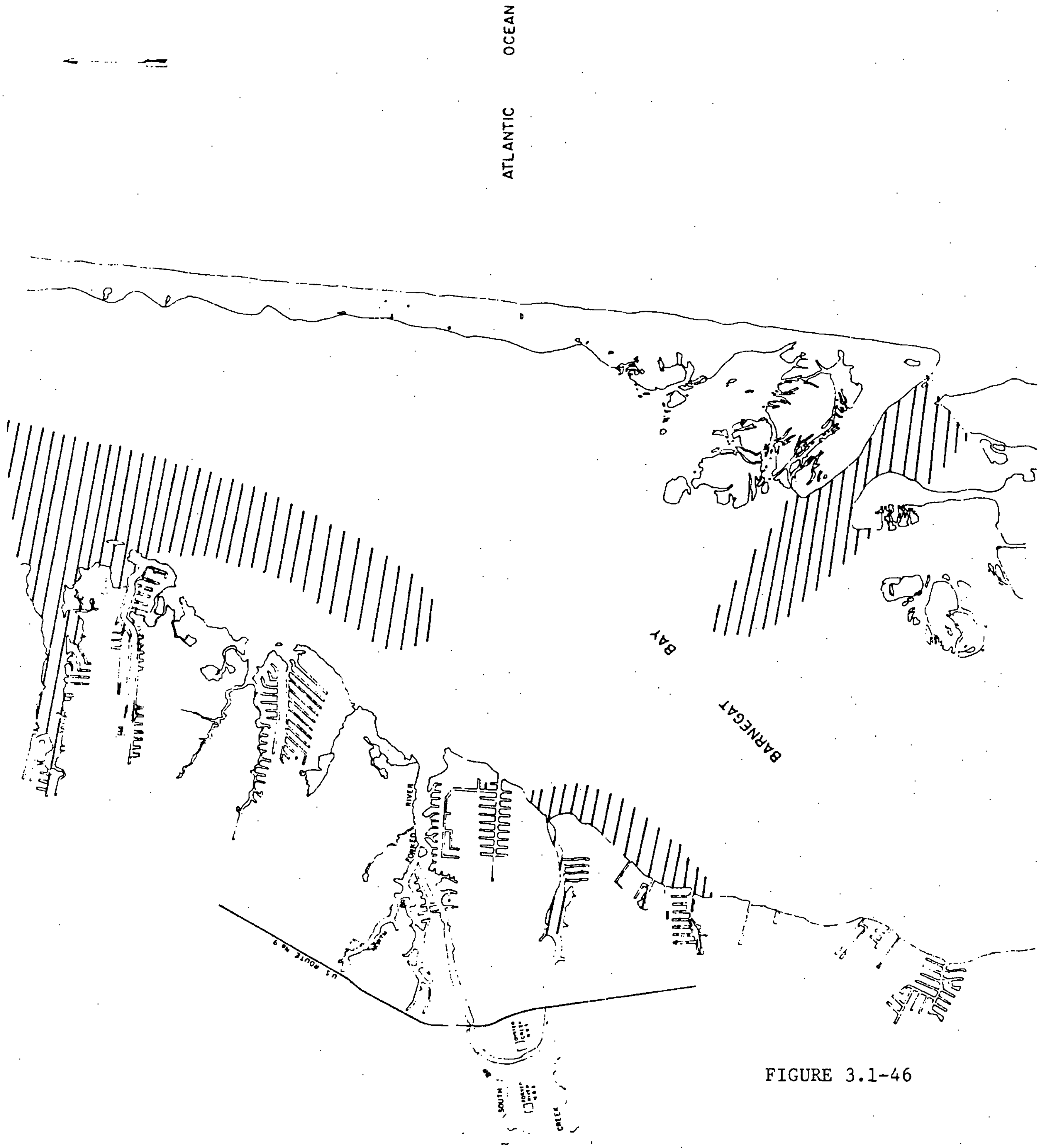


FIGURE 3.1-46

FIGURE 3.1-47. The avoidance temperatures of the winter flounder, Pseudopleuronectes americanus, against their respective acclimation (ambient) temperatures and the maximum ΔT of 10.0°C. The regression line is calculated from the regression equation in Table 3.1-30.

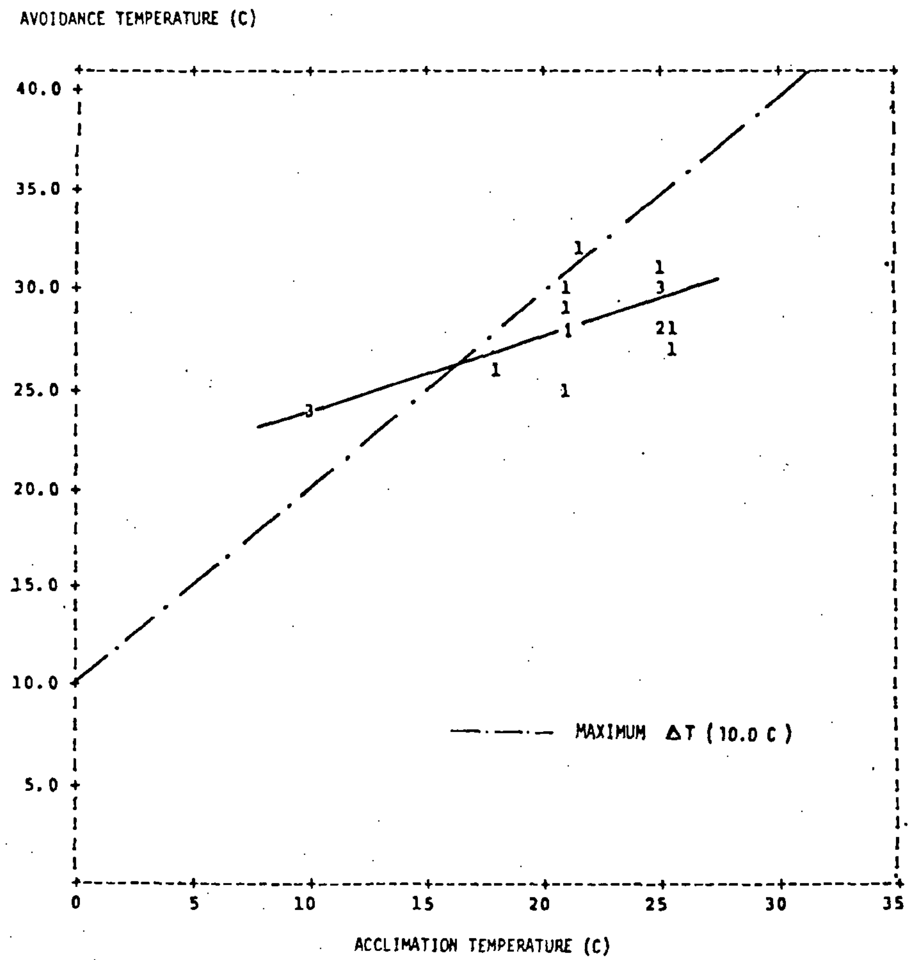

AVOIDANCE TEMPERATURE (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
5
10
15
20
25
30
35
ACCLIMATION TEMPERATURE (C)
MAXIMUM ΔT (10.0 C)

FIGURE 3.1-47

FIGURE 3.1-48. Heat shock experimental temperatures which resulted in greater than 30% mortality of winter flounder, *Pseudopleuronectes americanus*, during a 48-h exposure plotted against respective acclimation temperatures. The number of data points occurring at respective temperatures is numerically indicated.

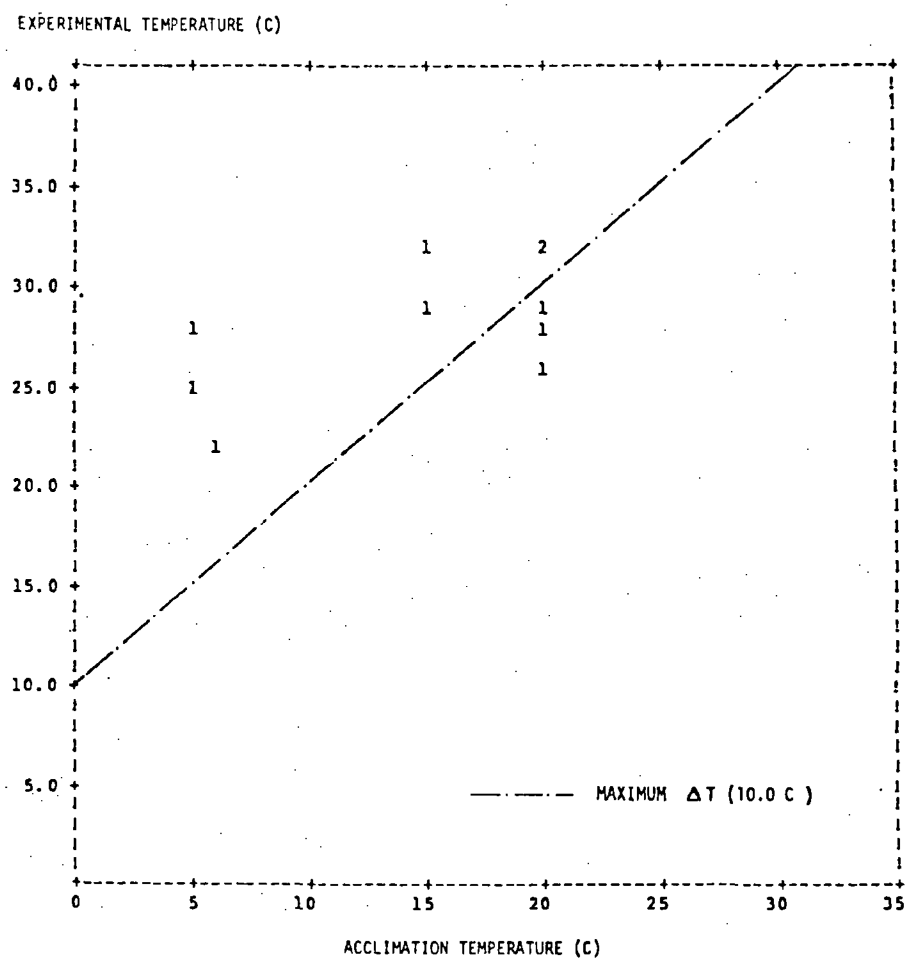

EXPERIMENTAL TEMPERATURE (C)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
1
2
1
1
1
1
1
1
1
0
5
10
15
20
25
30
35
MAXIMUM ΔT (10.0 C)
ACCLIMATION TEMPERATURE (C)

FIGURE 3.1-48

FIGURE 3.1-49. Area of the OCNGS and FRNGS thermal discharge from which adult winter flounder will be excluded during April. The far field temperature distribution was based on LMST 07 (LMS 1977).

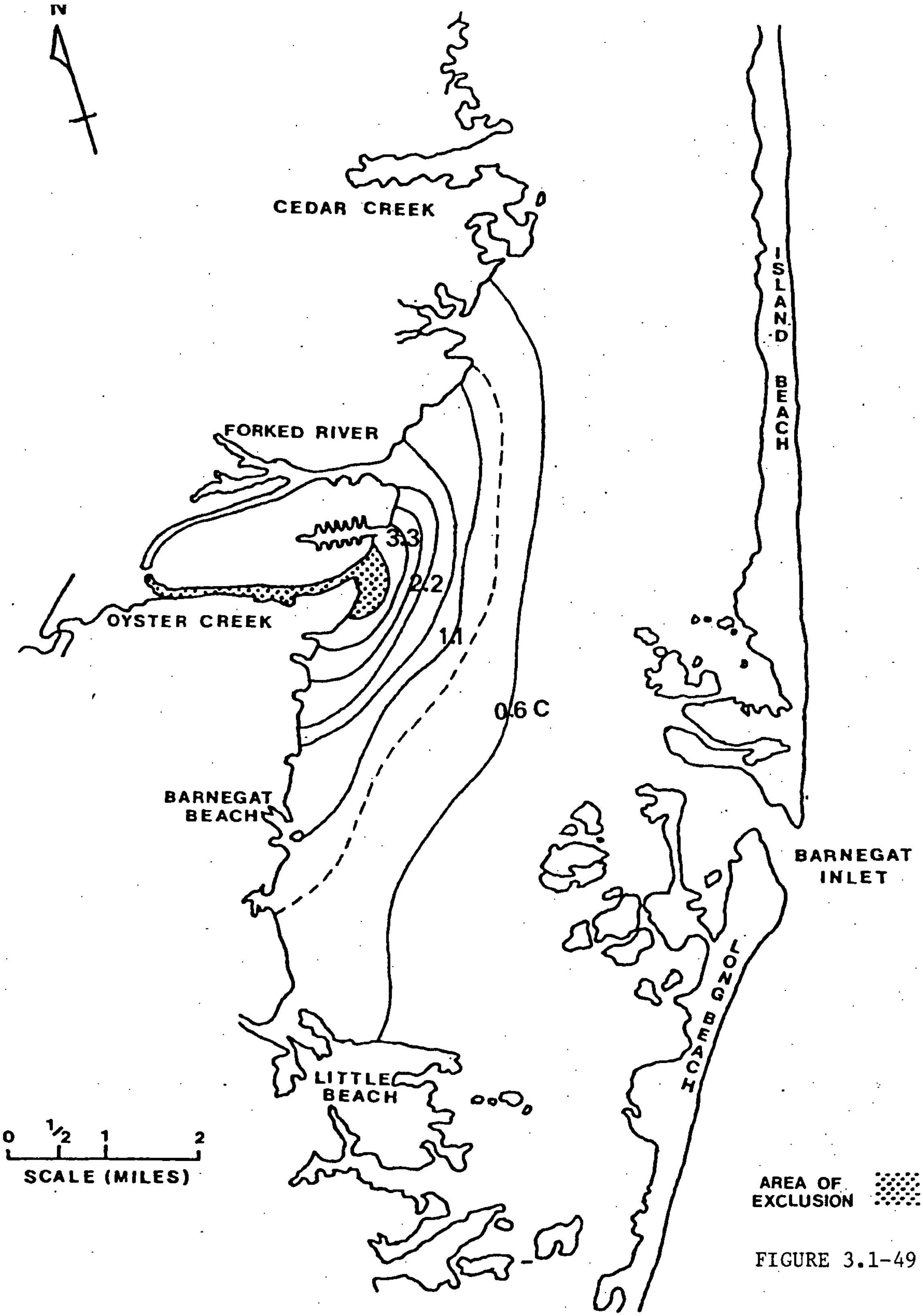
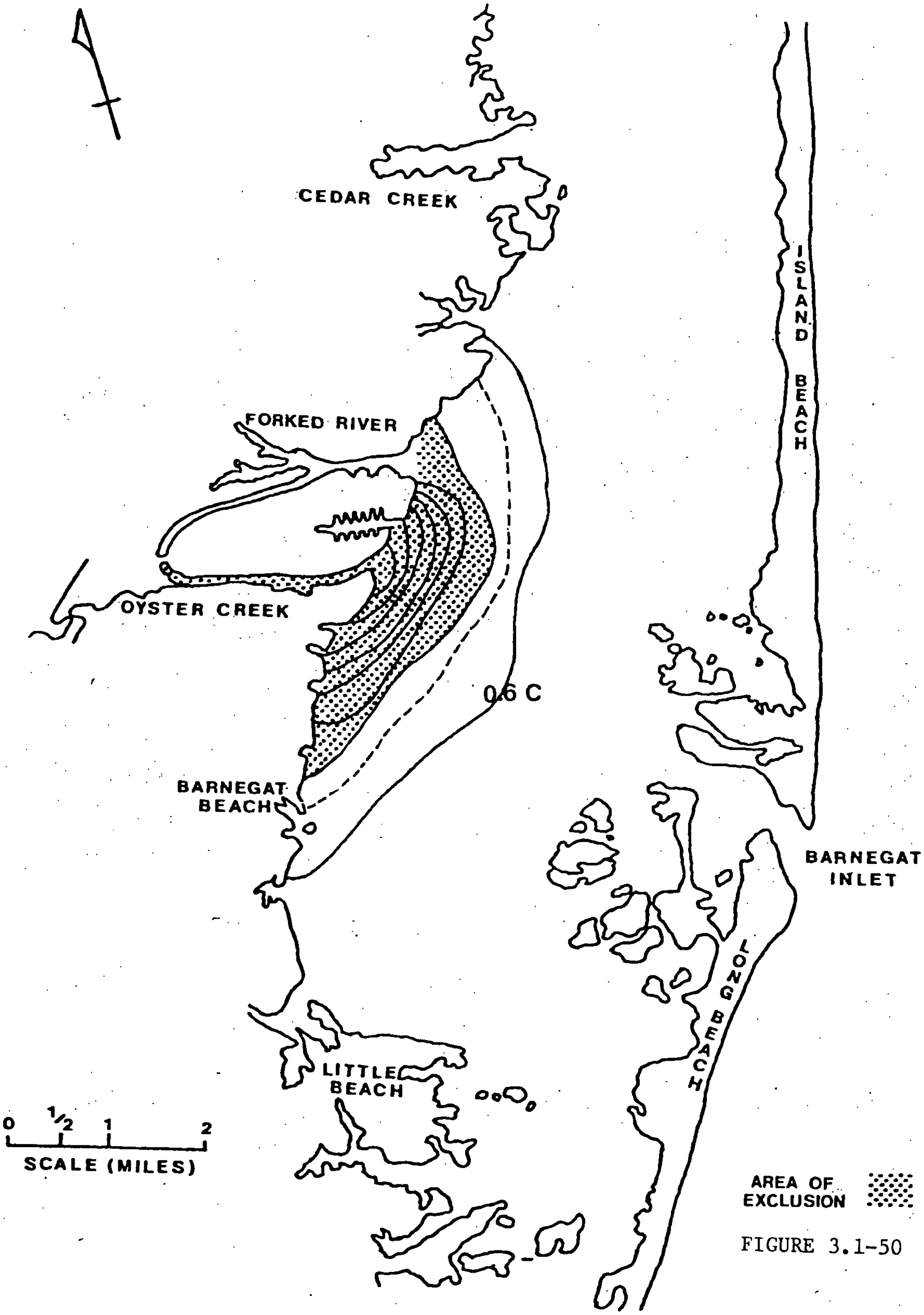

N
CEDAR CREEK
ISLAND BEACH
FORKED RIVER
3.3
2.2
1.1
OYSTER CREEK
0.6 C
BARNEGAT BEACH
BARNEGAT INLET
LONG BEACH
LITTLE BEACH
0 1/2 1 2
SCALE (MILES)
AREA OF EXCLUSION

FIGURE 3.1-49

FIGURE 3.1-50. Area of the OCNGS and FRNGS thermal discharge from which young of the winter flounder will be excluded during July and August. The far field temperature distribution was based on LMST 08 (LMS 1977).



CEDAR CREEK
ISLAND BEACH
FORKED RIVER
OYSTER CREEK
0.6 C
BARNEGAT BEACH
BARNEGAT INLET
LONG BEACH
LITTLE BEACH
0 1/2 1 2
SCALE (MILES)
AREA OF EXCLUSION

FIGURE 3.1-50

FIGURE 3.1-51. Area of the OCNGS and FRNGS thermal discharge from which the northern puffer will be excluded during July and August. The far field temperature distribution was based on LMST 08 (LMS 1977).

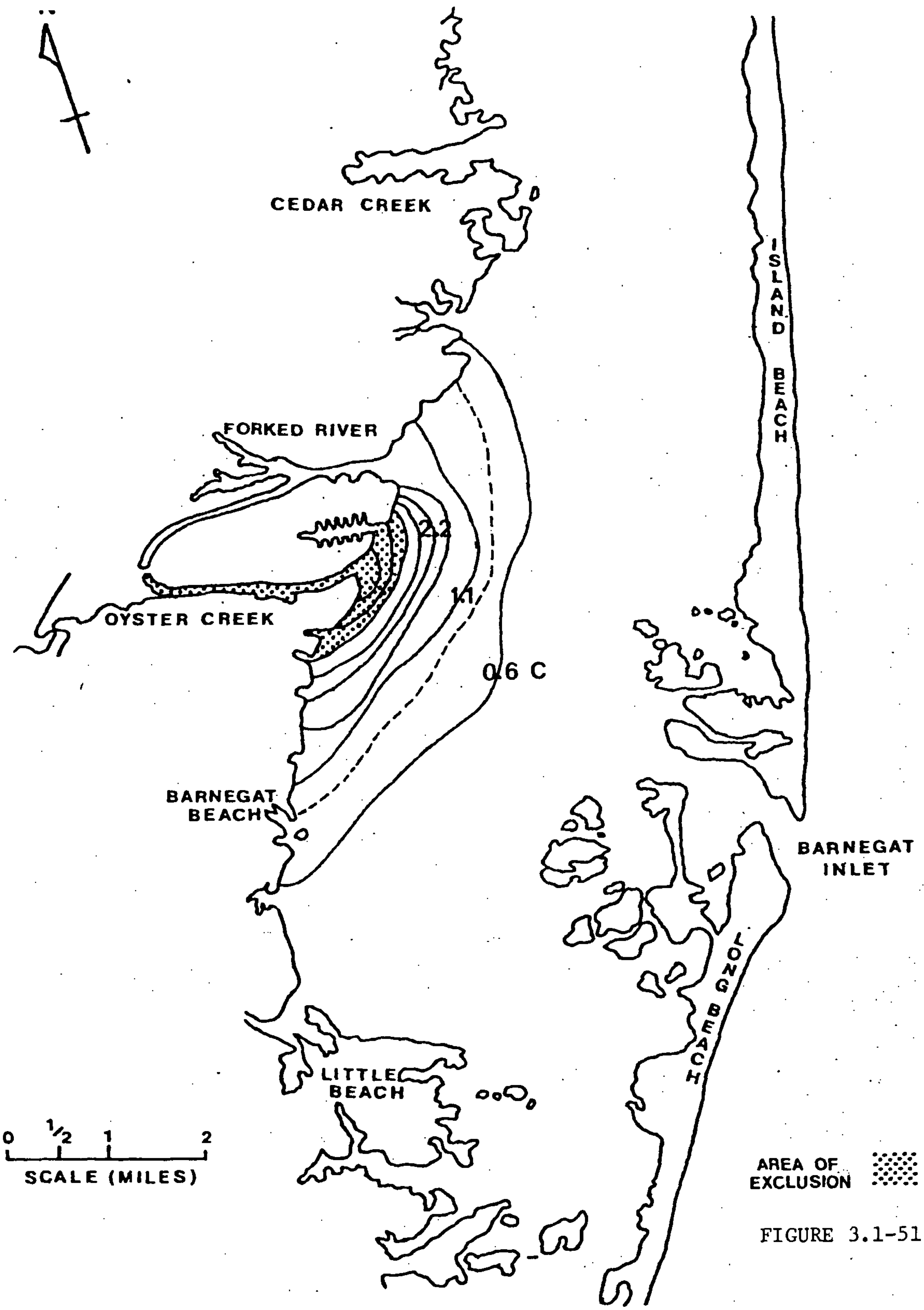

CEDAR CREEK
ISLAND BEACH
FORKED RIVER
2.2
1.1
OYSTER CREEK
0.6 C
BARNEGAT BEACH
BARNEGAT INLET
LONG BEACH
LITTLE BEACH
0 1/2 1 2
SCALE (MILES)
AREA OF EXCLUSION

FIGURE 3.1-51

FIGURE 3.1-52. Area of the OCNGS and FRNGS thermal discharge from which the mysid *Neomysis americana* will be excluded during July and August. The far field temperature distribution was based on LMST 08 (LMS 1977).

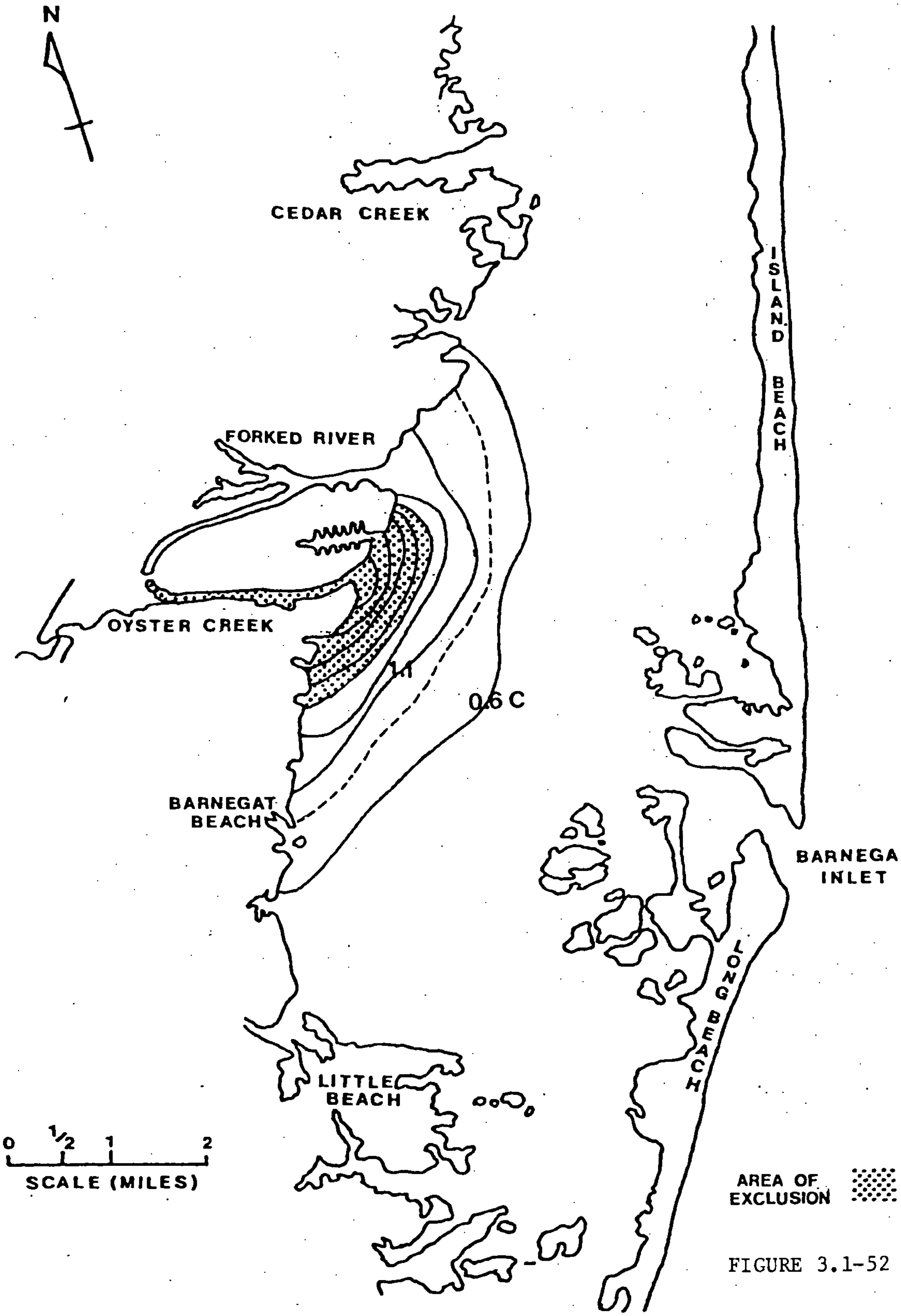

N
CEDAR CREEK
ISLAND BEACH
FORKED RIVER
OYSTER CREEK
1.1
0.6 C
BARNEGAT BEACH
BARNEGA INLET
LONG BEACH
LITTLE BEACH
0 1/2 1 2
SCALE (MILES)
AREA OF EXCLUSION

FIGURE 3.1-52

FIGURE 3.1-53. Area of the OCNGS and FRNGS thermal discharge from which juvenile and adult sand shrimp *Crangon septemspinosa* will be excluded during June. The far field temperature distribution was based on LMST 08 (LMS 1977).

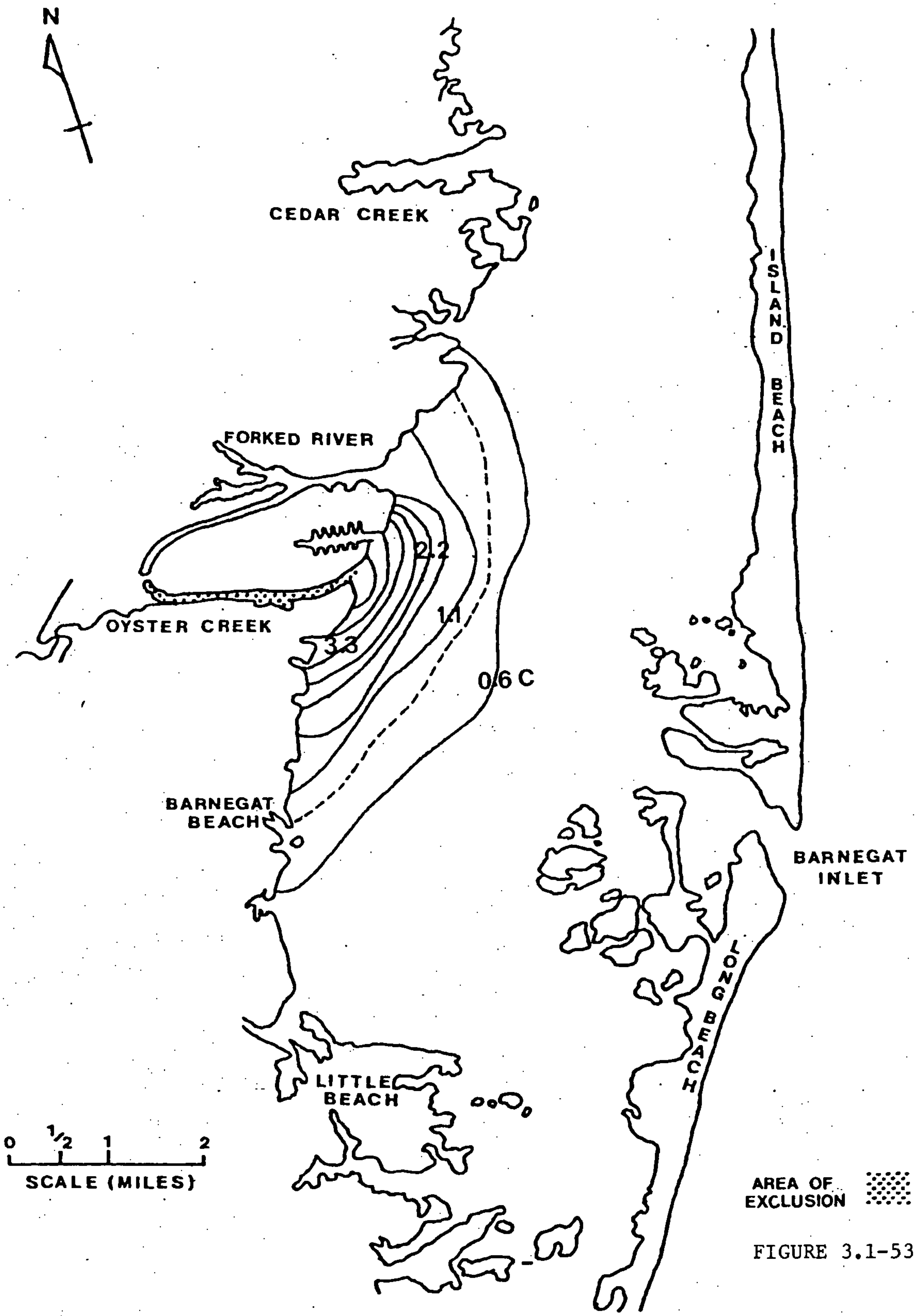

N
CEDAR CREEK
ISLAND BEACH
FORKED RIVER
2.2
OYSTER CREEK
1.1
3.3
0.6 C
BARNEGAT BEACH
BARNEGAT INLET
LONG BEACH
LITTLE BEACH
0 1/2 1 2
SCALE (MILES)
AREA OF EXCLUSION

FIGURE 3.1-53

FIGURE 3.1-54. Areas of greatest abundance (///////) of gravid female blue crab in Barnegat Bay from May through September based on collections taken in July and August.

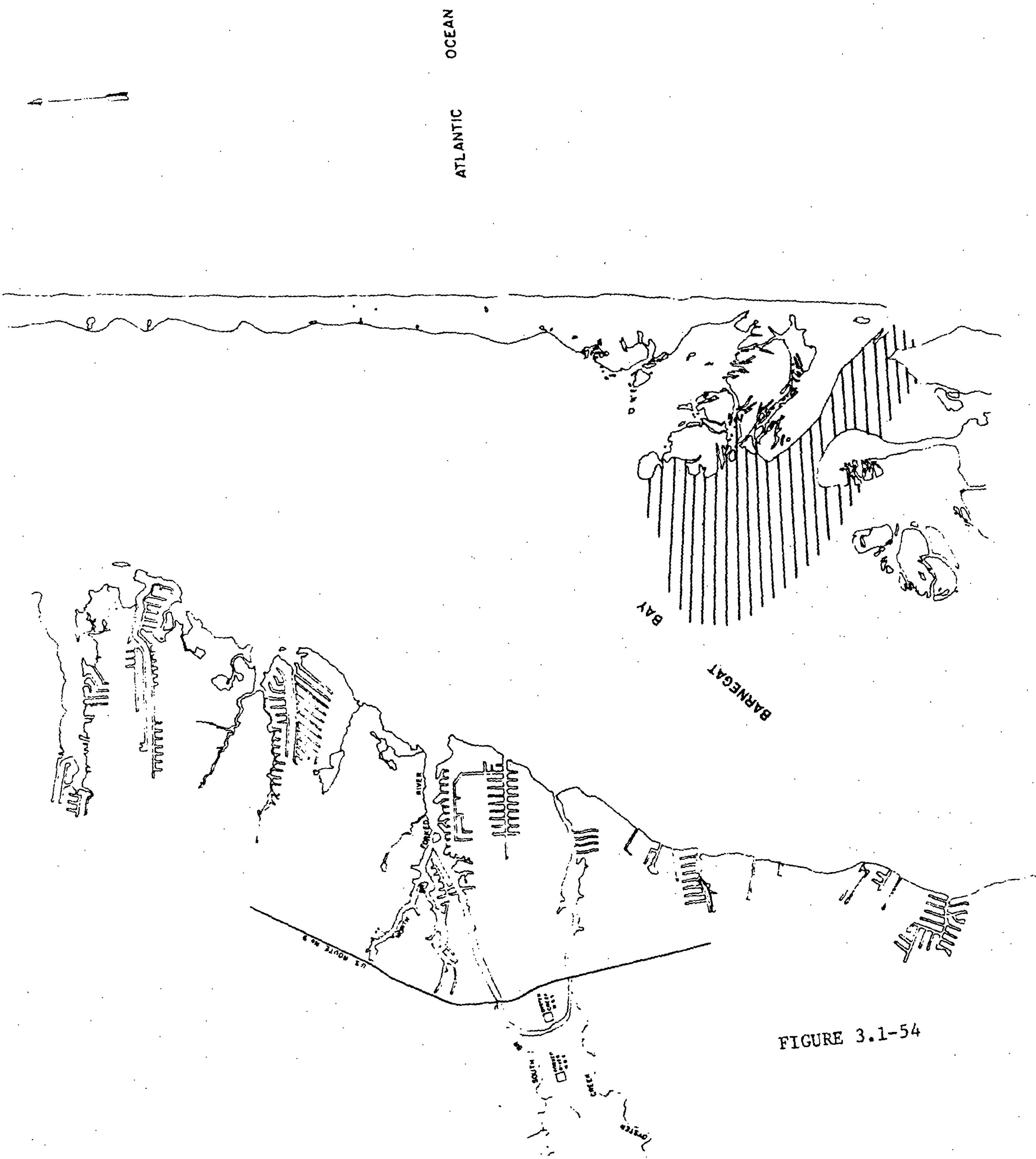

ATLANTIC
OCEAN
BAY
BARNEGAT
FORKED
RIVER
U.S. ROUTE No 9
SOUTH
CREEK
OYSTER

FIGURE 3.1-54

FIGURE 3.1-55. Distribution of blue crab zoeae on 22 June 1977. Collections were taken within the area bounded by the dashed line.

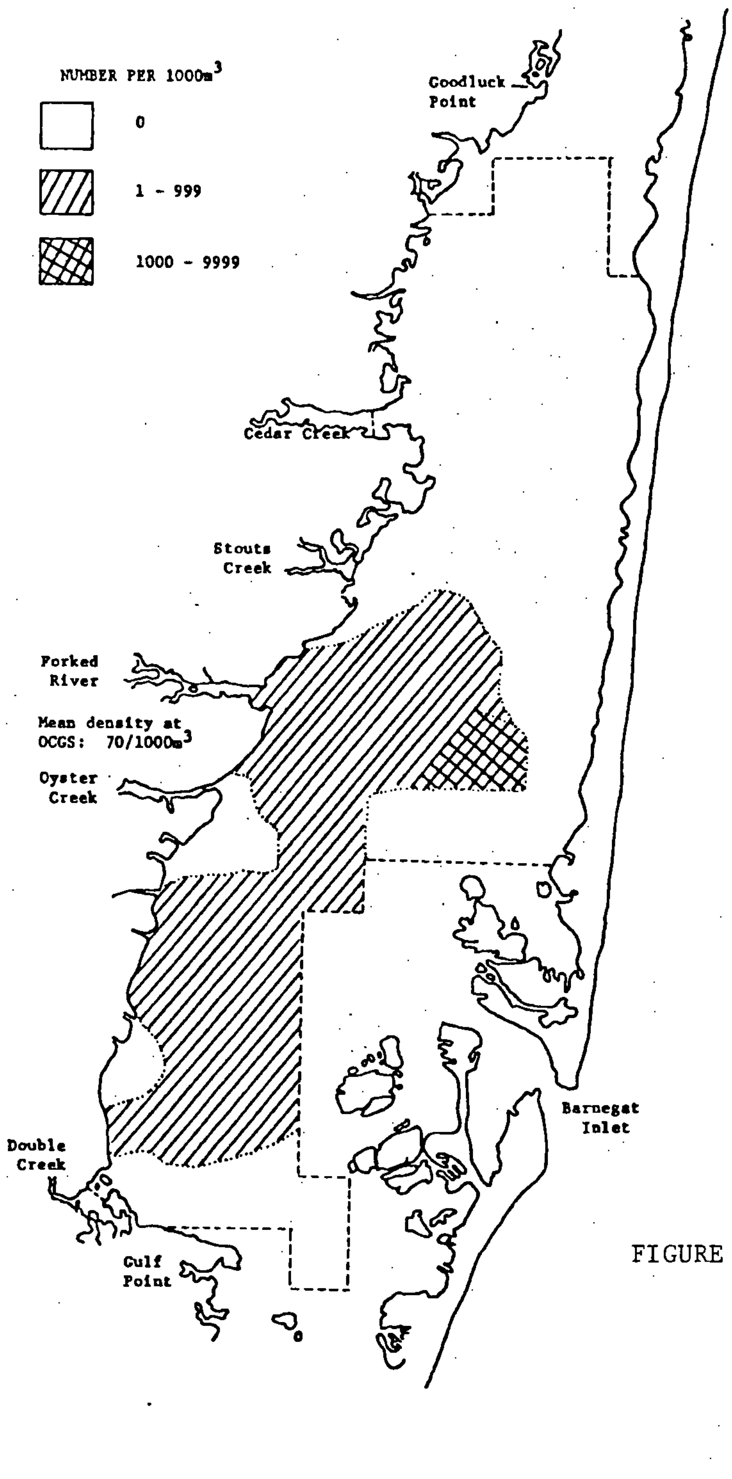

NUMBER PER 1000m^3
0
1 - 999
1000 - 9999
Goodluck Point
Cedar Creek
Stouts Creek
Forked River
Mean density at OCGS: 70/1000m^3
Oyster Creek
Double Creek
Gulf Point
Barnegat Inlet

FIGURE 3.1-55

FIGURE 3.1-56. Distribution of blue crab zoeae on 21 July 1977. Collections were taken within the area bounded by the dashed line.

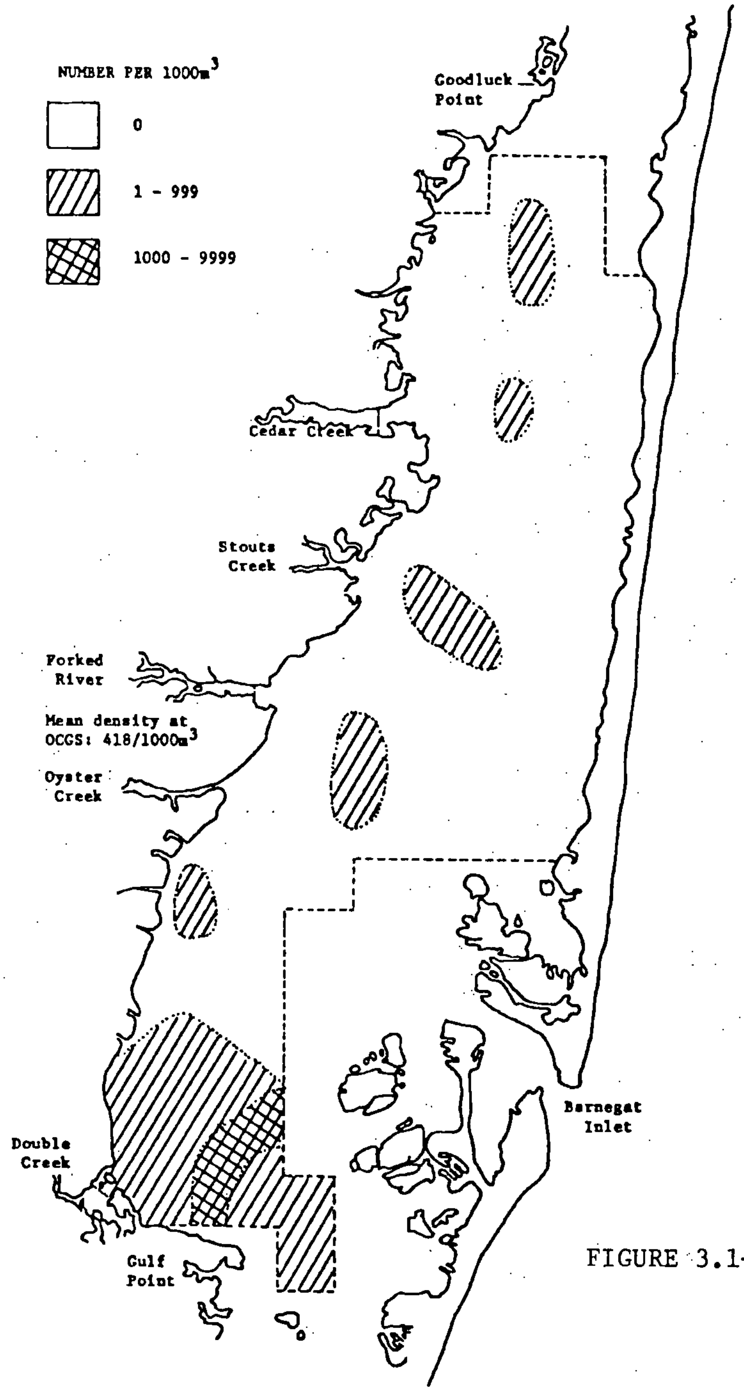

NUMBER PER 1000m³
0
1 - 999
1000 - 9999
Goodluck Point
Cedar Creek
Stouts Creek
Forked River
Mean density at OCGS: 418/1000m³
Oyster Creek
Double Creek
Gulf Point
Barnegat Inlet

FIGURE 3.1-56

FIGURE 3.1-57. Distribution of blue crab megalopae on the night of 19 September 1977. Collections were taken within the area bounded by the dashed line.

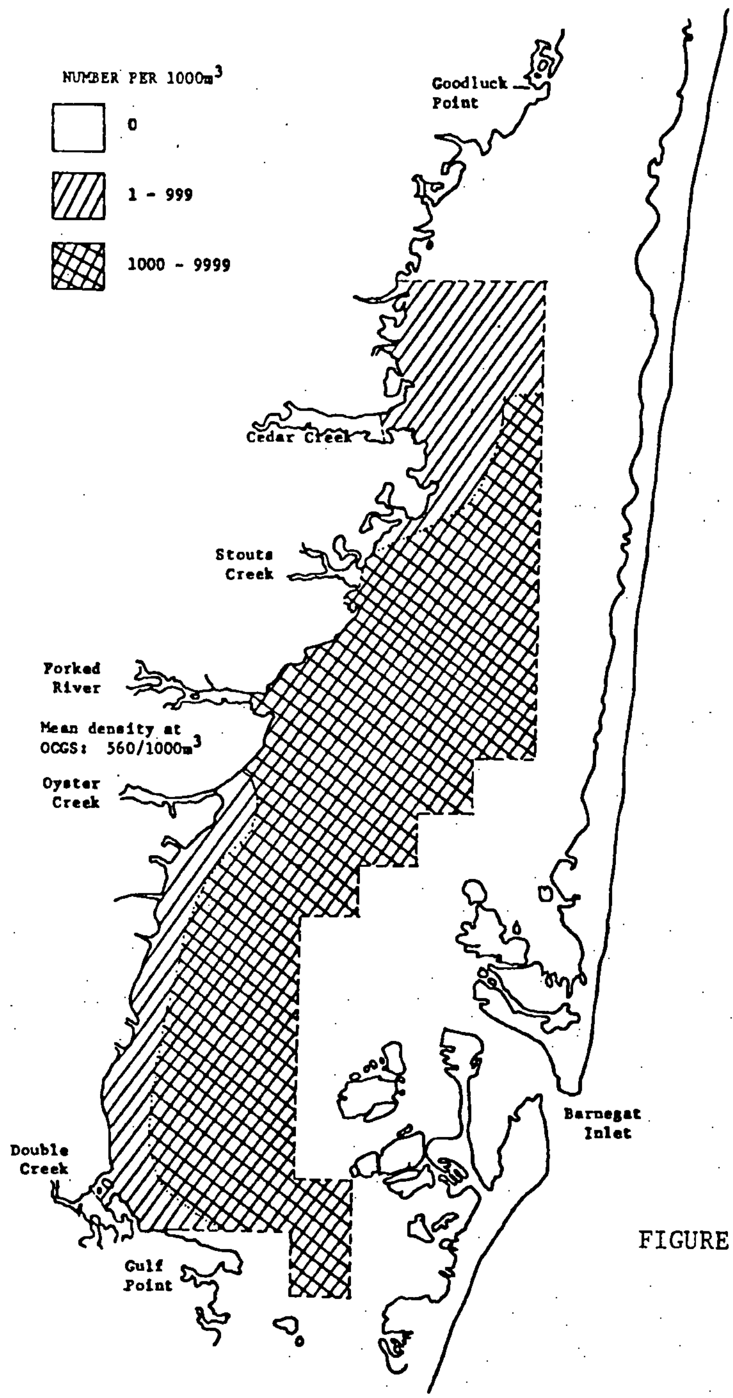

NUMBER PER 1000m³
0
1 - 999
1000 - 9999
Goodluck Point
Cedar Creek
Stouts Creek
Forked River
Mean density at OCGS: 560/1000m³
Oyster Creek
Double Creek
Gulf Point
Barnegat Inlet

FIGURE 3.1-57

FIGURE 3.1-58. Distribution of blue crab megalopae on the night of 28 September 1977. Collections were taken within the area bounded by the dashed line.

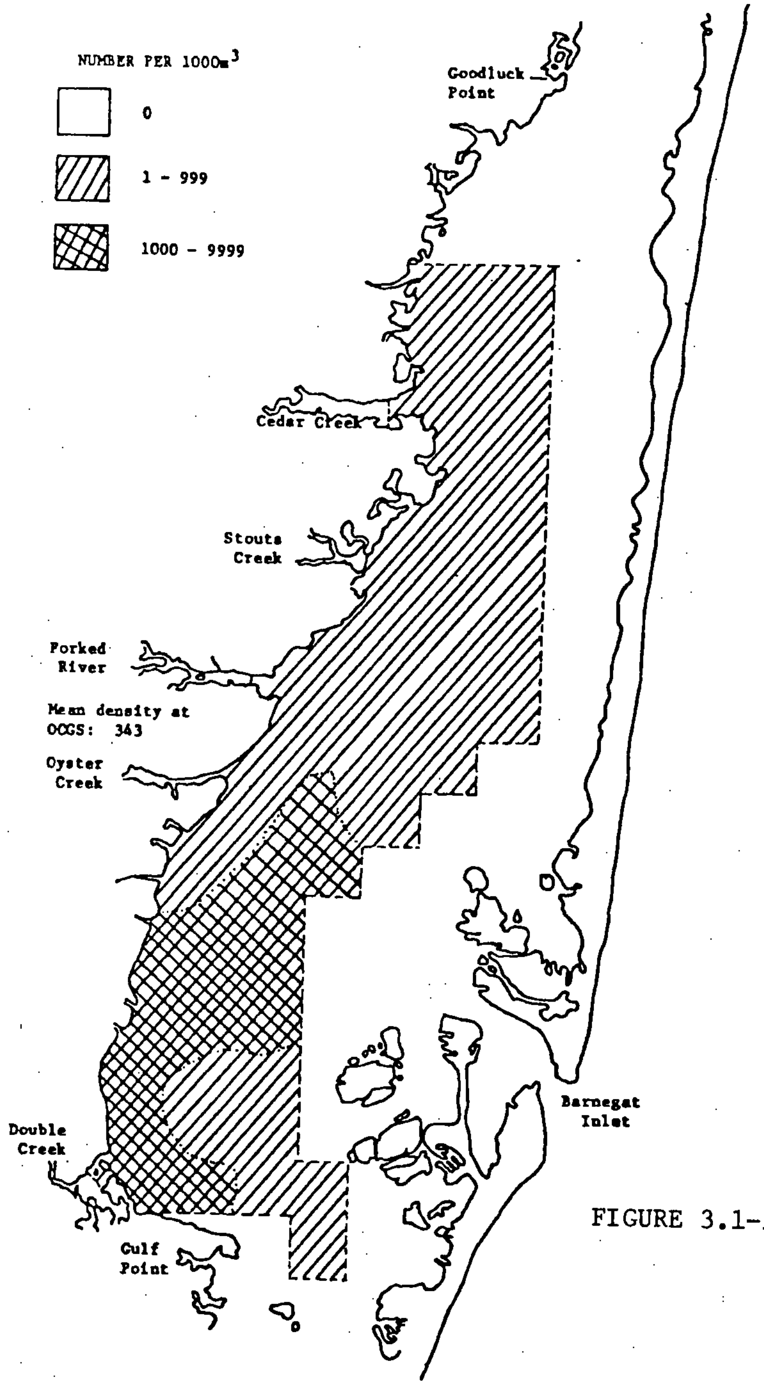

NUMBER PER 1000m³
0
1 - 999
1000 - 9999
Goodluck Point
Cedar Creek
Stouts Creek
Forked River
Mean density at OCGS: 343
Oyster Creek
Double Creek
Gulf Point
Barnegat Inlet

FIGURE 3.1-58

FIGURE 3.1-59. Areas of greatest abundance (///////) of immature blue crab in Barnegat Bay from May through September based on collections taken in July and August.

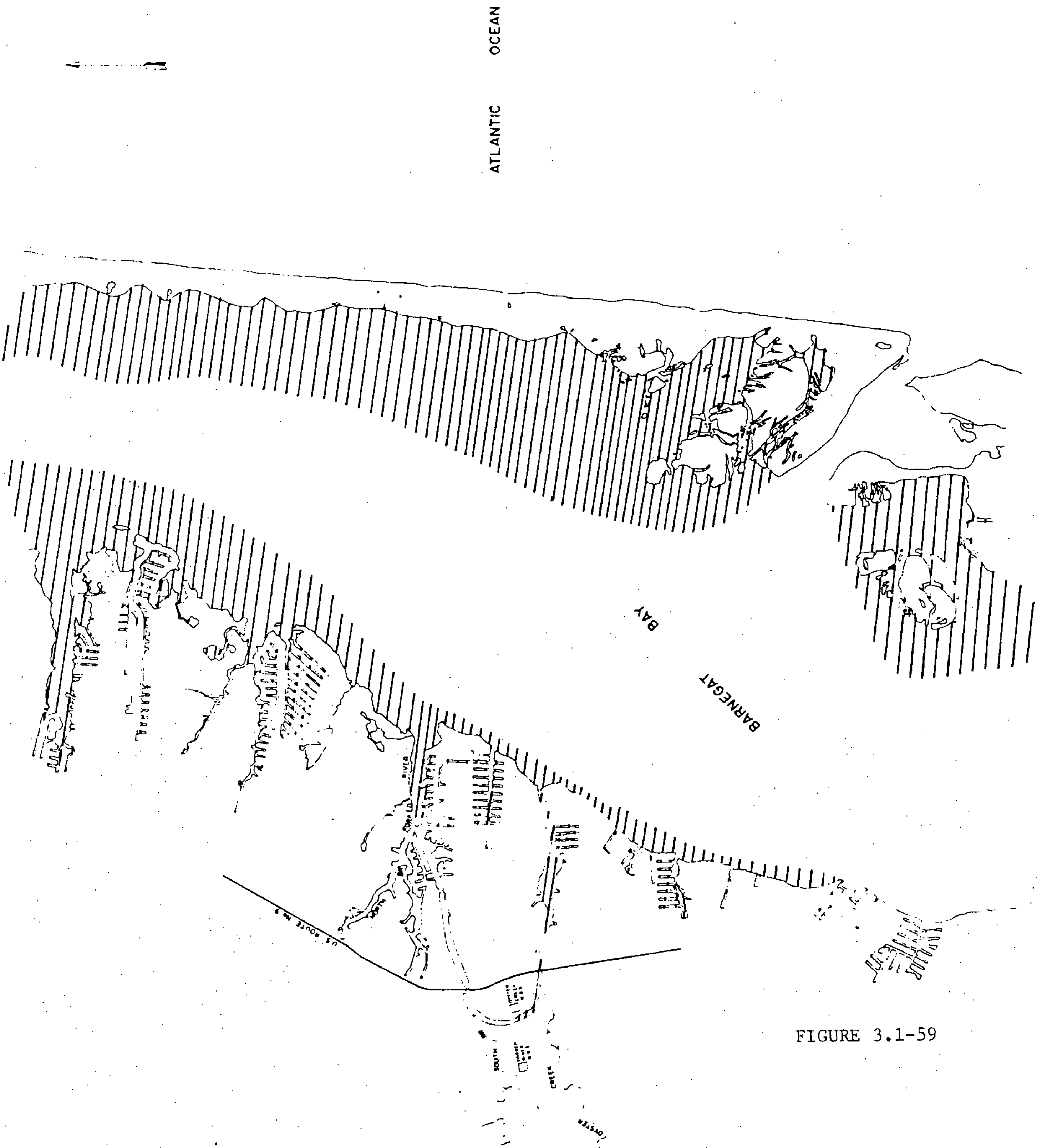


FIGURE 3.1-59

FIGURE 3.1-60. Areas of greatest abundance (///////) of mature male blue crab in Barnegat Bay from May through September based on collections taken in July and August.

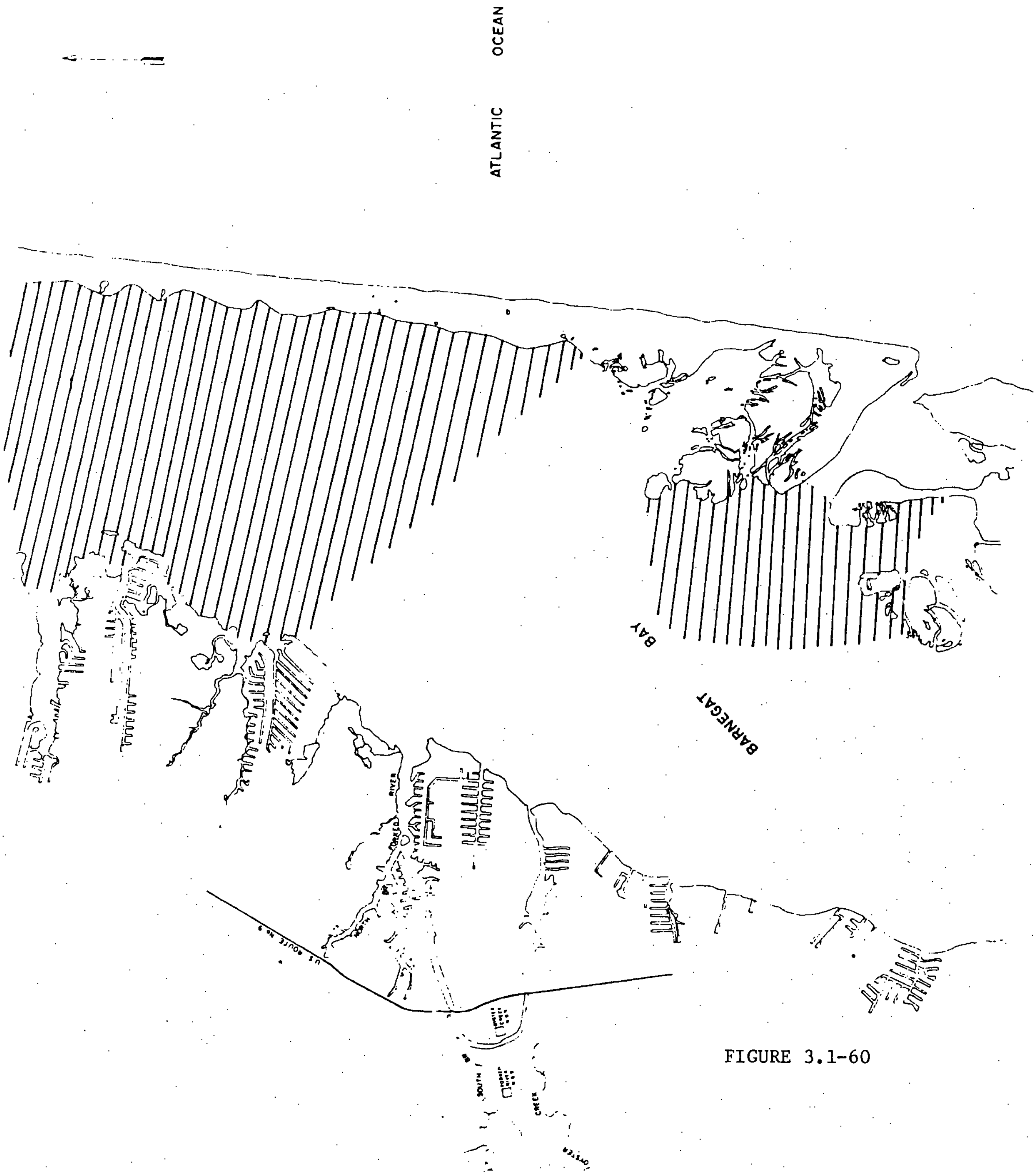


FIGURE 3.1-60

3.2 Absence of Prior Appreciable Harm Test

The results of the RIS demonstration set forth in Section 3.1 showing that the discharges from OCNGS and FRNGS will not interfere with protection and propagation of the balanced, indigenous community of Barnegat Bay, are confirmed by the absence of any appreciable harm caused by the OCNGS in the more than eight years of its operation. Studies on the various biotic categories of the Barnegat Bay community, conducted since 1965, are analyzed in this section.

As discussed hereafter, biological studies have not been conducted continuously since OCNGS began operation in 1969. For example, phytoplankton studies, with but a single exception, have not been undertaken since 1970. Accordingly, some consideration should be made of the timing of the studies when reviewing the data, and the particular modes of operation of OCNGS which obtained when the data were collected.

Generally speaking, thermal discharge conditions have been progressively moderating since OCNGS began operation. In 1970-1973, the standard operating was to operate only one dilution pump, and that only during the summer. In essence, then, the full operating delta T was experienced in the discharge canal and Oyster Creek October through June. The temperature was reduced by approximately 2.7°C (5°F) by operation of one dilution pump July through September, but this procedure was not followed uniformly and there were times during the summer when no dilution pumps were operated. At maximum load in summer, organisms in the discharge canal and Oyster Creek would have been exposed to temperatures as high as 42.2-43.3°C (108 to 110°F).

In 1973, JCP&L began making changes in OCNGS operating procedures to moderate discharge temperatures. Initially, one dilution pump was placed in operation during peak temperature periods, and whenever the intake temperature fell below 10°C (50°F). After modifications were completed to the canals, in only 1975, to permit higher flow rates, two dilution pumps were operated during these periods, reducing discharge temperatures by approximately 50 percent. As indicated by the plant operating records summarized in Table A2-5, two dilution pump operation is now the normal plan operating mode.

3.2.1 Phytoplankton

A number of important investigations of phytoplankton abundance, productivity, and species composition have been conducted in Barnegat Bay. Among these are the work of Martin (1929), Mountford (1967, 1969a, 1969b, 1971), Loveland et al. (1969, 1970, 1971, 1972), and Hein (1977). Martin (1929) examined dinoflagellates in upper Barnegat Bay from 1921 to 1928, and his survey revealed 41 species. Mountford (1967, 1969a, 1969b, 1971), collected four years of data on phytoplankton composition, abundance, and productivity, and also recorded the effects of operation of the OCNGS on these phytoplankton parameters. His research was part of a larger effort of Rutgers University headed by Loveland. Loveland et al. (1969 to 1972) researched the same phytoplankton parameters as Mountford (1969b, 1971), but their work extended from 1967 to 1972, whereas Mountford's was confined to the years 1967 to 1970. Hein (1977) studied the composition, abundance, and diversity of periphytic diatoms in the intake and discharge canals of the OCNGS. His research was undertaken from October 1975 to December 1976. Appendices C6, C7, and C8 contain the studies of Mountford (1969b, 1971), and Hein (1977), whereas section C of the working papers incorporates the reports of Loveland et al. (1967 to 1972). These documents represent the most comprehensive analysis of phytoplankton in Barnegat Bay and the intake and discharge canals before and after operation of the OCNGS. The discussion presented in this chapter draws heavily from the data contained in these works.

Mountford (1969b, 1971) sampled phytoplankton in Barnegat Bay along a 7.5 km (4.7 mi) north-south transect of five stations from 1967 to 1970 (Figure 3.2-1). Phytoplankton samples also were collected from the mouths of the intake and discharge canals of the OCNGS from 1969 to 1970. A total of 700 samples were taken on nearly 100 cruises during the study period, with samples being gathered semimonthly. A complete description of the materials and methods of research employed by Mountford is given in Appendices C6 and C7.

Loveland et al. (1969, 1970, 1971, 1972), sampled the same stations and used the same field and laboratory techniques of data analysis as Mountford (1969b, 1971). From August 4, 1971 to July 27, 1972 only four stations were sampled along the north-south transect (Figure 3.2-1). Station 5 was not sampled during that period.

Hein analyzed more than 200 periphytic diatom samples collected in the intake and discharge canals and in the South Branch of the Forked River (Figure 3.2-2). Between October 8, 1975 and December 19, 1975 diatoms were sampled at two week intervals; between December 19, 1975 and December 5, 1976 diatoms were collected at monthly intervals. Appendix C8 discusses the techniques of sampling and data analyses utilized by Hein. In addition to the data and analyses documented in the above reports, pertinent information on phytoplankton has been obtained from published literature noted in the text and described in the section of references at the end of the section.

With the exception of the work by Hein, no studies have been conduted on phytoplankton in Oyster Creek and Barnegat Bay since 1970. Considering the relatively minor importance of this biotic category to the 316(a) requirements, and the availability of more direct evidence of the vitality of fish and shellfish populations, JCP&L concluded that such studies would not yield additional information necessary to the demonstration. In reviewing JCP&L's plan of study for this demonstration, neither EPA nor NJDEP indicated that further phytoplankton studies would be necessary or useful.

3.2.1.1 Decision criteria

The phytoplankton community of Barnegat Bay and Oyster Creek has been analyzed both prior to and after the commencement of OCNGS operation to determine the extent of any impact upon it by the station's thermal discharge. This analysis has focused on the temporal and spatial variation of phytoplankton community structure (species composition, abundance, diversity, biomass and productivity). If the thermal discharge has had a significant adverse effect on the phytoplankton community, it would have been seen in a variation in the community structure or function which is beyond natural limits.

Phytoplankton are considered under the requirements of Section 316(a) because they may constitute a food source for organisms at higher trophic levels, such as zoo- and meroplankton and some fish species. Additionally, blooms of some species of phytoplankton can adversely affect the suitability of a water body to support other aquatic organisms, as well as render it less useable or unfit for recreational, agricultural or industrial purposes. Although not all phytoplankton blooms are harmful, some can make shellfish unfit for harvesting and otherwise interfere with the maintenance, migration and propagation of natural and established biota. In some cases, blooms may cause mortality of fish or shellfish species by depleting dissolved oxygen.

Considering the foregoing, the demonstration with respect to phytoplankton should be judged successful if the following criteria are met:

(1) There should not be a change in phytoplankton species composition or relative abundance resulting from the domination of the community by nuisance species.

(2) The thermal discharge should not cause the formation of large blooms of phytoplankton which will adversely affect the environmental or biological quality of Oyster Creek or Barnegat Bay.

(3) The thermal discharge should not cause a change in the structure, including biomass, of the phytoplankton community which would produce an adverse effect on the community of fish and shellfish in the bay and Oyster Creek.

If the decision criteria are met, then it may be concluded that the OCNGS discharge has not had an adverse effect on the phytoplankton community, and that this portion of the demonstration has been completed successfully. A failure to satisfy at least the first two criteria, however, would not constitute adequate grounds for denial of a Section 316(a) request. Since the ultimate test of Section 316(a) is the effect only on fish, shellfish and wildlife, changes in the phytoplankton community are material only to the extent that they adversely affect those higher trophic species. If the criteria are not met, then the data should be reviewed to determine whether it is caused by the thermal discharge and, if so, the significance of the condition. If the condition is not caused by OCNGS, or if it will not interfere with the maintenance and functioning of the fish, shellfish and wildlife communities, then the requirements of Section 316(a) pertaining to phytoplankton have been met.

The concept of "nuisance species" connotes organisms which produce toxic, foul tasting or odiferous compounds which impair water quality to the point that processing or purification of water for human consumption is impaired. Since the receiving water in this case are saline and otherwise unsuitable for drinking, the first criteria is not usually applicable to this demonstration type.

The key element of the demonstration for phytoplankton is found in the third criteria. The phytoplankton community should be maintained and function so as to provide an adequate food supply for higher trophic species, and should not produce any conditions which will cause significant stress to fish and shellfish. If the thermal discharge has had an appreciable adverse effect on phytoplankton, such that higher trophic levels could be affected, significant differences should be evident between phytoplankton data collected inside and outside of the thermal plume. This includes differences in species composition, abundance, biomass and primary productivity. Such "local" comparisons are feasible because of the rapid regeneration rates of phytoplankton, which limit the extent to which adverse effects will be observed outside of the immediate area of influence.

3.2.1.2 Rationale

The phytoplankton community in Barnegat Bay, Forked River and Oyster Creek is not appreciably harmed by thermal discharge from the OCNGS. The analysis of phytoplankton species composition, abundance, and primary productivity in both near and far field regions indicates that the phytoplankton community is not significantly different between areas that are affected and unaffected by thermal discharge. A comparison of pre- and operational data also shows that no significant change in phytoplankton species composition, abundance, and primary productivity has been detected in Barnegat Bay. A balanced, indigenous population of phytoplankton exists in the bay, and this population is unaffected by thermal discharge.

Thermal discharge from the OCNGS results in a number of effects on phytoplankton in the discharge canal; a decline in primary productivity, biomass, and diversity of phytoplankton has been demonstrated. In the worst case, Mountford (1971) observed a 30.3 percent reduction in gross productivity, a 20.1 percent decrease in net productivity, and a 17.7 percent reduction in chlorophyll a in Oyster Creek as compared to Forked River. Data from Loveland et al (1972) also reflect a drop in gross and net productivity in Oyster Creek amounting to 11.9 and 35.0 percent, respectively below that of Forked River. None of these differences are statistically significant (P 0.05).

In addition to reporting lower primary productivity and biomass in Oyster Creek than Forked River, Mountford (1971) recorded lower phytoplankton diversity in Oyster Creek following initiation of operations of the OCNGS. Hein (1977) also noted lower diversity values for diatoms in Oyster Creek. However, these changes have not resulted in a major shift in phytoplankton community structure in the discharge canal.

Although thermal discharge from the OCNGS causes some impact on phytoplankton in Oyster Creek, this impact is not substantial. No blooms or pollution-tolerant or nuisance species of phytoplankton have occured in Oyster Creek or in the bay within the area of the thermal plume. Because of the short generation time of phytoplankton, the partial reduction of primary productivity, abundance, and diversity in Oyster Creek does not adversely affect organisms at higher trophic levels. As discussed in Section 3.1 regarding individual representative, important species, and in other biotic category rationales in this section, no unexplained changes have occurred in the community structure of higher trophic levels which could be attributed to a change in the phytoplankton community.

3.2.1.3 Structure of the indigenous community

3.2.1.3.1 Composition, abundance and seasonal succession

Barnegat Bay contains a highly diverse assemblage of phytoplankton. More than 180 species of phytoplankton have been identified in the bay -- a figure which is consistent with other estuaries along the East Coast of the United States (Brooks et al, 1974). Table 3.2-1 lists the phytoplankton sampled by Mountford (1969b) from April 1967 to April 1969. Species of diatoms and dinoflagellates far outnumber all others, but only a small percentage of these species are numerically important during a given season.

The most conspicuous characteristic of phytoplankton in Barnegat Bay is its seasonal periodicity in species composition and abundance (Mountford, 1971). This periodicity is similar to that observed in other East Coast estuaries (Pattern et al, 1963; Marshall, 1967; Riley, 1967; Carpenter, 1971; Brooks et al, 1974). Seasonal shifts in the appearance and disappearance of 44 species and groups of species of phytoplankton in the estuary from 1967 to 1970 are presented in Figure 3.2-3. The seasonal cycles in occurrence of these organisms largely reflect the influence of changes in water temperature, photoperiod, and nutrient supply on the phytoplankton community. A persistent trend of alternating warm and cold water flora is evident. Many other species of phytoplankton also have distinct cycles in abundance, but they are present in at least trace quantities year round. Tables 3.2-2, 3.2-3 and 3.2-4 depict seasonal changes in water temperature and salinity in Barnegat Bay, Forked River and Oyster Creek through an annual phytoplankton cycle.

Phytoplankton abundance reaches a maximum in the summer and a minimum in the winter. Summer phytoplankton counts exceed 10^6 cells/l (Figure 3.2-4). Ultraplankton, chiefly Nannochloris, dominate the summer flora, attaining densities greater than 10 x 10^6 cells/l. The exact density of ultraplankton is difficult to assess because of the small size (2-4 microns) of the organisms and their extreme abundance (Figure 3.2-4). Microflagellates including Cryptomonas, Bipedomonas, and Pyraminas also are extremely abundant during the summer months, attaining concentrations greater than 10^6 cells/l at various times. Next to ultraplankton, nanoplankton (predominantly microflagellates) are the most numerous phytoplankton organisms in the bay.

Dinoflagellates surpass 10^6 cells/l during the summer when they are dominant. Occasionally, red tide blooms and intense bioluminescent activity characterize the dinoflagellate populations (Martin, 1929). The small naked forms Gymnodinium incoloratum, G. punctatum, Gonyaulax digitale, and G. spinifera are most important among the Dinophyceae. Thecate forms, particularly the genus Prorocentrum (P. redfieldi, P. micans, P. scutellum, P. triangulatum), also contribute significant numbers to the phytoplankton.

Only three diatoms have been found to be significantly abundant during the warmer months, Cyclottella sp., Nitzschia closterium, and Skeletonema costatum. Of these three, only Cyclotella sp. is consistently abundant from one summer to the next. The paucity of diatoms during the summer season is not surprising, considering they are essentially cold floral constituents.

The abundance of phytoplankton decreases in the fall, but much of the autumn community represents an extension of summer populations. In mid- to late fall, distinctly cold-water flora such as Thallassiomena nitzchiodes, Amphiprora sp., and Lichmophora begin to reestablish populations, and warm-water dinoflagellates gradually decline. By early to midwinter, diatoms dominate the flora, and the overall abundance of phytoplankton drops to a minimum.

A diatom bloom develops in Barnegat Bay in mid- to late winter as water temperature and light intensity increases. Thalassiosira nordenskioldi, Detonula confervacea, and D. cystifera are numerically the most significant members of the bloom. Thalassiosira outnumbers all diatoms. Although the diatoms are important constituents of the bloom, microglagellates exceed them in total numbers (615 of every 1119 cells are microflagellates). Microglagellates seem to be important numerically irrespective of season as many different species are included in this group.

Intense graxing of zooplankton (especially Acartia) terminates the winter-spring algal bloom. Skeletonema constatum, a residual species during the winter-spring bloom, replaces the Thalassiosira-Detonula complex in the spring as temperature rises from 2 to 20°C (35.6 to 68°F) and light intensity increases (Riley, 1966). In the early summer, as temperature rises above 20°C (68°F), the phytoplankton community shifts to a dominantly dinoflagellate composition. Increasing water temperature also favors the renewal of large populations of ultraplankton and microflagellates.

The composition of phytoplankton in the intake and discharge canals of the OCNGS is similar to that of Barnegat Bay. However, phytoplankton productivity is generally lower in both Oyster Creek and Forked River than in the bay (Loveland et al, 1972).

Hein (1977) identified 197 diatom taxa in Forked River and 145 in Oyster Creek. The most abundant taxa in Forked River in decreasing order of abundance were the following: (1) Skeletonema costatum; (2) Navicula pseudincerta; (3) Amphipleura rutilans; (4) Nitzschia dissipata; and (5) Nitzschia kutzingiana. Navicula pseudincerta was the most evenly distributed species The most abundant taxa in Oyster Creek in decreasing order of abundance were: (1) Navicula pseudincerta; (2) Skeletonema costatum; (3) Amphipleura rutilans; (4) Amphora coffeaeformis var. borealis; (5) Nitzschia communis var. abbreviata. Amphipleura rutilans was the most uniformly distributed species in the discharge canal.

Diatoms were most abundant in Oyster Creek and Forked River during the spring, fall, and winter and least abundant during the summer. Table 3.2-5 gives the seasonal distribution of the most abundant diatom taxa and some of the less abundant taxa. Of the dominant taxa Skeletonema costatum comprised the largest proportion of the populations during the winter; Navicula pseudincerta was most successful during late fall and winter; and Amphipleura rutilans was most abundant during the spring and fall. Nitzschia kutzingiana was more abundant in Oyster Creek during the summer. Nitzchia communis var. abbreviata attained maximum numbers in the summer, and Amphora coffeaeformis var. borealis reached maximum levels in the summer and fall.

3.2.1.3.2 Biomass

Seasonal changes in phytoplankton abundance in Barnegat Bay are reflected in biomass measurements. Using chlorophyll a concentrations as estimates of biomass, Mountford (1971) observed maximum values during the winter-spring diatom blooms. Secondary chlorophyll a maxima occurred during the summer, and were associated with peak cell numbers. Appendix IX in Appendix C7 lists chlorophyll a values at five bay stations in 1969 and 1970.

The temporal variation of chlorophyll a concentrations in Barnegat Bay, Forked River and Oyster Creek for 1969 and 1970 are depicted in Figures 3.2-5 and 3.2-6, respectively. The time of occurrence of maximum concentrations is similar for both the bay and the two streams with peak chlorophyll concentrations taking place in July 1969 and February 1970. Chlorophyll a levels are consistently lower in the summer of 1970 than in the summer of 1969. Phytoplankton were exceptionally abundant in the summer of 1969 (Figure 3.2-4) in Barnegat Bay, which would account for this difference.

Temporal and spatial variations in chlorophyll a concentrations are observed. Over an annual cycle, chlorophyll a levels range from 1 to 30 mg/l. This range of values is comparable to that of Chesapeake Bay (Flemer, 1970), but is less than that of other estuaries such as the Indian River estuary which has an annual chlogophyll a range from 10 to 400 mg/l (Brooks et al, 1974).

For any given date, the chlorophyll a values vary from one station to another in Barnegat Bay and in Forked River and Oyster Creek. The spatial variation of chlorophyll a is caused by the patchy distribution of phytoplankton in the bay. However, this variation seems to be less than that observed in other estuaries such as the Indian River estuary (Brooks et al., 1974), Chesapeake Bay (Flemer, 1970; Loftus et al, 1972), and the Patuxent River estuary (Stross and Stottlemyer, 1965) where chlorophyll a can vary by several orders of magnitude from one station to the next.

Table 3.2-6 shows the variation in chlorophyll a values in Barnegat Bay between April 16 and December 1, 1970 (OCNGS operating). This table contains the most complete and balanced set of chlorophyll a data for the bay, because replicate samples exist for each of five sampling stations. The mean chlorophyll a concentrations during this time interval range from a low of 6.6 mg/l at station 4 to a high of 7.6 mg/l at station 1 (Table 3.2-7). A single factor analysis of variance test performed on this data shows that chlorophyll a values are not significantly different ($P < .05$; $F = .73$) between stations 1 through 5 from April 16 to December 1, 1970.

Similar measurements hold for Forked River and Oyster Creek (Table 3.2-8). In 1969, the mean chlorophyll a concentration at station 6 (intake) was 9.4 mg/l, whereas it was 11.6 mg/l at station 7 (discharge). In 1970, the mean chlorophyll a minimum occurred at station 7 (8.1 mg/l) and the maximum at station 6 (9.9 mg/l). The Wilcoxon test (nonparametric) employed on these data reveals no significant difference in chlorophyll a measurements between stations 6 and 7 for 1969 ($P < .05$; $Z = .62$) and 1970 ($P < .05$; $Z = -.86$). Absolute chlorophyll a measurements indicate, however, an unpredictable temporal variation in the spatial distribution of biomass levels in Barnegat Bay, Forked River and Oyster Creek.

3.2.1.3.3 Primary productivity

Rates of primary production in Barnegat Bay follow a seasonal periodicity that is closely correlated with seasonal temperature and phytoplankton abundance cycles.

Mountford (1971) and Loveland et al. (1972) recorded maximum rates of primary production during the summer when temperature and phytoplankton abundance peaked. Minimum rates of primary production were observed during the winter when temperature and phytoplankton abundance fell to their lowest levels. A similar pattern of primary production is documented for other East Coast estuaries such as Chesapeake Bay (Flemer, 1970), the Beaufort estuarine system (Thayer, 1971), and the Indian River estuary (Brooks et al, 1974). Appendix VII in Appendix C7 discloses primary productivity determinations in Barnegat Bay between March 1969 and December 1970. Over an annual phytoplankton cycle, absolute gross productivity values range from near 0 mg $0_2/m^3$/hr in the winter to greater than 500 mg $0_2/m^3$/hr in the summer.

Figure 3.2-7 displays mean gross productivity values at five bay stations from 1969 to 1970 and at four bay stations for the summers of 1971 and 1972. Gross productivity at Forked River and Oyster Creek for the summer and fall of 1970 and for the spring and summer of 1972 is plotted in Figure 3.2.-8. Both figures indicate that peak gross productivity occurs at all stations during the warmer months of the year. The warmer months are also the time of greatest plankton respiration (Appendix VIII in Appendix C7).

Table 3.2-9 records gross productivity measurements at five bay stations from May 28 to December 1, 1970 (OCNGS operating). Because replicate samples of gross productivity are documented for each of the five sampling stations, this table retains the most complete and balanced set of gross productivity data for the bay. Table 3.2-10 tabulates the mean gross productivity at stations 1 through 5 for the period of May 28 to December 1, 1970. The values range from a high of 268.0 mg $0_2/m^3$/hr at station 6 to a low of 216.2 mg $0_2/m^3$/hr at station 5. A single factor analysis of variance test conducted on this data reveals no significant difference ($P < 0.05$; $F = 0.42$) in gross productivity between all stations.

Gross productivity, net productivity, and respiration values at stations 1 through 4 in 1971 and 1972 are presented in Table 3.2-11. These data reflect important spatial and temporal variations in primary productivity in Barnegat Bay. For example, station 3 contained the lowest gross and net productivity in 1971 (223.5 and 70.5 mg $0_2/m^3$/hr, respectively).

Station 1 possessed the lowest gross and net productivity in 1972 (178.3 and 110.8 mg $O_2/m^3/hr$, respectively) (Table 3.2-12). Primary productivity, therefore, is not consistently highest or lowest at any one station through time.

Although spatial and temporal variations in gross and net productivity occurred at stations 1 through 4 in 1971 and 1972, these differences are not statistically significant. For instance, a single factor analysis of variance test conducted on gross and net productivity data of 1971 and 1972 at stations 1 through 4 indicates no significant difference between stations ($P < 0.05$; $F = 0.31$ for gross productivity: $P < 0.05$; $F = 0.14$ for net productivity).

Table 3.2-13 gives absolute gross productivity, net productivity, and respiration measurements in 1970, 1971 and 1972, and Table 3.2-14 exhibits mean gross and net productivity determinations during these years in Forked River and Oyster Creek. Once again, the data reflect the existence of spatial and temporal variations in primary productivity, with no station being consistently highest or lowest through time. For example, station 6 had the highest gross and net productivity in 1970 and 1971, but station 7 had the highest readings in 1972.

The Wilcoxon test (nonparametric) executed on gross and net productivity data collected in 1970, 1971, and 1972 at stations 6 and 7 reveals no significant difference between the two stations. In 1970, gross and net productivity were not significantly different between the stations ($P < 0.05$; $Z = -0.32$ for gross productivity: $P < 0.05$; $Z = -0.63$ for net productivity). This was also true for the combined years of 1971 and 1972 ($P < 0.05$; $Z = -0.32$ for gross productivity: $P < 0.05$; $Z = -0.21$ for net productivity).

3.2.1.4 Observed Responses to the OCNGS Discharge

3.2.1.4.1 Effect in Barnegat Bay

Mountford (1971) could not detect any change in phytoplankton composition and abundance in Barnegat Bay which could be attributed to operation of the OCNGS. He also observed no substantial change in the average number of phytoplankton species in the bay subsequent to operation of the OCNGS. There has been no reported shift in the phytoplankton community toward pollution tolerant or nuisance species due to thermal discharge of the OCNGS.

For the period June through October 1969, Mountford (1971) found chlorophyll a and phytoplankton cell numbers to be highest at stations 2 and 3 and lowest at station 5 where more rapid renewal of ocean water occurs. During operation of the OCNGS from June through October 1970, station 2 had the highest chlorophyll a counts and stations 3, 4 and 5 the lowest.

It has already been shown that for the interval from April to December, 1970, stations 1 and 3 had the highest chlorophyll a concentrations and station 4 the lowest (Tables 3.2-6 and 3.2-7). But there was no significant difference ($P < 0.05$) in these values. Thus, no major change in biomass occurred at station 3 (affected by thermal discharge) subsequent to operation of the OCNGS.

Mountford (1971) noted that station 3 was highly productive from June through October 1969, being significantly more productive ($0.010 < P < 0.025$) than station 5 which served as a control station (unaffected by thermal discharge). Subsequent to operation of the OCNGS, from June through October 1970, Mountford discovered stations 3 and 5 to be no longer significantly different ($P < 0.05$) in terms of gross productivity.

All five stations had lower gross productivity in 1970 than 1969. The mean gross productivity for stations 1 through 5 is not significantly different ($P < 0.05$) for the interval from May to December, 1970 (Table 3.2-10). Since stations 1 and 5 are considered to be control stations outside the influence of thermal discharge and station 3 is not unlike these locations in respect to mean gross productivity, it is concluded that thermal discharge from the OCNGS has not adversely affected primary productivity in Barnegat Bay. This conclusion is supported by the data of Loveland et al. (1972) which demonstrate that a substantial variation existed among all stations and that station 3 was not consistently lowest in primary productivity in 1971 and 1972 (Table 3.2-11).

3.2.1.4.2 Effect in Oyster Creek and Forked River.

A number of differences in phytoplankton parameters between Forked River and Oyster Creek were observed by Mountford (1971), Loveland et al (1972), and Hein (1977) after operation of the OCNGS. Mountford (1971) determined from ten samples collected on five cruise dates between July 23, 1970 and December 6, 1970 that gross productivity in Oyster Creek (station 7) was depressed an average of 92.4 mg $O_2/m^3/hr$ (a 30.3 percent reduction) below that of Forked River (station 6). In applying a parametric statistical test, Mountford (1971) determined that gross productivity at the two stations was not significantly different at the 0.05 level but was significantly different at $0.05 < P < 0.10$. He attributed this depression in productivity to a decrease in the number of microflagellates and dinoflagellates in Oyster Creek which, in turn, was reflected as a general decrease in chlorophyll a concentrations at station 7 (Table 3.2-8).

The parametric statistical test utilized by Mountford assumed normality of the data and, considering the few data points examined (ten samples), this would be a difficult assumption to realize. In this case, a nonparametric statistical test would be more appropriate, because it makes no assumptions of normality or any specific distribution of the data and is analogous to normal theory procedures (Pine and Hubert, 1977).

Mountford's ten samples have been reanalyzed with this in mind. Applying the Wilcoxon text (nonparametric), gross productivity values at stations 6 and 7 were not found to be significantly different ($P < 0.05$; $Z = .73$).

Although Mountford (1971) found a mean gross productivity difference of 92.4 mg $O_2/m^3/hr$ between stations 6 and 7 from July to October 1970, gross productivity at station 7 averaged only 41.0 mg $O_2/m^3/hr$ less (a 16.6 percent reduction) than station 6 for 16 samples collected between July and December 1970. Net productivity between July and December 1970 averaged 27.2 mg $O_2/m^3/hr$ less (a 23.3 percent reduction at station 7 than station 6). Respiration was higher at station 7, averaging only 0.025 mg $O_2/m^3/hr$ above station 6 for the five month interval.

Only three out of eight samples taken by Loveland et al (1972) from station 6 in Forked River in 1971 and 1972 had higher gross productivity measurements than comparable samples taken from station 7 in Oyster Creek (Table 3.2-13). Gross productivity in Oyster Creek averaged 22.2 mg $O_2/m^3/hr$ less than in Oyster Creek (a 11.9 percent reduction), and net productivity at the discharge canal averaged 36.5 mg $O_2/m^3/hr$ less than in Forked River (a 35 percent reduction) for the combined years of 1971 and 1972). Both gross and net productivity differences were not statistically significant, however ($P < 0.05$; $Z = 0.32$ for gross productivity: $P < 0.05$; $Z = -0.21$ for net productivity) for those years.

In addition to documenting lower primary productivity at station 7 compared to station 6, Mountford (1971) reported a decrease in phytoplankton diversity at station 7 subsequent to operation of the OCNGS. Based on 22 pairs of samples from stations 6 and 7, phytoplankton diversity was higher at station 7, 63 percent of the time prior to operation of the OCNGS. After operations commenced, however, diversity was lower at station 7, 91 percent of the time. Mountford (1971) assumed that this drop in diversity was due to a selective loss of several phytoplankton groups during station operations, although this has never been proven.

Hein (1977) identified similar changes in diatom assemblages in Forked River and Oyster Creek during 1975 and 1976. Responses of some taxa indicate they were temperature sensitive, but others appeared to be unaffected by the temperature differences (Table 3.2-15). During station operations, the mean species diversity index and the mean number of diatoms encountered in Oyster Creek were lower than in Forked River. The mean redundancy index, however, was higher in Oyster Creek during these periods (Table 3.2-16).

During an extended outage of the OCNGS from December 26, 1975 to March 3, 1976, the assemblages of diatoms in Oyster Creek and Forked River were similar as indicated by the small degree of difference (Dhk) between the two areas (Table 3.2-17). Following the renewal of OCNGS operations, the degree of difference values (Dhk) increased.

In total, Hein (1977) observed 40 diatom taxa in Forked River that were not found in Oyster Creek. He identified only 15 taxa in Oyster Creek that were absent in Forked River.

3.2.1.4.3 Analysis of the effect of OCNGS discharge on the phytoplankton community

Based on the data of Mountford (1971) and Loveland et al. (1972), a balanced, indigenous community of phytoplankton exists in Barnegat Bay, and this population appears to be unaffected by thermal discharge from the OCNGS. The impact of the thermal discharge on phytoplankton seems to be con fined to the discharge canal and Oyster Creek where a decrease in phytoplankton diversity and primary productivity has been demonstrated. No change has been observed in Barnegat Bay. These changes observed in Oyster Creek correspond to a decline in the abundance of microflagellates and dinoflagellates, and a decrease in chlorophyll a concentrations. The magnitude of the effect on the aquatic ecology of Oyster Creek appears to be minimal with no appreciable harm to the balanced, indigenous community in that area.

In the worst case, Mountford (1971) recorded a 30.3 percent reduction in gross productivity and a 20.1 percent decline in net productivity on five samples from Oyster Creek as compared to five samples from Forked River. Data from Loveland et al. (1972) also show a decline in gross and net productivity in Oyster Creek amounting to 11.9 and 35.0 percent, respectively below that of Forked River. However, Loveland et al. (1972) found no difference in the average dissolved oxygen levels in the two areas (both had mean values of 7.47 mg O_2/l). The drop in primary productivity has not adversely affected the dissolved oxygen levels in Oyster Creek. Mountford's 1970 data disclose a 17.7 percent decrease in chlorophyll a and a concomittant decline in the abundance of flagellates in Oyster Creek as compared to Forked River. Hein (1977) identified lower diversity levels and higher redundancy values for diatoms in Oyster Creek. None of these changes has been substantial enough, however, to cause a shift in the phytoplankton community structure in Oyster Creek to one dominated by a pollution tolerant or nuisance species. In fact, no phytoplankton blooms have been reported in either Oyster Creek or the area of Barnegat Bay influenced by the thermal plume since the OCNGS commenced operation in 1969. In view of these findings, the phytoplankton community in Oyster Creek does not appear to be appreciably harmed by thermal discharge from the OCNGS.

The final test of Section 316(a) for phytoplankton is, of course, the extent to which any observed changes have adversely affected the higher trophic communities of shellfish and fish. The types of effects which might be caused by changes in the phytoplankton community -- e.g., population reductions consequent to decreased food supply; fish avoidance of areas of depleted or low dissolved oxygen; stress or mortality of fish or shellfish consequent to stressful chemical conditions -- would be soon realized after the OCNGS began operation. As discussed in the following sections, however, no such effects have been observed in the station's nearly nine years of operation. With the exception of those areas of the thermal plume from which individual species may avoid because of high temperatures during the summer months, the distribution and success of fishes and shellfish are the same in the near field of the thermal plume as in both the far field and in areas outside the plumes influence. From the absence of effects on the fish or shellfish communities, it may be concluded either that substantial changes have not occurred in the area of the thermal discharge or that actual changes are not biologically significant to higher trophic communities. In either event, the Section 316(a) test for phytoplankton is satisfied.

3.2.1.5 Incremental effect of the FRNGS

3.2.1.5.1 Temperature effect

The operating characteristics of the FRNGS are summarized in Section 1.3 and Appendix A3. The combined seasonal discharge temperature effects of the OCNGS and the FRNGS are reviewed in Table B10-1 through B10-3.

Temperature plays a major role in affecting the composition, abundance, and productivity of phytoplankton. However, little is known concerning the direct impact of thermal discharge on different species of phytoplankton. A number of investigations which have dealt with the effect of temperature on phytoplankton organisms include those of Dryer and Bensen (1957), Strangenberg and Pawlaczyk (1961), Warrinner and Brehmer (1966), Haertel et al. (1969), and Wilde et al. (1977). Most studies involving the responses of phytoplankton to temperature have been conducted in the laboratory (Patrick, 1969; Sorokin, 1971; Round, 1968). The results of some of these studies are presented in Table 3.2-21, which reflect the effects of temperature on some of the more important phytoplankton species in Barnegat Bay.

In the winter months, diatoms dominate the phytoplankton in Barnegat Bay, Oyster Creek and Forked River. In the bay, Thallassiosira nordenskioldi, Dentonula confervacea, and D. cystifera are most abundant, whereas Skeletonema costatum dominates the phytoplankton in Oyster Creek and Forked River. Skeletonema costatum reportedly grows between 6.0 and 28°C (42.8 and 82.4°F) (Jitts et al., 1964), and it can tolerate temperatures as high as 40°C (104°F). The optimum growth of Detonula confervacea is approximately 1.6 to 16.7°C (35 to 62°F) (Smayda, 1969), and Thallassiosira nordenskioldi has a maximum growth range between 11.5 and 14.0°C (52.7 and 57.2°F) (Jitts et al., 1964).

When the OCNGS is operating in the winter, the impact of the FRNGS blowdown on diatoms plus other phytoplankton in Oyster Creek and Barnegat Bay should be negligible. The addition of the FRNGS discharge to that of OCNGS will decrease temperature by approximately 0.42°C (0.75°F) during summer. In the worst case, the FRNGS will cause only a 0.64 to 2.5°C (0.36 to 4.6°F) temperature increase above ambient bay levels in Oyster Creek during the winter. About 20 percent of this thermal increase will dissipate in the discharge canal and Oyster Creek before it reaches the bay. In view of the above temperature requirements of important diatom species, a 2.5°C (4.5°F) temperature increase in Oyster Creek during the winter months should actually stimulate growth of these flora. Considering the observed response of phytoplankton to the warmer discharge of OCNGS, this stimulation is unlikely to result in overproduction or massive blooms.

In general, most common algae of the temperate zone have maximum growth betwen 20 and 25°C (68 and 77°F) (Cairns, 1956; Wallace, 1955). Their growth decreases appreciably above 25°C (77°F) except for the flagellates which grow best at higher temperatures. Research by Hand et al (1965) indicates the adaptive superiority of dinoflagellates over diatoms at higher temperatures. Hand et al (1965) shows that the activity rates of many dinoflagellates seem to be independent of temperature up to about 33.9°C (93°F).

In the summer months, flagellate populations dominate the phytoplankton in Barnegat Bay. When the OCNGS is operating at this time, the effect of the FRNGS blowdown should be of no consequence. In fact, the blowdown will reduce slightly the temperature of the thermal discharge from the OCNGS in the summer.

FRNGS blowdown will raise the temperature in the discharge canal by a maximum 1.5°C (2.7°F) above ambient bay levels in the summer when the OCNGS is not operating, or decrease slightly the temperature of the OCNGS discharge. Considering the responses of flagellates and ultraplankton to various temperature conditions (Table 3.2-21), a 1.5°C (2.7°F) temperature increase should not adversely effect the phytoplankton community in the discharge canal and Barnegat Bay. No shift toward pollution tolerant or nuisance species is anticipated under this condition.

3.2.1.5.2 Salinity effect

Table B10-4 recounts salinity changes in the discharge canal associated with blowdown of the FRNGS and discharge of the OCNGS. When the OCNGS is operating, the effect of blowdown salinity will be insignificant, with the total discharge salinity being raised from 0.36 to 0.53 ppt above ambient bay levels.

Seasonal discharge salinities should not exceed 27.0 ppt. The exact salinity will depend on the number of dilution pumps in operation.

Phytoplankton of the taxa present in Oyster Creek and Barnegat Bay are common to the near shore and estuarine areas of the middle Atlantic coast, and, based on the salinity ranges observed in Barnegat Bay, are tolerant of salinities within a range of approximately 15 to 30 ppt (Mountford, 1971). Because the discharges from OCNGS and FRNGS fall within the 15 to 30 ppt range it is anticipated that the incremental effect on salinity of FRNGS operation will not have any impact on phytoplankton in Oyster Creek and Barnegat Bay.

3.2.1.6 Summary and Conclusions

Research on phytoplankton composition, primary productivity, and biomass in Oyster Creek, Forked River and Barnegat Bay has been conducted by Mountford (1969b, 1971), Loveland et al (1969, 1970, 1971, 1972) and Hein (1977). Data presented by these investigators have been analyzed and evaluated. The following summary and conclusions are drawn from this analysis.

1. The phytoplankton community in Barnegat Bay consists of a diverse assemblage of species. More than 180 species of phytoplankton were identified in the bay from April 1967 to April 1969. A comparable diversity of phytoplankton exists in the Forked River and Oyster Creek, with Oyster Creek containing fewer species than Forked River.

2. The most conspicuous characteristic of phytoplankton in Barnegat Bay is its seasonal periodicity in species composition, abundance, and primary productivity. This periodicity largely results from seasonal changes in water temperature, photoperiod, and nutrient supply.

3. Phytoplankton abundance peaks in the summer and drops to a minimum in the winter. Maximum phytoplankton abundance exceeds 10^6 cells/l in the summer; ultraplankton dominate the flora in terms of total number of cells at this time.

   Microflagellates and dinoflagellates are also abundant in the summer, attaining densities greater than 10^6 cells/l. DABME,Cwellate "red tide" blooms have been observed occasionally during the summer in Barnegat Bay (Martin, 1929).

   In late fall, winter, and early spring, diatoms and microflagellates dominate the phytoplankton. By mid to late winter a diatom bloom occurs in the estuary, and it is composed mainly of *Thallassiosira nordenskioldi*, *Detonula confervacea*, and *D. cystifera*. *Skeletonema costatum* becomes the dominant phytoplankter in the spring months. Diatoms are also most abundant in Forked River and Oyster Creek during the fall, winter, and spring. The most abundant diatoms in these waters include *Skeletonema costatum*, *Navicula pseudincerta*, *Amphipleura rutilans*, *Nitzschia dissipata*, and *Nitzchia kutzingiana*.

4. Chlorophyll *a* concentrations have been employed to estimate biomass in different areas of the estuary. Maximum chlorophyll *a* values occur during the winter-spring diatom blooms, whereas secondary maxima develop in the summer in association with peak phytoplankton cell numbers. Conspicuous temporal and spatial variations in chlorophyll *a* values exist in Barnegat Bay. Over an annual phytoplankton cycle, chlorophyll *a* measurements range from 1 to 30 mg/l. On any given date of sampling, chlorophyll *a* measurements vary substantially from one station to another in Barnegat Bay, Oyster Creek and Forked River. However, fluctuation in the biomass of phytoplankton is a common phenomenon in natural, balanced ecosystems.

5. Maximum rates of gross and net productivity and respiration take place in the summer and minimum rates in the winter. Absolute gross productivity values range from near 0 mg O_2/m^3/hr to greater than 500 mg O_2/m^3/hr over an annual phytoplankton cycle. Temporal and spatial variations in primary productivity are characteristic of the bay as well as both Oyster Creek and Forked River. These variations result from an interplay of both density dependent and density independent mechanisms.

. No significant change in phytoplankton composition, abundance, and primary productivity has been detected in Barnegat Bay subsequent to operation of the OCNGS in December 1969. A balanced, indigenous population of phytoplankton exists in the bay, and this population appears to be unaffected by thermal discharge of the OCNGS.

7. A number of differences in phytoplankton parameters between Oyster Creek and Forked River have been attributed to operation of the OCNGS. Mountford (1971) reports mean gross productivity to be 92.4 mg O_2/m^3/hr less (a 16.6 percent reduction) at the mouth of Oyster Creek than at the mouth of the Forked River based on 16 samples collected in the summer and

fall of 1970. Gross and net productivity differences in 1970 are not statistically significant ($P < 0.05$). Data given by Loveland et al. (1972) reveal gross productivity on eight dates in 1971 and 1972 to average only 22.2 mg $O_2/m^3/hr$ less in Oyster Creek than in Forked River, and net productivity to average only 36.5 mg $O_2/m^3/hr$ less.

In addition to reporting lower primary productivity in Oyster Creek than in Forked River, Mountford (1971) documents marginally lower phytoplankton diversity in Oyster Creek. Hein (1977) also describes lower diversity values for periphyton at the discharge canal.

Although these studies indicate some impact of thermal discharge on phytoplankton in Oyster Creek, this impact is not considered to be significant enough to cause a major shift in community structure. The phytoplankton community in Oyster Creek is not dominated by pollution tolerant or nuisance species, and no blooms are known to have occurred there. In view of these findings, the phytoplankton community in Oyster Creek does not appear to be appreciably harmed by thermal discharge from the OCNGS.

Because of the short generation time and high turnover rates of phytoplankton, the partial reduction of primary productivity, abundance, and diversity in the discharge canal has not adversely affected higher trophic level organisms in Oyster Creek or the bay. As shown in the following sections, no stresses or changes to the communities of fish or shellfish have been observed which were outside of the range of natural variations in Barnegat Bay or of contemporaneous, natural changes observed in other middle Atlantic estuaries and closed embayments. There is no reason to believe, therefore, that any changes which may have occurred in phytoplankton as a result of the OCNGS thermal discharge were of any consequence at all to the successful maintenance and functioning of higher trophic level communities.

8. The operational effects of the FRNGS will not cause an impact on the phytoplankton community in Oyster Creek and Barnegat Bay. When the OCNGS is not operating, blowdown of the FRNGS will cause a maximum temperature increase in the discharge canal of between only 0.64 and 2.5°C (0.36 and

4.5°F) above ambient bay levels. This increase will occur in the winter months, and should stimulate phytoplankton grown and productivity. This stimulation will not result in overproduction, but may improve slightly the overall primary productivity of Oyster Creek. During summer months the FRNGS blowdown will reduce slightly the temperature of the OCNGS discharge by approximately 0.35°C (0.75°F). Under normal operating conditions, salinity in Oyster Creek will be increased from 0.26 to 0.53 ppt by the FRNGS blowdown, but should not exceed 27 ppt. This salinity concentration should not cause a significant impact on the phytoplankton community in the discharge canal.

References

Brooks, A.S., R.A. Smith, and L.D. Jensen. 1974. Phytoplankton and primary productivity. pp. 77-93. In: L.D. Jensen (ed.), Environmental Responses to Thermal Discharges from the Indian River Station, Indian River, Delaware. Cooling Water Studies (RP-49) conducted by Johns Hopkins Univ. for Electric Power Res. Inst., Rept. No. 12. Palo Alto, Calif.

Cairns, J., Jr. 1956. Effects of heat on fish. Industr. Wastes. 1: 180-183.

Carpenter, E.J. 1971. Annual phytoplankton cycle of the Cape Fear River Estuary, North Carolina. Chesapeake Sci. 12: 95-104.

Curl, H., and G.C. McLeod. 1961. The physiological ecology of a marine diatom Skeletonema costatum (Grev) Cleve. J. Marine Res. 19: 70-88.

Devine, J.C. 1974. The Forked River program a case study in salt water cooling. Unpub. Rept. GPU Service Corporation. 78 pp.

Dryer, W. and H.G. Bensen. 1957. Observations on the influence of the New Johnsonville Steam Plant on fish and plankton populations. Proc. Ann. Conf. S. E. Assoc. Game Fish Comm. 10: 85-91.

Flemer, D.A. 1970. Primary production in the Chesapeake Bay. Chesapeake Sci. 11: 117-129.

Haertel, L., C. Osterberg, H. Curl, Jr., and P.K. Park. 1969. Nutrient and plankton ecology of the Columbia River estuary. Ecology 50: 962-978.

Hand, W.G., P.A. Collard, and D. Davenport. 1965. The effects of temperature and salinity change on swimming rate in the dinoflagellates, Gonyaulax and Gyrodinium. Biol. Bull. 128: 90-101.

Hein, M.K. 1977. Effects of thermal discharges on the structure of periphytic diatom communities. Unpub. M. S. Thesis, Rutgers Univ. 62 pp.

Hellerman, J. 1962. A study of the diatoms of Mohonk Lake, New York, and vicinity. Unpub. M. S. Thesis, Rutgers Univ. 118 pp.

Ichthyological Associates. 1977. Preliminary final report of ecological studies for the Oyster Creek Station. September 1975 to August 1976. Unpub. Rept. 368 pp.

Jitts, H.R., C.D. McAllister, K. Stephens, and J.D.H. Strickland. 1964. The cell division rates of some marine phytoplankters as a function of light and temperature. J. Fish Res. Bd. Can. 21: 139-157.

Loftus, M.E., D.V.S. Rao, and H.H. Seliger. 1972. Growth and dissipation of phytoplankton in Chesapeake Bay. I. Response to a large pulse of rainfall. Chesapeake Sci. 13:282-299.

Loveland, R.E., E.T. Moul, F.X. Phillips, J.E. Taylor, and K. Mountford. 1969. Fifth Progress Report: The qualitative and quantitative analysis of the benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition. Unpub. Rept. Rutgers Univ.

Loveland, R.E., E.T. Moul, K. Mountford, P. Sandine, D. Busch, E. Cohen, N. Kirk, M. Moskowitz, and C. Messing. 1970. Sixth Progress Report: The qualitative and quantitative analysis of the benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition. Unpub. Rept. Rutgers Univ.

Loveland, R.E., E.T. Moul, K. Mountford, P. Sandine, D. Busch, and M. Moskowitz. 1971. Seventh Progress Report: The qualitative and quantitative analysis of the benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition. Unpub. Rept. Rutgers Univ.

Lowe, R.L. 1972. Diatom population dynamics in a central Iowa drainage ditch. Iowa State J. Res. 47: 7-49.

Marshall, H.G. 1967. Plankton in the James River estuary, Virginia. I. Phytoplankton in Willoughby Bay and Hampton Roads. Chesapeake Sci. 8: 90-101.

Martin, G.W. 1929. Dinoflagellates from marine and brackish waters of New Jersey. Univ. Iowa Stud. Nat. Hist. 12: 1-32.

Mountford, K. 1967. The occurrence of Pyrrhophyta in a brackish cove -- Barnegat Bay, New Jersey at Mantoloking, May through December, 1966. Bull. N. J. Acad. Sci. 12:9-12.

Mountford, K. 1969a. Plankton survey data for Barnegat Bay, New Jersey, 1964-1965. Bull. N. J. Acad. Sci. (abstract). 14: 50

Mountford, K. 1969b. A seasonal plankton cycle for Barnegat Bay, New Jersey. Unpub. M. S. Thesis, Rutgers Univ. 62 pp.

Mountford, K. 1971. I. Composition and periodicity of phytoplankton and zooplankton from Barnegat Vay, N. J. II. Phytoplankton and primary productivity in Barnegat Bay: changes associated with operation of a nuclear generating station. Unpub. Ph.D. Dissert. Rutgers Univ. 148 pp.

Mulford, R.A., and J.J. Norcross. 1971. Species composition and abundance of net phytoplankton in Virginian coastal waters, 1963-1964. Chesapeake Sci. 12: 144-155.

Patrick, R. 1969. Some effects of temperature on freshwater algae. In P.A. Krenkel and F.L. Parker (eds). Biological Aspects of thermal pollution. Vanderbilt Univ. Press, Nashville, Tenn.

Patrick, R. and C.W. Reimer. 1966. The diatoms of the United States. Vol. 1 Academy of Natural Sciences of Philadelphia Monograph No. 13. 688.

Patten, B.C., R.A. Mulford, and J.E. Warinner. 1963. An annual phytoplankton cycle in the lower Chesapeake Bay. Chesapeake Sci. 4: 1-20.

Pirie, W.R., and W.A. Hubert. 1977. Assumptions in statistical analysis. Trans. Am. Fish. Soc. 106, 6: 646-648.

Richards, F.A., and T.G. Thompson. 1952. The estimation and charaterization of plankton populations by pigment analysis. II. A spectrophotometric method for the estimation of plankton pigments. J. Marine Res. 11: 156-172.

Riley, G.A. 1966. Seasonal cycles and succession of societies. In C. H. Oppenheimer (eds.). Marine Biol. N. Y. Acad. Sci. Interdisciplinary Communications Program. N. Y. 369 pp.

Riley, G.A. 1967. The plankton of estuaries. In G.H. Lauff (ed.), Estuaries. Amer. Assoc. for the Advan. Sci. Washington, D.C. 757 pp.

Round, F.E. 1968. Light and temperature: some aspects of their influence on algae. In D.F. Jackson (ed.). Algae, Man and the Environment. Syracuse Univ. Press, Syracuse. 554 pp.

Ryther, J.H. 1954. The ecology of phytoplankton blooms in Morches Bay and Great South Bay, Long Island, N. Y. Biol. Bull. 106: 198-209.

Smayda, T.J. 1969. Experimental studies on the influence of temperature, light and salinity on cell division of the marine diatom. Detonala confervacea. J. Phycol. 5: 150-157.

Sorokin, C. 1971. Calefaction and phytoplankton. Bioscience 21: 1153-1159.

Strangenberg, M., and M.Z. Pawlaczyk. 1961. Nauk. Pol. Wroclaw No. 40. Inzyn. Sanit. Water Pollut. Abstr. 1: 67-106.

Stross, R.G., and J.R. Stottlemyer. 1965. Primary production in the Patuxent River. Chesapeake Sci. 6: 125-140.

Thayer, G.W. 1971. Phytoplankton production and the distribution of nutrients in a shallow unstratified estuarine system near Beaufort, N. C. Chesapeake Sci. 12: 240-253.

Ukeles, R. 1961. The effect of temperature on the growth and survival of several marine algae species. Biol. Bull. 120: 255-264.

Wallace, N.M. 1955. The effect of temperature on the growth of some fresh water diatoms. Not. Nat. Acad. Nat. Sci. Phila. 280: 11.

Warriner, J.E., and M.L. Brehmer. 1966. The effects of thermal effluents on Marine organisms. Air and Water Pollut. Int. J. 10: 277-289.

Wilde, E.W., L.L. Olmsted, and A. Gnilka. 1977. Some observations concerning the effects of a power station's thermal effluent on phytoplankton dynamics. J. Tennessee Acad. Sci. 52: 10-14.

3.2.2 Zooplankton and meroplankton (ichthyoplankton)

Between September 1975 and March 1977, Ichthyological Associates (I.A.) conducted studies on the effects of the OCNGS thermal discharge on zoo- and ichthyoplankton in Barnegat Bay from Goodluck Point to Gulf Point, and in Oyster Creek and Forked River. Results of these studies from September 1975 through August 1976, including a complete description of the materials and methods, were presented by Tatham et al (1977b) and from September 1976 through September 1977 by Tatham et al (1978b). From 1971 through 1977, I. A. also collected zoo- and ichthyoplankton samples from nearby estuarine and marine waters: Little Egg Harbor, the Great Bay-Mullica River estuary, the waterways behind Brigantine Island, and the ocean in the vicinity of Little Egg Inlet. Data from these studies were reported by Thomas et al. (1972, 1974, 1975), Thomas and Milstein (1973), Sandine et al. (1974), Sandine and Swiecicki (1975), and Milstein et al. (1976). The data from these studies form the basis for the following analysis and are set forth in Appendix Cl, Section 4.

Zooplankton are discussed as microzooplankton (organisms smaller than 500 microns, 0.02 in.) and macrozooplankton (organisms larger than 500 microns, 0.02 in.) and both groups included organisms that were planktonic during their entire life cycle (holoplankton) and those that occurred in the plankton either periodically or during a portion of their life cycle (meroplankton). Meroplankton of important fish or shellfish species also are discussed in Section 3.1 (RIS demonstration) and in Sections 3.2.3 (Benthic Macroinvertebrates) and 3.2.4 (Fish).

3.2.2.1 Decision criteria

Zooplankton and ichthyoplankton communities are important components of the estuarine ecosystem. Appreciable changes in the communities may affect the balanced indigenous populations of shellfish and fish in the near and far field regions. The species composition, distribution, abundance, and seasonal succession of zoo- and ichthyoplankton in Barnegat Bay and in Oyster Creek and Forked River were examined to determine effects of the thermal discharge from the OCNGS. Although statistical comparisons were made to evaluate variations in the community which could have been attributable to the thermal discharge, the high natural variability of both the species composition and abundance of individual estuarine populations often made it difficult to demonstrate whether changes in abundance of individual species were significant in a statistical sense. Therefore, changes in the abundance of a population can only be judged on a relative basis with past data for the bay or comparable data from another estuary, and these changes must be evaluated qualitatively rather than quantitatively. Fluctuations of these populations were assessed in view of their causes.

The absence of a significant effect on the zoo- and meroplankton community would be established if the following criteria are satisfied:

(1) The zoo- and meroplankton (ichthyoplankton) community should exhibit relative stability in the measurable aspects of community structure, including composition, relative abundance and seasonal succession, within the range of variability typical of mid-Atlantic estuaries and closed embayments.

(2) The thermal plume should not constitute a lethal barrier to the free movement of zoo- and meroplankton (ichthyoplankton).

If these criteria are met, then this aspect of the demonstration may be considered successful. If the community varies in some respect from that which is natural in such systems, then the data must be analyzed to determine the cause of the variation and its extent and significance. Where variations from natural conditions are not caused by the thermal discharge, or where the variation is not of significance to the community of fish and shellfish, then it may be concluded that the thermal discharge does not interfere with the existence and functioning of the indigenous community of zoo- and meroplankton.

The structure of the zoo- and meroplankton community was analyzed according to its component parts. The disappearance or decrease in relative abundance of a species sensitive to thermal discharge, or the increase and/or dominance of a pollution tolerant species could indicate a trend toward an unbalanced community. A change in seasonal succession could indicate potential harmful effects on reproductive cycles. Maintenance of community composition, with a diverse assemblage of species, would indicate maintenance of conditions suitable for the existence and functioning of the community.

Because no data exist on zoo- and ichthyoplankton populations in the bay prior to operation of the OCNGS, it was not possible to analyze community structure strictly according to preoperational and operational conditions and to make quantitative judgments about discharge effects. The demonstration, therefore, focused on a qualitative analysis of community structure. Because natural fluctuations in the relative abundance of estuarine organisms in nearby estuaries are often caused by widespread environmental factors rather than local phenomena, the structure of plankton communities in nearby estuaries often has been used as a standard of comparison to establish the extent of natural variations at the time of the study.

The effect of the thermal plume on the movement and critical functions of the species of the community also was evaluated. However, considering the configuration of the plume with respect to Oyster Creek and Barnegat Bay, the concept of thermal blockage does not apply here, as it would on a riverine site. The only drifting organisms present in Oyster Creek are those produced within the area of the thermal discharge, passed through the plant, or secondarily entrained through dilution pumps. For organisms secondarily entrained, examination does not indicate stress or mortality which would have more than a negligible impact on populations in Barnegat Bay.

In Barnegat Bay, the extent of the thermal plume is not such as to constitute a significant barrier to movement. The presence and movement of organisms occurs during all times of the year in all but a very small area of Barnegat Bay near the mouth of Oyster Creek. At average bay temperatures, the area avoided by free swimming species, and in which drifting organisms would be subject to stress, is within the 2.2°C (4.0°F) isotherm. At peak temperatures during summer, when stressful conditions are likely to occur, the 2.2°C isotherm extends to only 25 percent of both the surface width and cross-sectional area of the bay measured at its narrowest extent from the mouth of

Oyster Creek. Accordingly, the following discussion does not include a specific, discrete analysis of plume effects. The effects and significance of secondary entrainment are discussed in this section and in Chapter 4.

3.2.2.2 Rationale

The thermal discharge from the OCNGS had no apparent effect on the zoo- and ichthyoplankton communities in Barnegat Bay. Changes in the general structure of the communities in the bay were attributable to natural fluctuations in the constituent populations rather than to the thermal discharge. The species composition, abundance, distribution, and seasonal succession of zoo- and ichthyoplankton in Barnegat Bay were similar to those of other estuaries and enclosed embayments in the northeastern United States.

The dominant microzooplankton were holoplankton (86 percent of all microzooplankton), primarily copepods and rotifers. Meroplankton were seasonally abundant but comprised only 14 percent of the microzooplankton; larvae of barnacles, polychaetes, bivalves, and gastropods were the most abundant meroplankton. The dominant macrozooplankton were the mysid _Neomysis americana_; zoeae of the sand shrimp _Crangon septemspinosa_; the hydromedusae _Sarsia_ spp. and _Rathkea octopunctata_; xanthid zoeae; and amphipods. Between December and April, larvae of winter flounder and sand lance were the predominant ichthyoplankton but from May through September larvae and eggs of the bay anchovy and gobies were most numerous. The density of ichthyoplankton in Barnegat Bay was low during October and November.

In general, the density of most forms was greatest at night, partially because of increased migration of individuals and of the hatching of eggs at night. The distribution of the dominant plankton throughout the bay was patchy, but the patches appeared to be equally distributed from Goodluck Point to Gulf Point.

Noticeable effects of the thermal discharge on zoo- and ichthyoplankton in the bay were confined to Oyster Creek. Changes in the density of these organisms which were observed in Oyster Creek are the cumulative effect of entrainment through the OCNGS Circulating Water System (discussed in Chapter 4) and secondary entrainment in the thermal discharge. Losses may be offset to some extent, and thus masked, by reproduction of some forms between the OCNGS and the mouth of Oyster Creek.

Although the species composition and relative abundance of zoo- and ichthyoplankton were similar in both Forked River and Oyster Creek, some differences in absolute abundance were observed. Some microzooplankton were consistently less abundant at the mouth of Oyster Creek than at the OCNGS discharge. The density of barnacle larvae decreased 72 percent at the mouth of Oyster Creek, polychaete larvae 42 percent, copepod nauplii 19 percent, unidentified bivalve larvae 25 percent, *Acartia tonsa* 57 percent, and *Acartia* spp. 61 percent. However, other microzooplankton were more numerous at the mouth of Oyster Creek than at the OCNGS discharge; the density of rotifers increased 103 percent, cyphonaute larvae 3,547 percent, gastropod larvae 70 percent, and *Mulinia lateralis* larvae 155 percent.

The mean density of total macrozooplankton at two sampling stations in Forked River exceeded that at two comparable stations in Oyster Creek between March 1976 and March 1977. The density of the zoeae of Xanthidae (mud crabs), *Hippolyte* spp., *Upogebia affinis*, *Pagurus* spp., *Libinia* spp., and the sand shrimp were consistently greater in Forked River than Oyster Creek. Zoeae of *Palaemonetes* spp. were more abundant in Oyster Creek.

Although no significant difference in the density of bay anchovy eggs and goby larvae existed between the two streams, the density of these ichthyoplankton was lower in Oyster Creek. The density of larvae and juveniles of the bay anchovy and northern pipefish was significantly less in Oyster Creek.

In summary, although some zooplankton and ichthyoplankton probably die when secondarily entrained either into the discharge canal or the plume in the bay, changes in the balanced indigenous populations are apparently not related to the thermal discharge from the OCNGS. The species composition, distribution, and seasonal succession of zooplankton and ichthyoplankton were similar to those described from other estuaries and enclosed embayments in the northeastern United States. The holoplankton component of microzooplankton populations is resilient, and reduction of these forms in a heated discharge does not necessarily result in a decrease of these forms in the estuary.

3.2.2.3 Structure of the Indigenous Community

No data exist on zoo- and ichthyoplankton populations in Barnegat Bay prior to operation of the OCNGS. The area of Barnegat Bay outside the thermal plume is relatively unstressed and the community structure observed there, provides an accurate measure of the bay's indigenous community. The fact that the zoo- and ichthyoplankton populations outside the influence of the plume are similar to those in other estuaries in the northeastern United States supports their use as a standard for this demonstration. Collections of zoo- and ichthyoplankton were taken from September 1975 through March 1977 from areas of Barnegat Bay which were not influenced by the OCNGS thermal plume and compared against collections taken over the same period inside the area of the plume, both in Barnegat Bay and Oyster Creek.

3.2.2.3.1 Microzooplankton

Overall, microzooplankton (planktonic invertebrates <500 microns (.02 in.) in length) densities were highest from March through July and lowest from September through November (Table 3.2-25). Monthly densities ranged from 7,962/m^3 to 471,818/m^3 and averaged 101,320/m^3. The density in day and night collections at the OCNGS discharge was significantly different for only four forms: copepod nauplii and larvae of gastropods, bivalves, and barnacles.

Holoplankton (forms that are planktonic for their entire life cycle) were the dominant (86 percent) microzooplankton collected. Copepod nauplii (46 percent) and rotifers (24 percent) comprised more than half of the microzooplankton collected in most months. Copepod nauplii were abundant (>10,000/m^3) during most of the year except from September through November when they were common (1,000-10,000/m^3). Copepod nauplii were significantly more abundant in day collections. Rotifers were collected throughout the year and were common to abundant from December through May.

Copepods (adults and copepodites) composed 16 percent of all microzooplankton collected. The estuarine and marine copepods _Acartia clausi_, _A. tonsa_, and _Acartia_ spp. were the dominant species (72 percent of all adults and copepodites) in Barnegat Bay. _A. clausi_ (22 percent), a boreal-temperate form (Deevey, 1960), was collected from October through June. It was abundant in February and March and common in April. _A. tonsa_ (7 percent), a temperate-tropical species (Deevey 1960), dwarf surf clam, Mulinia lateralis. These larvae were found in all five months and averaged 688/m^3). Larvae of the bay scallop Argopecten irradians (4 percent) and the northern quahog Mercenaria mercenaria (5 percent) occurred in small numbers. Larvae of the northern quahog occurred from April through August, and the average density was 35/m^3.

Gastropod larvae were collected in every month and were significantly more abundant at night. They were common from May through October.

3.2.2.3.2 Macrozooplankton

The macrozooplankton (planktonic invertebrates >500 microns (.02 in.) in length) community was characterized by one assemblage at water temperatures below 18°C (64.4°F) and another assemblage above 18°C (64.4°F) (Table 3.2-26). The dominant (>5 percent of the community) macrozooplankton at temperatures below 18°C (64.4°F) (October 1976 to April 1977) were the mysid Neomysis americana (35 percent of all macrozooplankton collected below 18°C (64.4°F)); the hydromedusae Sarsia spp. (21 percent) and Rathkea octopunctata (18 percent); sand shrimp Crangon septemspinosa zoeae (9 percent); and amphipods (5 percent). The dominant forms at temperatures above 18°C (64.4°F) were mud crab (Xanthidae) zoeae (47 percent), amphipods (16 percent), N. americana (13 percent), and sand shrimp zoeae (6 percent).

N. americana and amphipods were the only dominant forms collected during all months. N. americana were abundant (>100/m^3) from February through June and during August and September; it was common (1-100/m^3) in other months. Amphipods were common in all months and were most abundant from May through October. The dominant amphipods, based on collections from the OCNGS discharge, were Ampelisca spp. (30 percent) of all identified amphipods), Jassa falcata (26 percent), Microdeutopus gryllotalpa (16 percent), and Corophium spp. (8 percent). From September through November 1977, 57 percent of all identified Corophium spp. were C. acherusicum, 28 percent were C. tuberculatum, 14 percent were C. bonelli, and 12 percent were C. insidiosum.

Zoeae of the sand shrimp were common from March through July and in November. Mud crab zoeae occurred from April through September, but were abundant only from May through July. Based on collections from the OCNGS discharge, the most numerous mud crab zoeae were those of *Neopanope texana* (67 percent of all mud crab zoeae) and *Panopeus herbstii* (32 percent). *R. octopunctata* occurred from November through April and *Sarsia* spp. from February through April.

All of the dominant forms were estuarine and marine (Jeffries, 1967). The distribution of many dominant forms was patchy, although these patches were equally distributed throughout the bay from Cedar Beach to Gulf Point. The portion of the bay within about a 1.6 km (1 mi) radius of the mouth of Oyster Creek, however, consistently had the maximum abundance for zoeae of the sand shrimp and mud crabs. The salinity in the western bay (16 to 30 ppt) was within the salinity range for estuarine and marine forms (about 15 to 32 ppt; Jeffries 1967).

The densities of forms in night collections at the OCNGS cooling water intake were from two to ten times greater than those in day collections. In general, vertical migration of macrozooplankton (primarily epibenthic mysids and amphipods, and benthic cumaceans) commences around sunset and occurs for various intervals throughout the night (Herman, 1963). Increased hatching of eggs of polychaetes, mud crabs, and the sand shrimp appeared to occur at night because larvae of these forms were generally more abundant then. Because of the many forms involved in vertical migrations and difference in hatching times, the period of maximum abundance during the night was highly variable from one night to the next.

3.2.2.3.3 Ichthyoplankton

The abundance and species composition of icythyoplankton can be naturally grouped during a cold season (December through April) and a warm season (May through September). Densities of ichthyoplankton during October and November were very low (average density $<0.05/m^3$). The common names of fishes are used throughout this section and the corresponding scientific names are presented in Tables 3.2-27 and 3.2-28.

The cold season was dominated by larvae of the winter flounder (59 percent of the larvae from December through April) and sand lance (41 percent), but few eggs were collected. Larvae of the sand lance first appeared in late December, and maximum densities ($0.5-2.4/m^3$) occurred in March. Winter flounder larvae first occurred in February, and the maximum abundance ($1.8-4.7/m^3$) also occurred in March. Densities of these larvae decreased during April because most had become replaced A. clausi in June and was common until September. It was generally found in low densities from October through January and was usually rare from February through May. Conover (1956), Deevey (1960), and Jeffries (1962, 1967) have documented a similar seasonal succession of A. clausi and A. tonsa. Early copepodite states of Acartia spp. (43 percent) were found in all months. Oithona colcarva (brevicornis) accounted for 5 percent of all copepods, Oithona spp. 7 percent, Paracalanus crassirostris 5 percent, and Paracalanus spp. 4 percent. They were also collected during most of the year and were common to abundant from June through August.

Meroplankton (forms which spend only a portion of their life or daily activity in the water column) comprised 14 percent of the microzooplankton collected. Densities were highest from April through August, gradually declined after September, and were lowest from December through March. Barnacle larvae (14 percent of all meroplankton), polychaete larvae (38 percent), bivalve larvae (17 percent), gastropod larvae (7 percent), and unidentified trochophores (9 percent) were the most abundant forms.

Polychaete larvae were abundant in April and May, common from June through August, and present in low numbers during the rest of the year. Polydora spp. accounted for 52 percent of all polychaete larvae and were collected in every month but September. They were common to abundant in April and May. Larvae of Nereis spp. (2 percent) were present from May through August.

Barnacle larvae were collected throughout the year and were common from March through June. Significantly more larvae were found during the day than at night. Young and Frame (1976) identified the barnacles Balanus improvisus, B. eburneus, B. balanoides, and B. crenatus on test panels in the OCNGS intake and discharge canals.

Bivalve larvae were common from April through August, steadily decreased in number after August, and were rare in February and March. The highest densities ($2,250-8,003/m^3$) occurred from April through June. Bivalve larvae were significantly more abundant in collections taken during the day. From April through August, 21 percent of all bivalve larvae were identified from five stations in the bay that were unaffected by the OCNGS thermal plume. The most numerous larvae (91 percent of all identified larvae) were those of the demersal. Norcross et al (1961) and Richards and Kendall (1973) reported a greater number of sand lance larvae captured at night. No consistent difference occurred between day and night catches of winter flounder larvae in either the Mystic River estuary (Pearcy, 1962) or in Barnegat Bay.

The warm season was dominated by the eggs of the bay anchovy (98 percent of all eggs during the period) and larvae of the bay anchovy (70 percent of all larvae) and gobies (24 percent). Atherinid larvae (4.5 percent) and young of the northern pipefish (1.3 percent) were common, but neither species had a well defined period of maximum abundance. Eggs of the tautog, cunner, and hogchoker also were collected.

Bay anchovy eggs were first collected in May. The density of eggs reached a maximum (7.1-$74.6/m^3$) in July and gradually decreased during August. Most spawning ceased by September. Densities of eggs were higher at night because of increased spawning at that time (Hildebrand and Cable, 1930).

Bay anchovy larvae were first taken in June, and maximum abundance (0.5-$11.9/m^3$) occurred in July. Larvae remained abundant through early August but decreased in abundance during September as larvae grew to juveniles. Larval abundance was greater at night, possibly due to decreased net avoidance (Bridger, 1956; Daiber, 1963; Isaacs, 1964) or diel vertical migrations (Russel, 1929).

Goby (<u>Gobiosoma</u> spp.) larvae were first collected in May, were most abundant (0-$1.4/m^3$) in July, and gradually decreased in abundance through September. The significantly higher density of goby larvae in night collections was probably due to decreased net avoidance or diel vertical migrations.

Goby larvae were more abundant in both Forked River and Oyster Creek than in other areas of the bay, and this may indicate habitat preference. Although the distribution of all other dominant forms was patchy, these patches were equally distributed throughout the bay from Cedar Beach to Gulf Point.

3.2.2.4 Observed responses to the OCNGS discharge

The density of macrozoo- and ichthyoplankton at stations in Forked River and Oyster Creek was examined statistically with the analysis of variance (ANOVA) and Friedman's nonparametric test. The effect of the heated discharge was also examined by determining the difference between the density of forms in Forked River and at the mouth of Oyster Creek. The temperature in the thermal discharge during the summer of 1976 may have been less than the maximum possible temperature (Table 3.1-4) because OCNGS operated at less than its full-rated capacity (670 MWe) during the months of June (548 MWe), July (526), August (569), and September (580).

It should be noted that this analysis necessarily considers the effects of the thermal plume, entrainment through the OCNGS Cooling Water System and secondary entrainment through the dilution pumps. Some 47 percent of the water in the discharge canal passes through the OCNGS Cooling Water System. Therefore, assuming 100 percent mortality of entrained organisms (as discussed in Chapter 4 immediate mortality rates for many species are substantially less than 100 percent), a decrease of about 50 percent in the density of a form at the mouth of Oyster Creek may be attributed to primary entrainment losses. Losses from primary entrainment are expected to exceed those from secondary entrainment because organisms passed through the OCNGS Cooling Water System are exposed to higher temperatures, biocidal stress, and more mechanical stress than those secondarily entrained. Thus, as discussed further in Chapter 4, the decreases in abundance observed at the mouth of Oyster Creek take into account the cumulative effects of the OCNGS intake and thermal discharge.

On the other hand, reproduction of forms in Oyster Creek may introduce eggs and larvae which would mask losses from primary and secondary entrainment. Some apparent differences in abundance may be caused by the large natural variation in plankton populations (Heinle, 1977); this is particularly true for forms that are present in low densities.

Because dead plankton settle to the bottom (Carpenter et al, 1974; Marcy, 1976; Tatham et al, 1977b), organisms collected both in Forked River and at the mouth of Oyster Creek were considered live. The numbers collected thus provide a direct measure of viability without requiring individual examination for condition.

Because the uppermost station in Forked River was not sampled for microzooplankton, collections at the OCNGS discharge were used to estimate the number of microzooplankton introduced into the discharge canal.

3.2.2.4.1 Microzooplankton

The microzooplankton community at the mouth of Oyster Creek was examined from collections taken from March through August 1976. The species composition and seasonal variation in abundance of the dominant taxa at this station were similar to those in thermally unaffected areas in Barnegat Bay.

Some forms were consistently less numerous at the mouth of Oyster Creek than at the OCNGS discharge (Table 3.2-29). Barnacle larvae (72 percent decrease between the OCNGS discharge and the mouth of Oyster Creek), polychaete larvae (42 percent), copepod nauplii (19 percent), _Acartia tonsa_ (57 percent), _Acartia_ spp. (61 percent), and unidentified bivalve larvae (25 percent) showed a decrease in number. Rotifers (103 percent increase), cyphonaute larvae (3547 percent), gastropod larvae (70 percent), and larvae of the dwarf surf clam (155 percent), however, were more abundant there.

Some secondary-entrainment losses of the copepod _Arcatia tonsa_ may occur between June and August (average bay temperature of 23.3 to 26.7°C, 73.9 to 80.1°F). After a 1.2 h exposure in the laboratory, _A. tonsa_ acclimated to 20°C (68°F) had no mortality at a delta T of 5°C (9°F) and 10 percent mortality at 10°C (18°F) (Heinle, 1969). At 25°C (77°F), a delta T of 5°C (9°F) produced no mortality but a 10°C (18°F) increase in temperature caused 40 percent mortality. _A. tonsa_ from Florida populations that were acclimated to increasing water temperature tolerated progressively higher temperature shocks in summer (Reeve and Cosper, 1970). At an ambient temperature of 27°C (80.6°F) and a delta T of 6°C (10.8°F), no mortality occurred after a 1.2 h exposure, but at 30°C (86°F) and a delta T of 7°C (12.6°F) mortality was 66 percent. Since the average temperature in the discharge canal and Oyster Creek during July and August is from 32.8 to 33.2°C (91 to 91.8°F) (Table 2.1-4), less than 40 percent mortality should occur from secondary entrainment of _A. tonsa_ passed through the dilution pumps. When the temperature in the mixed flow of the dilution water and the OCNGS heated discharge is from 34.5 to 36.5°C (94.1 to 97.7°F) (bay temperature of about 28 to 30°C, 82.4 to 86°F), mortality of secondarily entrained copepods may range from 40 to 66 percent.

3.2.2.4.2 Macrozooplankton

The species composition and relative abundance of macrozooplankton were similar in both Forked River and Oyster Creek. Losses of some macrozooplankton occurred in Oyster Creek because mean density of total macrozooplankton from both stations in Forked River exceeded that from both stations in Oyster Creek from March 1976 through March 1977. The mean density of zoeae of the sand shrimp ($4.3/m^3$ in upper Forked River, $1.7/m^3$ at the mouth of Oyster Creek); the mud crabs Neopanope texana, Panopeus herbstii, and Rhithropanopeus harrisii ($88.2/m^3$, $49.5/m^3$); Hippolyte spp. ($0.11/m^3$, $0.01/m^3$); the mud shrimp Upogebia affinis ($0.54/m^3$ $0.08/m^3$); hermit crabs, Pagurus spp. ($0.32/m^3$, $0.08/m^3$); and spider crabs Libinia spp. ($0.18/m^3$, $0.03/m^3$) were consistently greater in Forked River than in Oyster Creek. Zoeae of the grass shrimp, however, were more abundant in Oyster Creek ($8.6/m^3$) than in Forked River ($2.0/m^3$). When the bay temperature was below 18°C (64.4°F) the density of nine of eleven common or RIS forms generally present below 18°C (Section 3.2.2.3.2) was less in Oyster Creek than in Forked River (Table 3.2-30). When the bay temperature exceeded 18°C, the density of 14 of 15 common or RIS forms generally present above 18°C decreased although this decrease was statistically significant only for N. americana and sand shrimp zoeae.

Although no quantitative data were available on mortality of secondarily entrained macrozooplankton in Oyster Creek, temperature tolerance data for a 15-min exposure of adults and juveniles of the sand shrimp, grass shrimp, N. americana, epitokes of Nereis spp., blue crab megalopae, and zoeae of the grass shrimp were available from collections at the OCNGS discharge. These data were used to estimate the effects of secondary entrainment and the 1.2-h passage down the discharge canal and Oyster Creek. Entrainment collections were valid indicators of temperature tolerance because most entrainment mortality of macrozooplankton at OCNGS was related to temperature. Data from laboratory studies on the zoeae of mud crabs, grass shrimp, and sand shrimp were used to evaluate secondary entrainment of these forms.

Exposure of N. americana to temperatures above 35°C (95°F), from 32.5 to 35°C (90.5 to 95°F), and from 30 to 32.5°C (86 to 90.5°F) resulted in a mean percent mortality of 94 percent, 82 percent, and 36 percent, respectively. Below 30°C (86°F), mortality generally did not exceed 10 percent. Maximum abundance of N. americana was generally from February through April when the temperature in the discharge canal was below 30°C (86°F) (Table 3.1-4). However, N. americana secondarily entrained in the discharge canal in June and August (discharge canal temperature above 30°C, 86°F) may experience more than 80 percent mortality because the average temperature in the canal is 33.2°C (91.8°F) at that time. Mysids secondarily entrained from the bay during these months may also experience some mortality in areas of the plume that are warmer than 30°C (86°F). During June and September, some mortality of N. americana may also occur in the discharge canal because the temperature there averages 29.8 to 28.7°C (85.6 to 83.7°F), respectively.

Adult and juvenile sand shrimp had 75 percent mortality at temperatures above 35°C (95°F), 42 percent from 32.5 to 35°C (90.5 to 95°F), and 53 percent from 30 to 32.5°C (86 to 90.5°F), respectively. The apparent discrepancy of higher mortality at 30 to 32.5°C (86 to 90.5°F) than at 32.5 to 35°C (90.5 to 95°F) is small and probably reflects variability of the estimates rather than a real difference. At temperatures from 27.5 to 30°C (81.5 to 86°F), the average mortality was 23 percent, and below 27.5°C (81.5°F) it was generally less than 10 percent. When the sand shrimp is abundant from December through May, little secondary-entrainment mortality should occur (Table 3.1-4). Sand shrimp secondarily entrained into either the discharge canal or the area of the plume in the bay above 30°C (86°F) during July and August may experience about 50 percent mortality, but most sand shrimp in the bay emigrate to the ocean during the warmest months and therefore relatively few should be secondarily entrained. During June and September, mortality of the sand shrimp introduced into the canal may be about 20 percent, but little or no mortality of individuals entrained into the plume should occur.

Qualitative observations of sand shrimp zoeae indicated that their behavior was abnormal at OCNGS discharge temperatures above 30°C (86°F). This form did not survive at 24 h exposure to a cyclic temperature of 25 to 30°C (77 to 86°F) (Regnault and Costlow, 1970). Zoeae were most abundant from March through June; the temperature in the discharge canal was below 30°C (86°F) from March through May. From June through August, zoeae secondarily entrained into either the discharge canal or areas of the plume in the bay that are above 30°C (86°F) may die.

Few adult and juvenile grass shrimp were collected. At discharge temperatures above 35°C (95°F), mortality averaged 89 percent, and below 35°C (95°F), mortality ranged from 0 to 35 percent. Most grass shrimp were entrained during July and August, when the average temperature in the upper portion of the discharge canal was below 35°C (95°F). Mortality should not have exceeded 33 percent at this time. However, at high ambient temperatures (28 to 30°C, 83.4 to 86°F) during summer, the temperature in the discharge canal and Oyster Creek will exceed 35°C (95°F), and mortality may approach 90 percent. Little or no mortality of forms entrained into the plume from the bay should occur.

Zoeae of the grass shrimp Palaemonetes vulgaris have been reared successfully at 30.6 ± 0.5°C (87.1 ± 0.9°F) (Sandifer, 1972). Qualitative observations indicated that at temperatures below 35°C (95°F) the form was relatively unaffected by temperature. Chase (1977) found that grass shrimp zoeae survived a 180-min exposure to a temperature as high as 37°C (98.6°F) but at 38°C (100.4°F), none survived. Since the average temperature in the discharge canal in July and August was below 35°C (98.6°F), little or no mortality should occur from secondary entrainment. This form was usually more abundant in collections in Oyster Creek than collections from Forked River.

Nereis spp epitokes had about 65 percent mortality at temperatures from 27.5 to 30°C (81.5 to 86°F) in April and May, but below 27.5°C (81.5°F) mortality did not exceed 20 percent. In April and May, the temperature in the discharge canal was usually below 27.5°C (81.5°F), and little or no mortality of secondarily entrained epitokes should occur. From June through August, this form was tolerant of higher temperatures and mortality did not exceed 25 percent at temperatures from 27.5 to 37.5°C (81.5 to 99.5°F). Although the average temperature ranged from 29.8 to 33.2°C (85.6 to 91.8°F) during these months, mortality should not exceed 25 percent.

Of the 32 blue crab megalopae collected at a temperature above 30°C (86°F), four were dead. Chase (1977) found no mortality of megalopae entrained at the P. H. Robinson generating station in Texas at a discharge temperature of 36 and 37°C (96.8 and 98.6°F) and held for up to 1 h, or of megalopae exposed to temperatures as high as 38°C (100.4°F) for 180 min. Little or no mortality should result from secondary entrainment because most megalopae (<90 percent) occur in September (average bay temperature of 22.2°C, 72°F) and October (15.5°C, 59.9°F) when the discharge canal temperature is below 30°C.

Zoeae of the mud crabs Neopanope texana, Panopeus herbstii, and Rhithropaneopeus harrisii have been reared successfully at 30 ± 2°C (86 ± 3.6°F) and 30°C (86°F) by Chamberlain (1961) and Costlow et al (1962, 1966), respectively. R. harrisii zoeae had better survival over the cyclic temperature range of 30 to 35°C (86 to 95°F) than at a constant temperature of either 30 or 35°C (86 to 95°F) (Costlow and Bookhout, 1971). R. harrisii zoeae exposed to a temperature of 37°C (98.6°F) or below for 180 min survived, but at a temperature of 38°C (100.4°F) or above they died (Chase, 1977). Qualitative observations indicated that few mud crab zoeae were affected by entrainment through OCNGS at temperatures below 35°C (95°F). Although mud crab zoeae are most abundant from May through July, little or no mortality would be expected from secondary entrainment because these forms were tolerant of temperatures up to 35°C (95°F).

Because of the excess temperature in the discharge canal and Oyster Creek, forms residing there may spawn or have their eggs hatch earlier than individuals in the bay. Earlier spawning or hatching of eggs may explain the greater number of zoeae of the grass shrimp and mud crabs and of epitokes of Nereis spp. in Oyster Creek at the beginning of the reproductive season.

3.2.2.4.3 Ichthyoplankton

The species composition and relative abundance of ichthyoplankton were similar in both streams. No significant difference occurred between the density of bay anchovy eggs and of goby larvae between stations in Forked River and Oyster Creek. However, the density of larvae and juveniles of both the bay anchovy and northern pipefish were greater in Forked River. Regardless of statistical significance, all forms showed a decrease in density at the mouth of Oyster Creek (Table 3.2-31). This decrease ranged from 42 percent for goby larvae to 86 percent for young of the northern pipefish.

Based on laboratory data collected at a salinity of 12 ppt (Meldrim, unpublished), decreased survival of secondarily entrained bay anchovy eggs is not expected when the temperature in the discharge canal is 33.5°C (93.2°F) or lower (WPC, Appendix, Table 26). Some 84 percent of the eggs exposed to 33.5°C (93.2°F) (delta T of 6.5°C, 11.7°F) for 1 h hatched. This percentage was not substantially different than that (90 percent) of eggs held at ambient temperature. The average temperature in Oyster Creek during July and August is from 32.8 to 33.2°C (91 to 91.8°F) (Table 3.1-4). Eggs secondarily entrained into the plume in the bay should not experience mortality since the temperature in this area of the plume rarely exceeds 33.5°C (92.3°F).

3.2.2.5 Analysis of the effect of OCNGS discharge on the zoo- and meroplankton community

3.2.2.5.1 Microzooplankton

No evidence of changes in the general structure of the microzooplankton community in Barnegat Bay was found. The species composition, distribution, and seasonal succession of the microzooplankton were similar to those described from other estuaries and enclosed embayments in the northeastern United States (Deevey, 1952, 1956, 1960; Jeffries, 1964, 1967; Cronin et al , 1962; Sage and Herman, 1972, Swiecicki and Prendergast, 1976).

The density of Acartia tonsa and of other forms at the mouth of the discharge canal was less than that at the OCNGS discharge, and this decrease may indicate losses of some microzooplankton from both primary and secondary entrainment. These losses have not noticeably reduced their populations in the bay. In the Indian River estuary in Delaware, Davies and Jensen (1974) found that a reduction in the holoplankton populations in the discharge canal did not appear to result in a decrease of these forms in the estuary.

3.2.2.5.2 Macrozooplankton

The seasonal variation, species composition, and relative abundance of the macrozooplankton community in Barnegat Bay is similar to Great Bay, New Jersey (Swiecicki and Prendergast, 1976), and no drastic changes in this community due to the operation of OCNGS are suggested. A strict quantitative comparison is not valid because of differences in sampling techniques and in the type of estuary studied. Increased production by some populations in Oyster Creek may compensate for and mask losses which occur in the discharge canal.

3.2.2.5.3 Ichthyoplankton

The seasonal distribution, abundance, and species composition of the ichthyoplankton of Barnegat Bay were generally similar to those reported in estuaries from Long Island to Chesapeake Bay (Croker, 1965; Dovel, 1967; Scotton, 1970; Swiecicki, 1976; Perlmutter, 1939; Richards, 1959; Wheatland, 1956). Although various studies (Wheatland 1956; Richards, 1959; Perlmutter 1959; Scotton 1970; Croker 1965) found eggs and larvae of the Atlantic menhaden to be relatively common, few were taken in Barnegat Bay. This may reflect both the general decline of the Atlantic menhaden population in the mid-Atlantic Bight (Nicholson, 1975) and its tendency to spawn in offshore waters (Nicholson, 1972).

Although most zooplankton populations are resident in the bay, the winter flounder, bay anchovy, and northern pipefish are the only RIS of fish that had substantial local reproduction in 1975-77. Spawning of the Atlantic menhaden, bluefish, weakfish, northern kingfish, and summer flounder occur primarly in ocean water, and their larvae are uncommon in Barnegat Bay and nearby Great Bay. The relatively small exchange of water between Barnegat Bay and the ocean may also account for the low numbers of the larvae of marine spawners in the bay. The population of the threespine stickleback in southern New Jersey estuaries has been low in recent years; no eggs and no larvae were collected in the bay. Since this species spawns and young occur in vegetation, it is unlikely that a substantial number of eggs and young were affected by the thermal discharge because most vegetation occurs in the eastern bay. Few eggs or larvae of the northern puffer were collected because the population of this species has been at low levels throughout New Jersey in recent years. Their decrease in abundance occurred in the late 1960s and early 1970s and was related to natural phenomena. Most New Jersey estuaries are relatively unimportant to the reproduction of the anadromous striped bass (Raney, 1952).

The loss of a substantial number of fish eggs was not expected because the temperature in the mixing zone was usually 33.5°C (92.3°F) or less. Any losses of eggs of the bay anchovy in the discharge canal are difficult to evaluate because some spawning apparently occurred in the canal. If losses of eggs and larvae occurred, they had no apparent effect on the population in the bay. The mean density of eggs (7-82/m^3) and larvae (0.1-11.9/m^3) during June and July 1976 was approximately equal to the density of eggs (17-115/m^3) and larvae (0.1-6.9/m^3) from nearby Great Bay and Little Egg Harbor during June and July of 1972 through 1975. The abundance of adults and juveniles in the bay has apparently not declined since OCNGS began operation (Section 3.2.4.7).

An assessment of the effect of the OCNGS thermal discharge on the larvae of the winter flounder, the Atlantic silverside, and the northern pipefish is difficult because no temperature shock data exist for these larvae, but it does not appear that the OCNGS thermal discharge has affected these species. Although the population levels of the winter flounder have declined in southern New Jersey estuaries in recent years, the seine catch of young winter flounder at selected stations in Barnegat Bay was within the range of catches in the bay before OCNGS began operation (Figure 3.5-19, Section 3.2.4.7). Most of the northern pipefish population is found in the eastern bay where the thermal plume has little effect, and the apparent decline in abundance of this species (Figure 3.5-17, Section 3.2.4.7) may be due to changes in habitat at the few stations sampled in the western bay rather than to a real decline in the population. The recent (1975-76) catch of the Atlantic silverside in seine collections in the bay was not lower than the catch prior to 1969 (Figure 3.2-15, Section 3.2.2.7). The population of this species in Great Bay has steadily declined from 1972 (242/seine collection) through 1974 (82/seine collection).

3.2.2.6 Incremental effect of FRNGS

The FRNGS discharge, as described in Appendix A3, will have very little effect on the temperature or salinity of the OCNGS discharge. The discharge of FRNGS (32,000 gpm) will account for only 3.16 percent to 4.25 percent of the water in the discharge canal. According to LMS (1978), the heat added by FRNGS (24,580 Btu/sec) will be only 2 percent of the heat added by OCNGS (1,213,420 Btu/sec). After mixing, the increase in temperature attributable to the FRNGS discharge (with OCNGS operating) during winter will be only 0.25°C (0.45°F). The increase in salinity after mixing will be only 0.26 to 0.53 ppt (LMS, 1978), and the maximum salinity in Oyster Creek should not exceed about 27 ppt.

Because of the low volume and high velocity (1.5 m/sec, 4.9 ft/sec) of the FRNGS discharge, few plankton in Oyster Creek will experience the maximum increase in temperature and salinity from the FRNGS discharge. After mixing, the increase in temperature and salinity in Oyster Creek should not affect the distribution or increase the mortality of zoo- or ichthyoplankton. Most zooplankton are estuarine and marine forms tolerant of a range of salinity from 15 to 32 ppt (Jeffries, 1967). The ichthyoplankton in Barnegat Bay is also tolerant of a wide range of salinity. The abundant eggs and larvae collected in the bay were also common off Little Egg Inlet (28 to 32 ppt). During the warmest months, the temperature of the FRNGS discharge will actually be less than the temperature in the discharge canal.

3.2.2.7 Summary and conclusions

No evidence exists that the OCNGS thermal discharge has caused a detectable change in the species composition, relative abundance, distribution, and seasonal occurrence of zoo- and ichthyoplankton in Barnegat Bay since these characteristics of the plankton population were similar to those in nearby New Jersey estuaries. Similarly no detectable changes in either the shellfish (Section 3.2.3) or fish (Section 3.2.4) community that can be attributed to the OCNGS thermal discharge have occurred. The entire central area of the bay is utilized in the spawning and development of zooplankton and for the few fishes which reproduce throughout this area of the bay and therefore, no portion of the central bay is considered critical. Only the northern pipefish and the blue crab reproduce in limited areas and these areas are not affected by the OCNGS thermal discharge. The localized population of gobies in the estuarine portions of Oyster Creek and Forked River has not been adversely affected and it is unlikely that the thermal discharge has affected other goby populations in the bay.

References

Bridger, J.P. 1956. On day and night catches of fish larvae. J. Cons. Perm. Int. Explor. Mer. 22(1): 42-57.

Carpenter, E.J., B.B. Peck, and S.J. Anderson. 1974. Survival of copepods passing through a nuclear power station on Northeastern Long Island Sound, U.S.A. Mar. Biol. 24: 49-55.

Chamberlain, N.A. 1961. Studies on the larval development of Neopanope texana sayi (Smith) and other crabs of the family Xanthidae (Brachyura). Chesapeake Bay Inst. Tech. Rept. 22: 1-35.

Chase, C.L. 1977. Survival of zooplankton entrained into the cooling water system and supplemental cooling towers of a steam-electric generating station located on Galveston Bay, Texas. M. S. Thesis. Texas A & M Univ. 230 pp.

Conover, R.J. 1956. Oceanography of Long Island Sound, 1953-1954. VI. Biology of Acartia clausi and A. tonsa. Bull. Bing. Oceanogr. Coll. 15: 156-233.

Costlow, J.D., Jr., and C.G. Bookhout. 1971. The effect of cyclic temperatures on larval development in the mud crab Rhithropanopeus harrisii, Pages 201-210 in D.J. Crisp, ed. Fourth European Mar. Biol. Symp. Cambridge Univ. Press, London.

Costlow, J.D., Jr. and C.G. Bookhout, and R. Monroe. 1962. Salinity-temperature effects on the larval development of the crab, Panopeus herbstii reared in the laboratory. Physiol. Zool. 35(1): 79-93.

Costlow, J.D., Jr., and C.G. Bookhout, and R. Monroe. 1966. Studies on the larval development of the crab, Rhithropanopeus harrisii. The effect of salinity and temperature on larval development. Physiol. Zool. 39(2): 81-100.

Croker, R.A. 1965. Planktonic fish eggs and larvae of Sandy Hook estuary. Chesapeake Sci. 6(2): 92-95.

Cronin, L.E., J.C. Daiber, and E.M. Hulbert. 1962. Quantitative seasonal aspects of zooplankton in the Delaware River estuary. Chesapeake Sci. 3(2): 63-93.

Daiber, F.C. 1963. Tidal creeks and fish eggs. Estuarine Bull. 7(2-3): 6-14.

Davies, R.M., and L.D. Jensen. 1974. Entrainment of zooplankton at three mid-Atlantic power plants. Pages 131-155 in L.D. Jensen, ed. Proc. of Second Workshop on Entrainment and Intake Screening. Johns Hopkins Univ., Baltimore, Md.

Deevey, G.B. 1952. Quantity and composition of the zooplankton of Block Island Sound, 1949. Bull. Bing. Oceanogr. Coll. 13(3): 120-164.

Deevey, G.B. 1956. Oceanography of Long Island Sound, 1952-1954. V. Zooplankton. Bull. Bing. Oceanogr. Coll. 15: 113-155.

Deevey, G.B. 1960. The zooplankton of the surface waters of the Delaware Bay region. Bull. Bing. Oceanogr. Coll. 17(2): 1-53.

Dovel, W. 1967. Fish eggs and larvae of the Magothy River, Maryland. Chesapeake Sci. 8(2): 125-129.

Heinle, D.R. 1969. Temperature and zooplankton. Chesapeake Sci. 10(3-4): 189-209.

________. 1977. Phytoplankton and zooplankton collection problems and relevance of entrainment to the ecosystem. Pages 101-117 in L.D. Jensen, ed. Third Nat. Workshop on Entrainment and Impingement. Ecological Analysts, Inc., Melville, NY.

Herman, S.S. 1963. Vertical migration of the oppossum shrimp, Neomysis americana. Smith. Limnol. Oceanogr. 8(2): 255-271.

Hildebrand, S.F., and L.E. Cable. 1930. Development and life history of fourteen teleostean fishes at Beaufort, North Carolina. Bull. U. S. Bur. Fish. 46: 383-488.

Isaacs, J.D. 1964. Night-caught and day-caught larvae of the California sardine. Sci. 144(3622): 1132-1133.

Jeffries, H.P. 1962. Succession of two Acartia species in estuaries. Limnol. Oceanogr. 9: 348-358.

Jeffries, H.P. 1964. Comparative studies on estuarine zooplankton Limnol. Oceanogr. 9: 348-358.

Jeffries, H.P. 1967. Saturation of estuarine zooplankton bay congeneric associates. Pages 500-508 _in_ G. Lauf, ed. Estuaries. Amer. Assoc. Adv. Sci., Publ. No. 83, Wash., D.C.

Jeffries, H.P. and W.C. Johnson. 1976. Petroleum, temperature, and toxicants: examples of suspected responses by plankton and benthos on the continental shelf. Univ. Rhode Is. Mar. Report 69: 96-108.

Marcy, B.C., Jr. 1976. Planktonic fish eggs and larvae of the lower Connecticut River and the effects of the Connecticut Yankee Plant including entrainment. Pages 115-139 _in_ D. Merriman and L.M. Thorpe, eds. The Connecticut River ecological study: the impact of a nuclear power plant. Publ. Amer. Fish. Soc. Monograph No. 1.

Milstein, C.B., D.L. Thomas, and Associates. 1976. Ecological studies in the bays and other waterways in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Ichthyological Assoc., Inc., Ithaca, NY. 757 pp.

__________, __________, __________. 1976. Ecological studies in the bays and other waterways in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress report for the period January-December 1975. Ichthyological Assoc., Inc., Ithaca, NY. 572 pp.

Nicholson, W.R. 1972. Population structure and movements of Atlantic menhaden, _Brevoortia tyrannus_, as inferred from back-calculated length frequency. Chesapeake Sci. 13(3): 161-174.

Nicholson, W.R. 1975. Age and size composition of the Atlantic menhaden, _Brevoortia tyrannus_, purse seine catch, 1963-71, with a brief discussion of the fishery. NOAA Tech. Rept. NMFS SSRF-684. 28 pp.

Norcross, J.J., W.H. Massman, and E.B. Joseph. 1961. Investigations of inner continental shelf waters off lower Chesapeake Bay. Part II. Sand lance larval, _Ammodytes americanus_. Chesapeake Sci. 2(1-2): 49-59.

Pearcy, W.G. 1962. Ecology of an estuarine population of winter flounder. Part III. Distribution, abundance, growth, and production of juveniles; survival of larvae and juveniles. Bull. Bing. Oceanogr. Coll. 18(1): 39-64.

Perlmutter, A. 1939. A biological survey of the salt waters of Long Island. Sect I. An ecological survey of young fish and eggs identified from tow-net collections. Suppl. 28th Ann. Rept. 1938. N. Y. State Conserv. Dept. Albany. No. 15, Pt. 2: 11-71.

Raney, E.C. 1952. The life history of the striped bass, *Roccus saxatilis* (Walbaum). Bull, Bing. Oceanogr. Coll. 14(1): 5-97.

Reeve, M.R., and E. Cosper. 1970. The acute thermal effects of heated effluents on the copepod *Acartia tonsa* from a sub-tropical bay and some problems of assessment. FAO Tech. Conf. on marine pollution and its effects on living resources and fishing, Rome, Italy, 9-18 Dec. 8 pp.

Regnault, M., and J.D. Costlow. 1970. Influence de la temperature et de la salinite sur le development larvaive de *Crangon septemspinosa sayi* (Decapoda, Caridea). Vie et milieu, Ser. A. 21(2-A): 453-466.

Richards, S.W., and A.W. Kendall, Jr. 1973. Distribution of sand lance, *Ammodytes* sp., larvae on the continental shelf from Cape Cod to Cape Hatteras from R.V. Dolphin surveys in 1966. Fish. Bull. 71(2): 371-386.

Richards, S.W. 1959. Oceanography of Long Island Sound. VI. Pelagic fish eggs and larvae of Long Island Sound. Bull. Bing. Oceanogr. Coll. 17(1): 95-124.

Russell, F.S. 1929. The vertical distribution of marine macroplankton.IX. The distribution of the pelagic young of teleostean fishes in the daytime in the Plymouth area. J. Mar. Biol. Assoc. U. K. 13(2): 639-676.

Sage, L.E., and S.S. Herman. 1972. Zooplankton of the Sandy Hook Bay area, New Jersey. Chesapeake Sci. 13(1): 29-39.

Sandifer, P.A. 1972. Morphology and ecology of Chesapeake Bay decapod crustacean larvae. Ph.D. Dissertation. Univ. Virginia. 531 pp.

Sandine, P.H., V.J. McDermott, and J.H. Chamblin. 1974. Zooplankton. Pages 52-74 in Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress report for the period January-December 1973. Vol. Three Ichthyological Assoc., Inc., Ithaca, NY. 393 pp.

Sandine, P.H., and F.A. Swiecicki. 1975. Zooplankton. Pages 72-94 in Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress Report for the period January-December 1974. Vol. Two. Ichthyological Assoc., Inc., Ithaca, NY. 467 pp.

Scotton, L.N. 1970. Occurrence and distribution of larval fishes in the Indian River and Rehoboth Bays, Delaware, June 1968 - March 1970. M.S. Thesis. Univ. Delaware. 65 pp.

Swiecicki, D.P. 1976. Ichthyoplankton. Pages 61-67 in Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress Report for the period January-December 1975. Ichthyological Assoc., Inc., Ithaca, NY. 572 pp.

Swiecicki, F.A., and P.A. Pendergast. 1976. Zooplankton, Pages 110-138 in Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress Report for the period January-December 1975. Ichthyological Assoc., Inc., Ithaca, NY. 572 pp.

Tatham, T.R., P.H. Sandine, R.P. Smith, H.W. Hoffman, K.A. Tighe, and D.L. Thomas. 1977b. Ecological studies for the Oyster Creek Generating Station. Progress report for the period September 1975 - August 1976. Vol. Two. Plankton. Ichthyological Assoc., Inc., Ithaca, NY. 368 pp.

Tatham, T.R., P.H. Sandine, R.P. Smith, K. A. Tighe, and F.A. Swiecicki, 1978b. Preliminary report of ecological studies for the Oyster Creek Generating Station. Progress report for the period September 1976 - August 1977. Vol. Two. Part 1. Plankton. Ichthyological Assoc., Inc., Ithaca, NY.

Thomas, D.L., and C.B. Milstein. 1973. Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress report for the period January-December, 1972. Part One. Ichthyological Assoc., Inc., Ithaca, NY. 666 pp.

Thomas, D.L., C.B. Milstein, T.R. Tatham, R.C. Beider, D.J. Danila, H.K. Hoff, D.P. Swiecicki, R.P. Smith, G.J. Miller, J.J. Gift, and M.C. Wyllie. 1975. Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress report for the period January-December 1974. Vol. I. Fishes. Ichthyological Assoc., Inc., Ithaca, NY. 490 pp.

__________, __________, __________, __________, F.J. Margraf, D.J. Danila, H.K. Hoff, E.A. Illjes, M.M. McCullough, and F.A. Swiecicki. 1974. Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress report for the period January-December 1973. Vol. I. Fishes. Ichthyological Assoc., Inc., Ithaca, NY. 709 pp.

Thomas, D.L., C.B. Milstein, T.R. Tatham, E.Van Eps, D.K. Stauble, and H.K. Hoff. 1972. Ecological considerations for ocean sites off New Jersey for proposed nuclear generating stations. Vol. One. Part One. Ichthyological Assoc., Inc., Ithaca, NY. January 1972. 115 pp.

United States Environmental Protection Agency. 1977. Draft of interagency 316(a) technical guidance manual and guide for thermal effects sections of nuclear facilities environmental impact statements. U. S. EPA, Off. Water Enforcement, Permits Div., Industrial Permits Branch, Wash., D.C. 79 pp.

Wheatland, S.B. 1956. Oceanography of Long Island, 1952-1954. VII. Pelagic fish eggs and larvae. Bull. Bing. Oceanogr. Coll. 15: 234-314.

Young, J.S. and A.B. Frame. 1976. Some effects of a power plant effluent on estuarine epibenthic organisms. Int. Revue. ges. Hydrobiol. 61(1): 37-61.

3.2.3 Benthic Macroinvertebrates

From 1965 to 1974 and again in 1976 and 1977, samples of the benthos in Barnegat Bay were collected and analyzed by Rutgers University (Loveland et al, 1966 to 1974) and JCP&L. These studies spanned five pre-operational (1965 to 1969) and six operational (1970 to 73 and 1976 to 77) years.

The Rutgers University studies resulted in a total of 694 samples being collected on 106 sampling dates with 271 species identified between 1965 and 1974. In 1976 and 1977, 88 additional samples were collected by JCP&L. These investigations were undertaken for the purpose of documenting any changes in the benthos that might occur as a result of the construction and operation of the OCNGS. Standing crop, species composition, diversity and dominance were studied in areas within and outside of the influence of the thermal discharge (Figure 3.2-9). Appendix C9 contains a complete description of the methodology as well as the statistical analyses of the data.

Two species of importance in the benthic community, Mercenaria mercenaria (the northern hard clam) and Callinectes sapidus (the blue crab), have been discussed in detail above in Sections 3.1.6 and 3.1.20, respectively. Both are important commercial species, and maintenance of their populations is significant to satisfying the decision criteria for this biotic category. The conclusion of the analyses for Sections 3.1.6 and 3.1.20 is that the thermal discharge of OCNGS and FRNGS will not appreciably affect the growth, reproduction and abundance of the hard clam and the blue crab.

3.2.3.1 Decision Criteria

The Section 316(a) demonstration for this biotic category must be assessed according to the following criteria:

(1) The benthic community in the Barnegat Bay study area should be composed of self-sustaining populations that are considered normal to the estuarine environment. Any indigenous species of recreational or commercial importance must be included.

(2) The community should be relatively stable in species composition, dominance, diversity, relative abundance and standing crop. Such stability must be assessed within the limits of variability, both seasonal and annual, normally encountered in mid-Atlantic estuarine and closed embayment communities.

If both criteria are satisfied, then it may be concluded that the discharge has not interfered with the maintenance and functioning of the indigenous community. If either criteria cannot be met, then the cause and extent of the variation must be examined. If the thermal discharge is found not to cause the variation, or if the variation is not of significance to the maintenance of a balanced, indigenous population of fish, shellfish and wildlife in Barnegat Bay, then it may be concluded that the requirements of Section 316(a) have been satisfied.

3.2.3.2 Rationale

Between 1965 and 1974 a total of 694 benthic invertebrate samples were collected from Barnegat Bay to assess the impact of the OCNGS on the benthic macroinvertebrate community. Both qualitative and quantitative sampling was conducted, with qualitative sampling predominating during the 1965 to 1968 survey period and quantitative sampling during the 1969 to 1974 survey period. In regard to quantitative sampling, ten variables were tested for year to year differences within a region (Stouts Creek mouth, Forked River mouth, and Oyster Creek mouth) and for region to region differences within a year. These variables included: (1) number of individuals per square meter; (2) number of species; (3) diversity index; (4) dry weight of sample; (5) number of _Mulinia lateralis_/m^2; (6) number of _Pectinaria gouldii_/m^2; (7) number of _Ampelisca_ sp./m^2; (8) number of _Retusa canaliculata_/m^2; (9) water temperature at bottom; and (10) salinity at bottom.

During the qualitative survey period (1965 to 1968), before initiation of operations at the OCNGS, there was no noticeable yearly change in the benthic invertebrate community, although the number of individuals of all species tended to fluctuate with reproductive seasons. *Pectinaria gouldii*, *Mulinia lateralis*, and *Tellina agilis* dominated the benthos at that time.

In the fall of 1969, large increases in the density of *Pectinaria gouldii* and *Mulinia lateralis* occurred at the mouths of Stouts Creek, the Forked River, and Oyster Creek. From 1969 to 1970 the abundance of benthic invertebrates at these three locations returned to levels approximating those during the 1965 to 1968 sampling period. Although the greatest decline in density was observed at the mouth of Oyster Creek, this was within the range of natural variability demonstrated by the other two stations and attributed to natural population dynamics rather than the OCNGS thermal discharge. Concomitant with the decrease in density was a drop in sample dry weight and the average number of species per sample and an increase in diversity at all three stations. The density of benthic invertebrates continued to decrease from 1970 to 1971 and from 1972 to 1973 as did the dry weight of samples, but the average number of species per sample increased.

While the density and diversity of benthic invertebrates changed significantly from 1970 to 1973 at the mouths of Stouts Creek, the Forked River, and Oyster Creek, the composition of the community remained basically unchanged. The dominant benthic species during this interval were *Mulinia lateralis* and *Pectinaria gouldii*.

Except for the discharge canal and the region immediately around the mouth of Oyster Creek, thermal discharge from the OCNGS has not affected the abundance of benthic populations in Barnegat Bay. In addition, thermal discharge has not influenced yearly standing crop, species composition, and diversity of benthic organisms in the bay. Changes in the benthic community are best explained by natural variations in the dynamics of constituent populations rather than from adverse impact of thermal discharge from the OCNGS.

3.2.3.3 Structure of the Indigenous Community

The benthic invertebrate data collected prior to 1969 are largely qualitative but do provide a description of the composition of the benthos of Barnegat Bay prior to the operation of the OCNGS. Phillips (1972) collected 304 benthic samples and found 110 species from 1965 to 1968. Table 2.2 in Appendix C9 presents the mean density (number/m^2) and observed density ranges of the dominant benthic invertebrates found at three Barnegat Bay sampling stations (Stouts Creek, Forked River and Oyster Creek mouths) over the period 1965-1968. Pectinaria gouldii, a polychaete, and Mulinia lateralis, a bivalve, were among the three most abundant species at all three sampling regions. Another bivalve, Tellina agilis, was among the three most abundant species at Oyster Creek and the Forked River but was uncommon around the mouth of Stouts Creek. Pectinaria gouldii was the most abundant organism at all three sampling stations and appeared in more than 50 percent of the samples collected (Phillips, 1972). Since all species were not enumerated during this period, it is impossible to determine the total number of individuals per square meter but, in general, it appears that densities at the mouths of the Forked River and Oyster Creek were slightly greater than those at the mouth of Stouts Creek.

In terms of species diversity, Phillips (1972) reported that the communities around the mouths of the Forked River and Oyster Creek were the most diverse during the 1965-1968 period (mean Shannon-Weaver diversity indices of 2.28 and 1.98, respectively). Phillips makes no mention of diversity in the area around the mouth of Stouts Creek, but lists the mean value as 2.59.

In general, during this early survey period, a few dominant species, Pectinaria gouldii, Mulinia lateralis, and Tellina agilis tended to outnumber all other species which were rather equally represented within any sample. Phillips (Loveland et al., 1971) indicated that although the numbers of individuals of all species in Barnegat Bay vary with reproductive seasons, there was no noticeable change in the benthic invertebrate community composition during the period 1965-1968.

After 1968, a rigorous quantitative method of sampling the benthos was utilized (Appendix C9) making it possible to more accurately characterize the species composition as well as abundance of benthic invertebrates. Samples were collected primarily at three localities (Figure 3.2-9): 1) the mouth of Oyster Creek, directly in the path of the thermal discharge; 2) the mouth of Stouts Creek, which served as a control area since it is quite similar to the region around the mouth of Oyster Creek in terms of its sediment composition and hydrographic characteristics, but is outside of the influence of the thermal discharge; and 3) the mouth of the Forked River, located approximately midway between the other two stations and only periodically affected by the thermal discharge, and then only to a very limited degree (Appendix B, Section 2).

Detailed discussions of these aspects of the benthic studies are presented in Appendix C9. The following sections discuss several important aspects of the benthic community and their relation to the thermal discharge from the OCNGS.

3.2.3.4 Effects of the OCNGS on Community Structure

3.2.3.4.1 Standing Crop

Although statistically significant annual changes in the standing crop (number of individuals per square meter) of benthic invertebrates have been documented, these changes do not appear to have been related to the thermal discharge from the OCNGS.

During the fall of 1969, coincident with the beginning of operation of the OCNGS, large increases in the abundance of at least two of the dominant benthic invertebrate species (*Mulinia lateralis* and *Pectinaria gouldii*) were observed at the Stouts Creek, Forked River and Oyster Creek mouths (Appendix C9, Section 2.1.3). The mean densities for these species in 1969 were outside of the range of densities found during the 1965 to 1968 period. When the mean water temperatures (measured at the sediment surface) at the three sampling stations were compared using a one-way analysis of variance (Appendix C9, Table 2.11) no significant differences were found. Furthermore, studies of the physical behavior of the thermal plume (Appendix B, Section 2) have indicated that the plume seldom extends as far north as the mouth of the Forked River. Even when recirculation occurs, the thermal plume is primarily a surface phenemenon which rarely extends to the bottom as far north as Forked River and is, therefore, unlikely to have any direct influence upon the benthos, particularly in the area north of the Forked River to the mouth of Stouts Creek. Since the tremendous increase in the abundance of *Mulinia* and *Pectinaria* occurred at all three sampling stations, it is unlikely that the increase was caused by the operation of the OCNGS. In addition, large fluctuations in the abundance of these species have been observed in other areas along the East Coast (Taylor et al., 1970, Boesch, 1973, Kaplan et al., 1975, Stickney and Perlmutter, 1975) and appear to be the rule rather than the exception.

The tremendous increase in the standing crop of benthic invertebrates in 1969 appears to have been a year class phenemenon, as 1970 showed a reduction in abundance at all three sampling stations (Appendix C9, Table 2.3) which produced density values similar to those found during the 1965-1968 period. Further decreases in the standing crop of benthic invertebrates occurred from 1970 to 1971 and from 1972 to 1973 at all three sampling stations (Appendix C9, Table 2.13). No change in density was observed from 1971 to 1972. Samples collected in 1976 have shown that the baywide decline in standing crop has leveled off (Figure 3.2-10).

As Boesch et al. (1975) point out, most coastal soft-bottom benthic communities exhibit significant seasonal and long term fluctuations. These fluctuations occur primarily in the form of the widely varying standing crop of the constituent populations (e.g. Mulinia and Pectinaria) while species composition tends to remain remarkably constant. This appears to be the case in Barnegat Bay as standing crop has varied considerably since 1965 whereas the species composition has remained essentially the same (Section 3.2.3.4.2).

During the winter-spring period of any one year, greater numbers of individuals/m^2 were found at Oyster Creek than at Forked River and Stouts Creek (Appendix C9, Table 2.15 and Figure 2.5). During the summer-fall period, greater numbers of individuals/m^2 were found at Stouts Creek and Forked River than at Oyster Creek. The net result was an averaging over the entire year which produced no significant regional differences in density. This phenemenon may be indicative of an effect of the thermal discharge on the seasonal abundance of benthic invertebrates at the mouth of Oyster Creek.

Young and Frame (1975), in a comparative study of the epibenthos in Forked River and Oyster Creek, found that during late fall and early summer species abundance was higher in Oyster Creek than in the Forked River. From midsummer to early fall, species abundance was lower in Oyster Creek. Peaks in the abundance of some species appeared earlier in the year at Oyster Creek when compared with the Forked River. The authors suggest that these differences between the intake and discharge canals are due to the temperature difference between the two regions.

If spawning peaks for some species occur earlier in Oyster Creek than in the Forked River, the differences in seasonal standing crop between these two regions are not surprising. Since no significant differences between the yearly standing crop estimates at the mouths of Oyster Creek and Forked River were observed, this seasonal shift does not seem to have affected the annual production of the benthic communities in these areas.

3.2.3.4.2 Species Composition

No major changes in the species composition of western Barnegat Bay have occurred since the benthos was first studied in 1965. Mulinia lateralis and Pectinaria gouldii have consistently been the dominant species in terms of density per square meter.

The average number of species per sample increased from 1970 to 1971 at Stouts Creek, the Forked River and Oyster Creek (Appendix C9, Table 2.16 and Figure 2.6). From 1971 to 1972, a significant increase in the number of species per sample was observed at Oyster Creek and the Forked River but not at Stouts Creek (Appendix C9, Table 2.18 and Figure 2.7). The reasons for these changes are not obvious but they are most likely due to increases in the ability of the investigators to speciate the benthic invertebrates as more detailed taxonomic keys became available.

Appendix C9, Tables 2.38 to 2.40 present the ten most abundant benthic invertebrate species found at the Oyster Creek, Forked River and Stouts Creek sampling stations from 1969 (pre-operational) to 1973. These data clearly show that the species composition of the western portion of Barnegat Bay has remained remarkably consistent.

3.2.3.4.3 Species Diversity

Since the number of species per sample remained rather constant throughout the study period (Section 3.2.3.4.2) but the abundance of a given species showed large fluctuations, changes in the value of the Shannon-Weaver (1949) diversity index were largely controlled by changes in abundance. The drops in abundance which followed the tremendous increase in 1969 resulted in a decrease in dominance and increase in diversity at all sampling stations in Barnegat Bay (Appendix C9, Tables 2.3 and 2.5).

Young and Frame (1975) found no significant difference in species diversity between the intake (Forked River) and discharge canals (Oyster Creek).

3.2.3.5 Incremental Effect of FRNGS

With both OCNGS and FRNGS in operation, most of the water in the discharge canal will pass through either the OCNGS Cooling Water System or the dilution pumps. Operational characteristics of FRNGS and its effect on the temperature and salinity of the discharge canal and

Oyster Creek were presented in Chapter 1, Appendix A3, and Appendix B.

The FRNGS discharge will have an extremely small effect on the temperature and salinity regimes in Oyster Creek and Barnegat Bay. The minor changes in temperature and salinity which result from the FRNGS discharge should have no effect on the benthic invertebrate communities in Oyster Creek and Barnegat Bay.

3.2.3.6 Summary and Conclusions

Although a possible seasonal effect of the thermal discharge on the abundance of benthic macroinvertebrates has been detected, the effect appears to be confined to the discharge canal and the region immediately around the mouth of Oyster Creek and does not result in a significantly different yearly standing crop estimate in those regions when compared to control areas.

No effects of the thermal discharge have been detected on yearly standing crop, species composition or species diversity of the benthic macroinvertebrates in the western portion of Barnegat Bay. Based on the analysis of the impact of the thermal discharge on growth, reproduction and abundance of Mercenaria mercenaria and Callinectes sapidus (Section 3.1.6 and 3.1.20) no effects have been detected. Commercial landings of these species have not decreased since OCNGS began operation and for blue crab, the age structure of the population is similar to that in nearby estuaries.

References

Boesch, D.F. 1973. Classification and community structure of macrobenthos in the Hampton Roads area, Virginia. Marine Biology 21: 226-244.

Boesch, D.F., M.L. Wass and R.W. Virnstein. 1975. The dynamics of estuarine benthic communities: Contribution no. 000 from the Virginia Institute of Marine Science.

Kaplan, E.H., J.R. Welker and M.G. Kraus. 1974. Some effects of dredging on populations of macrobenthic organisms: FISH BULL 71(2) 445-480.

Loveland, R.E. and E.T. Moul. 1966. The qualitative and quantitative analysis of the benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition. An Initial Progress Report to Jersey Central Power & Light Company. Contract #27-4656. 39 pp.

Loveland, R.E., E.T. Moul, F.X. Phillips and J.E. Taylor. 1967. The qualitative and quantitative analysis of the benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition. Second Progress Report to Jersey Central Power & Light Company. Contract #27-4656. 7 pp.

Loveland, R.E., E.T. Moul, J.E. Taylor, F.X. Phillips and K. Mountford. 1968. Barnegat Bay thermal addition. Progress Report No. 3. Jersey Central Power & Light Company. Contract #27-4656. 123 pp.

Loveland, R.E., E.T. Moul, J.E. Taylor, K. Mountford and F.X. Phillips. 1968. The qualitative and quantitative analysis of the benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition. Fourth Progress Report to Jersey Central Power & Light Company. Contract #27-4656. 17 pp.

Loveland, R.E., E.T. Moul, F.X. Phillips, J.E. Taylor, and K. Mountford. 1969. The qualitative and quantitative analysis of the benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition. Fifth Progress Report to Jersey Central Power & Light Company. Contract #27-4656. 115 pp.

Loveland, R.E., E.T. Moul, K. Mountford, P. Sandine, D. Busch, E. Cohen, N. Kirk, M. Moskowitz and C. Messing. 1970. The qualitative and quantitative analysis of the benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition. Sixth Progress Report to Jersey Central Power & Light Company. Contract #27-4656. 30 pp.

Loveland, R.E., K. Mountford, E.T. Moul, D.A. Busch, P.H. Sandine and M. Moskowitz. 1971. The qualitative and quantitative analysis of the benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition. Seventh Progress Report to Jersey Central Power & Light Company. Contract #27-4656. 49 pp.

Loveland, R.E., E.T. Moul, D.A. Busch, P.H. Sandine, S.A. Shafto, J. McCarty. 1972. The qualitative and quantitative analysis of the benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition. Eighth Progress Report to Jersey Central Power & Light Company. Contract #27-4656. 81 pp.

Loveland, R.E., P. Edwards, J.J. Vouglitois and D. Palumbo, 1974. The qualitative and quantitative analysis of the benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition. Ninth Progress Report to Jersey Central Power & Light Company. Contract #27-4656. 78 pp.

Phillips, F.X. 1972. The ecology of the benthic macroinvertebrates of Barnegat Bay, New Jersey: Ph.D. dissertation, Rutgers University, New Brunswick, New Jersey.

Sahnnon, C.E. and W. Weaver. 1949. The mathematical theory of communication. University of Illinois Press.

Stickney, Robert R., and D. Perlmutter. 1975. Impact of intracoastal waterway maintenance dredging on a mud bottom benthos community. Biol. Conserv. 7(3): 211-226.

Taylor, J.L., J.R. Hall and C.H. Saloman. 1970. Mollusks and benthic environments in Hillsborough Bay, Florida: FISH BULL 68(2).

Woodward-Clyde Consultants. 1975. The physical behavior of the thermal plume discharged from the Oyster Creek Nuclear Generating Station: Report to Jersey Central Power & Light Company.

Young, J.S. and A.B. Frame. 1976. Some effects of a power plant effluent on estuarine epibenthic organisms: Int. Revue ges. Hydrobiol. 61(1) 37-61.

3.2.4 Fish

Data on the fish community in Barnegat Bay and in the intake and discharge canal and Forked River and Oyster Creek are based on samples collected from September 1975 through August 1977 by Ichthyological Associates (I.A.) (Tatham et al., 1977a, 1978); previous studies of Barnegat Bay (Marcellus, 1972; Appendix C10; McClain, 1973); the literature; and extensive research by I. A. in nearby New Jersey estuaries (Thomas et al., 1972, 1974, 1975; Thomas and Milstein, 1973; Milstein et al., 1976, 1977). Between September 1975 and August 1977, samples were taken with trawl, seine and gill net in Barnegat Bay from Goodluck Point to Gulf Point, Oyster Creek, Forked River, and in the intake and discharge canal (Tatham et al., 1977a, 1978a). Although the common names of fishes are used throughout the text, the corresponding scientific names are presented in Tables 3.2-27 and 3.2-28. Complete discussions of the methods and data from these studies are contained in Appendix C1.

3.2.4.1 Decision Criteria

Barnegat Bay is a spawning area for many fishes. Some are resident in the estuary, while many others are migratory and present only seasonally. The decision criteria for this category of the demonstration must address the functional characteristics of the fish community and take into account the regulatory interests encompassed in Section 316(a), as reflected in various elements of EPA's "316(a) Technical Guidance Manual". For Oyster Creek and Barnegat Bay and the OCNGS and FRNGS, then, the Section 316(a) demonstration should be evaluated according to the following criteria:

(1) The fish community of Oyster Creek and Barnegat Bay should include species which are typical of mid-Atlantic estuaries and embayments. The composition, relative abundance and seasonal succession of the species of the community should be within the range of natural variation for such water bodies.

(2) Species which use Oyster Creek and the bay for spawning or nursery activities should evidence successful reproduction, growth and population maintenance in the bay, within the range of natural variation encountered among such species. Fishes should not be excluded from an area of Oyster Creek and Barnegat Bay that will result in an adverse effect on the functioning and maintenance of the bay populations.

(3) The thermal plume should not prevent the successful seasonal migration, movement or dispersal of important species to or from spawning or nursery grounds within Oyster Creek, Barnegat Bay or the Atlantic Ocean.

Although not expressly recognized as a "decision criterion" in the drafts of the Guidance Manual, the occurrence of stressful conditions -- heat or cold shock or gas bubble disease -- causing fish mortality within the area of the thermal plume is a further area of concern. All three conditions have been observed from time-to-time in connection with various operating conditions of OCNGS, and are addressed in this section. Mortalities within the area of the plume as a consequence of stressful conditions should not be permitted to continue if they will imperil preservation of the bay's populations.

If the criteria are satisfied, then the demonstration should be held successful. If they are not, the cause and significance of any departure from the criteria should be determined. If the departure is not attributable to the thermal discharge, or is not important to the maintenance and function of a representative community of fishes, then the 316(a) test may be deemed satisfied.

Considering the length of time that OCNGS has been operating, the structure of the fish community (i.e. species composition, relative abundance, and seasonal succession) probably is the most important indicator of the effect which the thermal discharge has had and, thus, these aspects of the community are examined in the first of the decision criteria. Data on species composition and relative abundance is of importance because their similarity with respect to comparable mid-Atlantic estuaries would reflect the maintenance of the many functions and interactions necessary for the protection and propagation of the various populations and the fish community. Although data for all species in all areas of study were not gathered before OCNGS began operation in August 1969, a direct comparison of the pre-operational (1966 to 1969) and operational (1970 to 1977) community of shore-zone fishes was possible for three stations sampled throughout these studies. The analysis of this community was supported by comparisons of these data to data gathered in other mid-Atlantic estuaries.

Successful spawning and development of resident species of the bay is, of course, necessary to their continued presence and prosperity. Therefore, the second of the three decision criteria requires that the thermal plume not adversely affect the functioning and maintenance of the bay populations. Successful reproduction would be reflected in the presence of an assemblage of life stages of each resident species which is typical of similar estuaries and embayments. This section discusses the juvenile and adult populations. The zoo- and meroplanktonic communities are discussed in Section 3.2.2, and that analysis is not repeated here.

The last of the three decision criteria reflects the fact that the migration of fish is also an important element of reproduction and maintenance of bay populations. If the OCNGS discharge presented a barrier to such movements to critical spawning or nursery areas, successful reproduction and development would be severely impaired. In Barnegat Bay, the extent of blockage may be evaluated according to the area of the plume which would exclude a species. As a practical matter this is a conservative criteria, since fish may migrate through an area which they might otherwise avoid because of elevated temperatures. If the area of the plume is relatively small (e.g., falling within 25 percent of the cross sectional area or width of the receiving body, as proposed as a guideline in the New Jersey Surface Water Quality Standards), then it may be concluded that the plume does not constitute a barrier to the successful migration, dispersal or other movements important to reproduction and development. It should be noted that in defining "low potential impact areas" for fish, EPA's "316(a) Technical Guidance Manual" considers blockage to be of significance only to the 2.0°C (3.6°F) isotherm. That is, where the 2.0°C (3.6°F) isotherm bounds only a relatively small area of the zone required for passage, then the discharge is eligible to be considered as having a low potential impact for fish. The analysis in the following section is consistent with this concept.

3.2.4.2 Rationale

The thermal discharge from the OCNGS has affected, to a minor extent, the distribution of fishes in the bay and has caused mortality of some individuals in the Oyster Creek. However, this has not harmed the fish community of the bay. Changes in the species composition and relative abundance of fishes in Barnegat Bay since 1969 were apparently not related to the OCNGS thermal discharge. Comparisons of relative abundance of fishes during pre-operational years (1966 to 1969) to the operational years (1969 to 1970; 1975 to 1977) and to nearby estuaries indicate that most changes in the fish community were due to natural fluctuations of the various populations. During 1975 to 1976 and 1976 to 1977, some of these natural variations in abundance were on the order of 50 to 100 percent. Similar year-to-year fluctuations in abundance of these fishes were also documented for nearby New Jersey estuaries (i.e., Great Bay and adjacent bays). Other major decreases (e.g., silver perch, northern puffer) and increases (e.g., spot) in abundance have occurred along the mid-Atlantic Coast. A noticeable decline in one resident species, fourspine stickleback, has been observed at four sampling stations in the bay since 1966-67, and appears to have been related to local environmental stresses other than the OCNGS discharge because the largest increment of the decline occurred prior to the commencement of OCNGS operation.

Effects of the thermal discharge were confined primarily to the Oyster Creek. The thermal discharge affected the distribution and abundance of some species in Oyster Creek because they either avoided or preferred the thermal discharge during different seasons of the year. From June through September, some fishes (e.g., winter flounder) avoided Oyster Creek while other species (e.g., Atlantic menhaden, bluefish, weakfish) avoided only some portion of the discharge canal. In either case, the loss of habitat was relatively small.

From November through May, some species (e.g., Atlantic menhaden, bluefish, weakfish) were attracted to the warmer water in Oyster Creek and the discharge canal; more of these fishes were collected in these areas than in the Forked River and the intake canal during the fall, winter, and spring. Some individuals of the Atlantic menhaden, bluefish, weakfish, and spot resided in the discharge during winter. In general, fishes collected from the discharge canal and Oyster Creek did not have abnormally high rates of parasitism and disease, retarded growth, or aberrant reproductive characteristics.

The most visible effect of the OCNGS thermal discharge on fish populations has been due to mortality of fishes in the thermal discharge due to sudden changes, primarily decreases, in temperature. Heat shock was documented only twice since 1969, and both occurrences were during unusual operating or natural conditions. The magnitude of these kills was small, and they were of little significance to the local populations.

Shutdown of the OCNGS during winter and subsequent mortality of fishes, primarily the Atlantic menhaden, has occurred in the past. Although some losses of the Atlantic menhaden were relatively large, they represented less than one percent of the average annual commercial catch of the Atlantic menhaden in New Jersey and were probably inconsequential. Two dilution pump operation to discourage over wintering of fish and cessation of dilution pumping immediately after shutdown to delay the cooling of the heated water in Oyster Creek and the discharge canal have mitigated substantially the potential for cold-shock mortalities. The operation of FRNGS should reduce this potential further, since the discharge will provide some additional temperature stability in the event of OCNGS shutdown.

The elimination of small numbers of other overwintering fishes (i.e., the bay anchovy, bluefish, and weakfish) by either an OCNGS shutdown or gradual attrition during the winter was also of little consequence because these fishes, like the Atlantic menhaden, were from large populations along the Atlantic coast rather than from small, localized populations in the bay. The numbers of these fishes, particularly the bay anchovy, bluefish, and weakfish, which overwintered in the thermal discharge were small. If OCNGS shuts down in the future, a portion of the heated discharge from FRNGS may provide an area of warm water for some overwintering fishes.

Most fish secondarily entrained into the discharge canal can withstand a resultant temperature increase of 4 to 6°C (7.2 to 10.8°F). Few fish were secondarily entrained in this area during summer when temperatures in the discharge canal might have caused mortality. Most fish were secondarily entrained into the discharge canal during the spring and fall when temperatures were less extreme.

The discharge of the FRNGS is small in relation to the OCNGS discharge, and the combined discharges should be very similar to that when only OCNGS is in operation. The small increase in temperature (0.25°C, 0.45°F) and salinity (1 ppt) associated with the FRNGS discharge (with OCNGS operating) during winter should not affect the distribution or increase the mortality of organisms in the thermal discharge. During the summer the FRNGS discharge will cause a slight reduction in OCNGS discharge temperature.

3.2.4.3 Structure of the Indigenous Community

The fish community in Barnegat Bay is dominated numerically by a few species which usually comprised more than 90 percent of the total catch. Most fishes are either small forage fishes that are primarily resident in the bay or young and juveniles of marine species that are present seasonally. Adults of some marine species are also present in the bay at various times.

From September 1975 through August 1977, 76.3 percent of the fish taken by trawl in the bay were the bay anchovy. The fourspine stickleback (7.6 percent), spot (5.1 percent), Atlantic silverside (4.2 percent), and winter flounder (1.4 percent) were also numerous. Fifty other fishes comprised the remainder of the trawl catch (Table 3.2-32).

From 1975 to 1977 the Atlantic silverside (46.6 percent) and the bay anchovy (43.8 percent) dominated the catch by 12.2 m (40 ft) seine. The mummichog, tidewater silverside, fourspine stickleback, and spot represented an additional 5.5 percent; 47 other fishes made up 3.9 per cent of the total catch (Table 3.2-33). From October 1976 through August 1977, catch by 45.7 m seine consisted mostly (82.0 percent) of the Atlantic silverside, blueback herring, winter flounder, spot, bay anchovy, and Atlantic needlefish. Some 41 other fishes were also taken (Table 3.2-34).

Catch by gill net from September 1975 through August 1976 was dominated by the Atlantic menhaden (48.8 percent) and bluefish (22.5 percent). Fifteen other fishes were also collected (Table 3.2-35).

Although differences in salinity, bottom sediment, vegetation, and depth affect local abundance in the bay and creeks, most fishes are found throughout the bay. The bay serves as a nursery and feeding area for the Atlantic menhaden, bay anchovy, bluefish, weakfish, summer flounder, winter flounder, and many other fishes. Since few threespine stickleback, striped bass, northern kingfish, and northern puffer were collected, their distribution in the bay could not be determined.

The general distribution of all RIS fishes is discussed in Section 3.1. The Atlantic silverside and northern pipefish spawn in the shore zone and in shallow, vegetated areas. Most young and adults are also found in these restricted areas from spring through fall and move into deeper areas of the bay and into the ocean during winter.

3.2.4.4 Observed Responses to OCNGS Discharge

To assess the effects of the OCNGS thermal plume, the catch in the discharge canal and Oyster Creek was compared to the catch in the intake canal and the Forked River from March 1976 through March 1977. These areas were generally similar except for water temperature and some differences in bottom composition. When OCNGS was not in operation, the fish populations in these areas and the bay were generally similar. During the summer of 1976, OCNGS operated at less than its full-rated capacity (640 MW) during June (548 MW), July (526 MW), August (569 MW), and September (580 MW), and the temperatures in the discharge canal and Oyster Creek during these months were lower than the temperatures predicted in the LMS (1978) model (Table 3.1-4). Because the actual temperatures were lower, the response of some RIS fishes to the heated discharge was often markedly different from that predicted under maximum power output (Section 3.1).

The presence of the thermal plume in the discharge canal and Oyster Creek usually caused changes in the local distribution of some fishes. Over the year, more Atlantic menhaden, herrings, bay anchovy, white perch, bluefish, jacks, spot, and flatfishes were taken in these areas, while more oyster toadfish, fourspine stickleback, weakfish, and tautog were collected in the intake canal and Forked River. More fishes usually were captured in the discharge canal and Oyster Creek during most months. The catch in the thermal discharge was largest from November through April when the warmer water temperature attracted many species. However, during August and September when the water temperature in the thermal discharge was high, the catch was usually larger in the intake canal and Forked River. In some cases, numerical differences in catch between the thermal discharge and bay reflected not only the difference in water temperature but also differences in other factors (e.g., current, habitat preference) that affected distribution.

The distribution and abundance of most RIS in relation to the heated discharge is discussed below. The threespine stickleback, striped bass, northern kingfish, and northern puffer were not discussed because few specimens were taken.

The Atlantic menhaden was one of the most numerous fishes collected in the thermal plume, and it was collected there in all months. Schools of the Atlantic menhaden that returned to the bay during late March and April were attracted to Oyster Creek. By late spring, the number of Atlantic menhaden captured in the immediate vicinity of the OCNGS discharge decreased although it was abundant in Oyster Creek and in the dilution pump discharge. The catch of the Atlantic menhaden in Oyster Creek was comparable to similar areas in the Forked River during summer. Most specimens apparently avoided temperatures above 30°C (86°F) although a few specimens were taken in the immediate vicinity of the OCNGS discharge at 36°C (96.8°F). After September, it was collected only in the thermal discharge and from November through early March, most specimens were taken in the immediate vicinity of the OCNGS discharge.

The bay anchovy was the most abundant fish taken. It was attracted to the heated discharge in April when it returned to the bay. During the year, most bay anchovy were taken at water temperatures from 12 to 31°C (56.6 to 87.8°F), and it apparently avoided areas of the thermal discharge where the temperature exceeded 31°C (87.8°F). It was uncommon in the discharge canal and Oyster Creek in August and September when more were taken in the intake canal and Forked River. Marcellus (1972) noted that catches of the bay anchovy, mostly young, decreased at the mouth of Oyster Creek after OCNGS commenced operation.

The Atlantic silverside and northern pipefish were primarily resident fishes. Catches of the Atlantic silverside were large in March and April when it was attracted to the thermal discharge. The northern pipefish was apparently neither attracted to nor avoided the heated plume. The catch of this species was smaller in Oyster Creek, Forked River, and the discharge and intake canals than in other areas, apparently because vegetation, its preferred habitat, was lacking in the former areas.

The bluefish was attracted to and collected almost exclusively in the thermal discharge in May and from November through January. It was collected in Oyster Creek and throughout the bay from June through October. Many individuals were found in the immediate vicinity of the OCNGS discharge during most of the year, although they were rare at a temperature above 32°C (89.6°F). Many were taken by sport fishermen in Oyster Creek from July through October (Section 3.3).

The weakfish was attracted to the thermal discharge in April and after October, and some adults overwintered there. More adults and large juveniles were taken in the discharge canal and Oyster Creek than in the intake canal and Forked River during spring, fall, and winter. However, more young were taken in the intake canal and the Forked River than in the thermal discharge during August and September.

Although the summer flounder was caught throughout the bay by sport fishermen (Halgren, 1973), few were collected in either the intake canal and Forked River or in the heated discharge. Summer flounder that entered the bay were attracted to the heated discharge from April through early May but few were taken there or in either the intake canal or Forked River afterwards. None overwintered in the heated discharge.

The winter flounder was both attracted to and avoided the heated discharge at various times and it was collected in this area during all months. Adults were numerous in the immediate vicinity of the OCNGS discharge from December through March but left the area of the discharge after early April when the water temperature exceeded 15°C (59°F). A substantial sport fishery for the winter flounder existed in Oyster Creek in winters when OCNGS operated. Most young apparently avoided the discharge canal and Oyster Creek in July and August when OCNGS was in operation and the water temperature was above 24°C (75.2°F). However, other factors (e.g., current) may have been more important in the distribution of young. Young were taken in Oyster Creek at a temperature as high as 30°C (86°F) in July 1977 when OCNGS was not in operation and current was reduced.

The blueback herring and alewife were attracted to the thermal discharge in March, and the Atlantic needlefish, jacks, spot, and mullets were attracted in summer and fall. Uncommon species of southern origin such as the bluntnose stingray, ladyfish, gray snapper, and mojarras were taken almost exclusively in this area.

The Atlantic herring and spotted hake may have avoided the discharge canal and Oyster Creek when they were present in the bay in spring, and fewer fourspine stickleback were taken in the discharge canal and Oyster Creek than in other areas. Marcellus (1972) noted a decline in the catch of the four-spine stickleback at the mouth of Oyster Creek, but he felt this decline was related to the disappearance of eelgrass beds rather than to the heated plume.

Fishes which survive impingement on the traveling screens or passage through the dilution pumps are introduced into ambient temperature water in the discharge of the dilution pumps (Figure 3.2-11). This ambient temperature water and water from the OCNGS discharge remain fairly discrete until mixing occurs about 200 m (660 ft) down the discharge canal. The temperature of this partially mixed water averages 4.5°C (40.1°F) (range of 2.0 to 7.5°C (3.6 to 13.5°F)) above ambient with two dilution pumps in operation. Fishes introduced into the discharge canal either by passage through the dilution pumps or impingement on the traveling screens and subsequent release into dilution pump water may be able to avoid the maximum discharge temperature by remaining in ambient temperature water in the dilution pump discharge. However, they can leave this area of ambient temperature water only via the mixed flow of ambient and heated discharge water.

Most fishes introduced into the discharge canal were tolerant of the maximum 7.5°C (13.5°F) temperature increase (delta T) found in some areas of the mixed flow (Table 3.2-36). Of the dominant fishes introduced into the discharge canal, only the bay anchovy during fall and blueback herring during spring may have substantial (30 percent) mortality at or below delta T's of 7.5°C (13.5°F). Although few fishes survive a temperature above 35°C (95°F) (de Sylva, 1969), the temperature in the area of the discharge canal with mixed flow will average 32.9 to 33.2°C (91.2 to 91.8°F) only during July and August (average bay temperature of 26.7°C, 80.1°F). Relatively few fish were introduced into the discharge canal during spring and fall. Since fishes are released into the ambient temperature water of the dilution pump discharge, they may choose to remain there and thus avoid the higher temperatures in the mixing area.

Fishes found in the heated discharge did not have abnormally high rates of parasitism or disease. The rate of parasitic infestation of the Atlantic menhaden, bay anchovy, and bluefish was no greater in this area than in other areas of the bay. Parasitism of other RIS was low in both the discharge canal and Oyster Creek and in the bay.

The allometric condition factor (Ricker, 1975) was examined to determine if the physical condition of fishes in the heated discharge was poorer than that of fishes in other areas. No significant difference in condition was found between 150 to 190 mm (5.9 to 7.5 in.)bluefish, 45 to 215 mm (1.8 to 8.5 in.) weakfish, and 90 to 210 mm (3.5 to 8.3 in.) winter flounder from the discharge canal and Oyster Creek and in the intake canal and Forked River. Most 90 to 109 mm (3.5 to 4.3 in.) Atlantic menhaden taken either in the immediate area of the OCNGS discharge or in Oyster Creek were in better condition than those taken in the intake canal and Forked River.

Atlantic menhaden (91 to 190 mm, 3.6 to 5.1 in.) which resided in the thermal discharge from November through March lost weight, but this loss did not occur in large (211 to 260 mm, 8.3 to 10.2 in.) specimens. Small Atlantic menhaden that overwintered in the immediate vicinity of the OCNGS discharge were in better condition in January than in either February or March, but no difference in condition was detected for large specimens.

The length of the bay anchovy taken in the discharge canal and Oyster Creek was not significantly different from those taken in the intake canal and Forked River and in the Bay. Young weakfish taken during August in the discharge canal and Oyster Creek were significantly smaller than those from the intake canal and Forked River and in the bay.

The thermal discharge from OCNGS has not eliminated the anadromous spawning migration of herrings to the freshwater areas of Oyster Creek in the spring, if they ever existed. Documented information regarding use of the stream by anadromous alewife prior to the operation of OCNGS was lacking (letter from A. B. Pyle, New Jersey Division of Fish and Game, to R. Hayford, chief of NJ Bureau of Fisheries; May 1, 1964), but Zich (personal communication) mentioned verbal accounts of spawning runs of the alewife in Oyster Creek and of spawning of the blueback herring in low salinity lagoons. During construction of the OCNGS, herring were reportedly abundant in the upper canals during the spring (B. Johansen, Public Service Electric and Gas Co., Newark, NJ; personal communication). After OCNGS began operation, Zich (1977) reported that Oyster Creek had an unconfirmed spawning run of herrings during 1972 through 1976. No spawning herrings were sighted or collected in fresh water areas of Oyster Creek during 1976 and 1977. It does not appear that there is or has been significant reproduction of clupeids in Oyster Creek or Forked River. Even were some individuals to prefer the small remaining freshwater reaches in these streams, the temperature of the thermal discharge may block some runs only in the late portion of the spawning season, after late May (discharge canal temperature of 27°C, 80.6°F). In Connecticut, spawning runs of the blueback herring ceased at a water temperature of 27°C (80.6°F) (Loesch and Lund, 1977). Spawning of both herrings has been confirmed in numerous other tributaries of the bay (Zich, 1977) and therefore Oyster Creek is not a critical habitat for these species.

The OCNGS thermal discharge to the 2.2°C (4.0°F) isotherm occupies less than 25 percent of the cross-sectional area of the bay and does not physically block the movement or migration of fishes. Resident fishes and species which enter the bay during spring and emigrate in the fall are found throughout the bay. Even though the plume may cover 20 to 25 percent of the bay during spring and fall, the periods of most migration, many fishes will prefer the temperatures in the plume, and therefore the thermal discharge will not prevent migration. Although most fishes would avoid the plume to the 2.2°C (4.0°F) isotherm during summer under maximum OCNGS output conditions, no evidence exists that the plume forms a barrier to the free movement of fishes during these months because these fishes were found throughout the area of the bay studied.

The thermal discharge results in a behavioral response of attraction, rather than a physical blockage of the emigration of some fishes from the bay during fall. Since these fishes usually do not tolerate the low temperature found in the bay during winter, they are susceptible to cold shock mortality if OCNGS shuts down. A discussion of the mortality observed during previous winter shutdowns is presented in Section 3.2.4.5.2. Even when OCNGS operates for the entire winter, some mortality of the bay anchovy, bluefish and weakfish may occur, and a reduction in the size of these overwintering populations may occur by spring. Warm-water fishes (e.g., jacks) may die before spring because the temperature in the thermal discharge ultimately drops below their lower lethal temperature. However, the FRNGS thermal discharge will maintain the temperature in the discharge canal and Oyster Creek at 0.6 to 2.5°C (1.1 to 4.5°F) above the ambient bay temperature after the OCNGS has shut down during winter, and this may mitigate the impact of OCNGS shutdown on overwintering fishes.

3.2.4.5 Fish Mortality

Thermal discharge from OCNGS may cause fish to be attracted to and/or repelled from the thermal discharge, or it may have no discernible effect on their distribution. The heated discharge can also potentially affect the survival of those fish in four ways: by heat shock, cold shock, supersaturation of nitrogen resulting in the gas bubble disease, and release of toxic chemical substances into the water. From the time the OCNGS began operation to the present, eleven fish kills have been documented. The species of fish most often affected by these kills has been the Atlantic menhaden (*Brevoortia tyrannus*), and discussion will center on this species. On three other occasions fish kills have been suspected, but complete documentation is lacking. These potential fish kills as well as OCNGS shutdowns during 1977, which did not result in fish kills, are discussed below.

3.2.4.5.1 Heat Shock

As referenced in the Final Environmental Statement (FES), two summer fish kills in the discharge canal and Oyster Creek were attributed to the heated discharge (AEC, December 1974). On July 24, 1972, the first summer fish kill was reported by a local resident whose property is adjacent to the westernmost lagoon on the south bank of Oyster Creek. No estimates of the number or species of fish killed were reported.

The first documented summer fish kill occured on August 9, 1973, when the OCNGS was operating at 605MW, running four circulating water pumps and one dilution pump. Ambient water temperature of the intake water measured at 12:30 p.m. was 28.3°C (83°F), and the temperature was 41.1°C (106°F) at the discharge. At 2:15 p.m., the one dilution pump in operation tripped off. It was not until 2:44 p.m. that another dilution pump could be turned on; during the 29 minute interval no dilution pumps operated. Assuming a delta T of 12.8°C (23°F) (based on the 12:30 p.m. temperature readings), the fish swimming in the waters at the confluence of the dilution and condenser discharges were subjected to a water temperature of 41.1°C (106°F). Charles B. Wurtz, a JCP&L biological consultant, estimated between 1,000 to 5,000 Atlantic menhaden were killed by heat shock (Wurtz, 1973). Approximately 500 to 600 dead Atlantic menhaden and 20 to 30 dead blue crabs were also observed along the banks of the discharge canal. To prevent recurrence of this event, the station now operates two dilution pumps in the summer and operators are instructed to start the reserve dilution pump immediately after a dilution pump trips (Ross, 1973).

Between April 20 and 21, 1976, a third suspected heat kill occurred. Most of the affected organisms were bay anchovy and blue crab; a few American eel, Atlantic menhaden, spotted hake, white mullet and rock crab were observed dead on or near the banks of the discharge canal. The mortality was probably related to rapidly increasing bay temperatures from April 15 to 20, when intake temperatures increased from 13.3 to 21.2°C (56 to 70°F) respectively. OCNGS was operating with two dilution pumps, but shut one down when the bay temperature rose above 15.6°C (60°F). The decrease in the dilution water flow, coincident with rapidly increasing bay temperatures, may have caused the heat shock mortality of the fish and crabs.

3.2.4.5.2 Cold Shock

On January 28, 1972, the first cold shock kill was reported at OCNGS. Prior to a shutdown, OCNGS was operating at a reduced load (370 MW), with three circulating water pumps and no dilution pumps in operation. The intake temperature was 1.7°C (35°F) and the discharge temperature was 10.6°C (51°F) resulting in an 8.9°C (16°F) delta T. When OCNGS shut down water temperature in the discharge canal and Oyster Creek fell from 10.6 to 1.7°C (51 to 35°F) (ambient Barnegat Bay temperature), and between 100,000 and one million juvenile and adult Atlantic menhaden died (Tables 3.2-37,38). Forty-eight hours prior to the OCNGS shutdown, the ambient water temperatures dropped from 8.3 to 1.7°C (47 to 35°F) due to a cold front, and the discharge temperature fell from 22.2 to 15.6°C (72 to 60°F). The Atlantic menhaden in the thermal discharge were acclimated to water temperatures well above 15°C (59°F). When OCNGS shutdown, the temperature in the discharge canal and Oyster Creek fell to 1.7°C (35°F), far below the 7.2°C (45°F) thermal tolerance of Atlantic menhaden acclimated to 10°C (50°F) or above.

During two previous winters, OCNGS did not experience fish kills despite three shutdowns (Table 3.2-37). Temperatures in the discharge canal and Oyster Creek during the January 25 to 28, 1971 shutdown dropped below the lower lethal temperature 3.1°C (37.5°F, Reintjes, undated report A) for Atlantic menhaden, with no apparent mortality resulting. Based on fish survey data for Oyster Creek (Tatham, et al., 1977; Wurtz, 1974; and NJDEP, 1973), Atlantic menhaden were not always abundant in the heated discharge during every winter month. If OCNGS shuts down when Atlantic menhaden are not present, there is, of course, no mortality of this species. No explanation has been given for the absence of this species during some winter months.

Following the January 1972 cold shock mortality, two studies were initiated. John W. Reintjes of the Atlantic Estuarine Fisheries Center of the National Marine Fisheries Service, Beaufort, North Carolina, compiled and correlated published and unpublished data on the distribution, abundance, and migratory behavior of young Atlantic menhaden in the mid-Atlantic. He reported that based on data on Atlantic menhaden from the Great Egg Harbor in southern New Jersey, juvenile Atlantic menhaden usually migrate from the bays and estuaries of New Jersey beginning in late August through early September, with the most marked period of movement occurring in October when water temperatures are 15°C (59°F) or below. Analysis of data from Great Egg Harbor did not show a significant correlation of temperature with abundance, but generally agreed with the results of other studies in Delaware and North Carolina. The movement of Atlantic menhaden is believed to be triggered by the onset of cold weather and concomitant drop in water temperature in late summer to early autumn. By late November and early December, this migration to the ocean is usually complete. Young Atlantic menhaden may not migrate if warm water obscures the fall decline in temperature. A few young Atlantic menhaden have been collected in Barnegat Bay in January and February (Tatham et al., 1977; NJDEP, 1973).

The lethal temperature at all salinities is 3.1°C (37.5°F) for young Atlantic menhaden, and temperatures of 5 to 7.2°C (41 to 45°F) will be lethal if young Atlantic menhaden acclimate to temperatures of 15°C (59°F) or above. The assumption is that the greater the rate of change the greater the mortality, and the higher the acclimation temperature, the greater the lower lethal temperature (Reintjes, 1973). Despite the above, field studies have shown that Atlantic menhaden have been collected in Barnegat Bay and other estuarine waters at a water temperature of 1.7°C (35°F).

Reintjes recommended that, in order to flush the young Atlantic menhaden out of the thermal discharge, the water temperature in Oyster Creek should be allowed to approximate those temperatures in Barnegat Bay after the first autumn cold spell when water temperatures go below 15°C (59°F). To achieve the lower temperatures in Oyster Creek, two dilution pumps operate continuously when water temperatures fall below 15°C (59°F).

The second study was a field survey conducted by Charles Wurtz, Biological Consultant, and Roy Younger, Resource Management, Inc. Monthly sampling in Oyster Creek, the Forked River and Barnegat Bay began late in August 1972 and extended through January 1974. Based upon the data collected (Table 3.2-39), Atlantic menhaden moved out of the bay into the thermal discharge at temperatures lower than 15°C (59°F). Between November and December 1972, water temperatures ranged from a minimum of 6.1°C (43°F) to 11.1°C (52°F). The catch at the U.S. Route 9 bridge on Oyster Creek increased from November (0 fish) to December (205 fish). Wurtz believed that Atlantic menhaden movements are possibly feeding dependent. Were this the case, then it is not feasible to control their migratory movements by controlling the dilution and condenser water flow from the station.

Data (Table 3.2-40) collected during the late fall and early winter of 1975 indicated emigration of Atlantic menhaden from Barnegat Bay at temperatures lower than the 15°C (59°F) reported by Reintjes (undated) Tatham et al., 1977).

Further investigation of the conditions surrounding the cold shock mortalities of January 28, 1972, shows that the OCNGS was shut down from September 18 to November

11, and again from November 16 to 21, 1971, at which time the discharge canal water temperature in Oyster Creek was at ambient levels. If Atlantic menhaden migrate during the early fall, then migration would have been nearly completed by the time the OCNGS returned to service on November 22, 1971, and Atlantic menhaden would not be expected in the thermal discharge. However, between 100,000 and one million Atlantic menhaden were killed by cold shock in January 1972, and this may have several explanations. One explanation is that Barnegat Bay supports a relatively small resident or overwintering population of Atlantic menhaden. Data from Wurtz (1974) and the NJDEP (1973) support this explanation. A second and more probable explanation is that emigration may not occur until late fall or early winter when temperatures have dropped much lower than 15°C (59°F) (Tatham, et al., 1977; Wurtz, 1974). If this occurred, then Atlantic menhaden moved into Oyster Creek shortly after the November shutdown.

The second cold shock kill occurred during the week of January 5 to 8, 1973, after OCNGS shut down on December 29, 1972. Prior to the shutdown, the OCNGS operated at 616 MW, running four circulating water pumps and no dilution pumps. The water temperature at the intake was 4.4°C (40°F) and 16.7°C (62°F) at the discharge, resulting in a 12°C (21.6°F) delta T across the condenser. Temperatures in the discharge canal and Oyster Creek had decreased from 15-15.6°C (59 to 60°F) to 6.7-7.2°C (44 to 45°F) on December 29, after shutdown, over a period of approximately 11 hours. The rate of temperature drop was the same as in the January 1972 event. The mortalities occurred after a cold front moved through the area, and water temperatures dropped to 1.7°C (35°F).

C. B. Wurtz estimated that 18,000 Atlantic menhaden were dead in the surface ice and an unestimated number were dead on the bottom. Paul E. Hamer, director of the New Jersey Fish, Game, and Shellfish Nacote Creek Research Station in Absecon, estimated that a total of 1.2 million fish were killed, 23,000 fish in the surface ice and the remainder on the bottom. A third estimate was made by Mr. R. Mallie, formerly of Briarwood Yacht Basin, Oyster Creek; he estimated that a total of 58,000 fish were ice bound. Twenty dead bay anchovy were the only other fish observed to be affected by the cold water. Due to the uncertainty of the number of dead Atlantic menhaden, the total number of fish killed is difficult to ascertain.

Prior to the shutdown on February 18, 1973, the OCNGS was operating at 560 MW; the intake temperature was 1.1°C (34°F), and the discharge was 11.7°C (53°F). Four circulating water pumps were operating, but no dilution pumps.

The shutdown caused a smaller mortality than that of January 8, 1973. Estimates range from several thousand to 112,000 Atlantic menhaden (NJDEP, undated). The Atlantic menhaden was the only species observed to be affected.

On January 12, 1974, OCNGS load was 450 MW, with four circulating pumps and one dilution pump in operation. The intake temperature was 1.7°C (35°F), and the discharge temperature was 11.7°C (53°F). After shutdown, the intake temperature had dropped to 1.1°C (34°F), the discharge to 3.3°C (38°F), and at the U.S. Route 9 bridge to 1.7°C (35°F), which was below the lethal temperature for Atlantic menhaden.

Between January 11-15, stressed and dead fish were sited in and along the banks of Oyster Creek and at the blind end of the lagoons. The majority of the fish killed were Atlantic menhaden. NJDEP reports that 10,000 to 20,000 fish were killed, including Atlantic menhaden, bluefish, butterfish, spot, striped bass, and striped searobin (NJDEP, undated).

In the previous October (1973), the winter dilution pump operation procedure using one dilution pump had been implemented. It was believed that this action may have been effective in reducing the size of the January 1974 kill (20,000 vs. as compared to 1.2 million fish killed in January 1973).

Four winter shutdowns were experienced during 1975. The first shutdown occurred on February 4, 1975. Prior to the shutdown OCNGS was generating 638 MW and running four circulating water pumps and two dilution pumps. The intake temperature was 1.1°C (34°F); the discharge temperature was 13.3°C (56°F), and the bridge temperature was 4.4°C (40°F). Approximately 200 to 300 fish died as a result of cold shock. More than half these fish were Atlantic menhaden; the remainder were bluefish. The relatively small number of fish killed was attributed to four factors. The OCNGS had begun operation of two dilution pumps in 1974, possibly causing some Atlantic menhaden to leave the heated discharge. Immediately following the shutdown, two dilution pumps and one circulating water pump were shut off, allowing the water in the discharge canal and Oyster Creek to reach ambient temperatures approximately 3.3°C (38°F) over a longer duration. In addition to these two conditions, strong easterly winds immediately following the shutdown pushed ocean water with a temperature of 6.1°C (43°F) across Barnegat Bay and into Oyster Creek, creating a temperature gradient in the Creek from 6.1°C (43°F) at the mouth to 2.2°C (36°F) at the U.S. Route 9 bridge. The warmer water may have allowed the fish to move into the bay, thereby avoiding the lethal temperature (3.1°C, 37.5°F) of waters in the discharge canal. Air temperature, during the pre- and post-shutdown periods, was not sufficiently low to drive the water temperature below the lethal temperature for juvenile Atlantic menhaden. In surveys of Oyster Creek on February 5, 1975, mullet and winter flounder were collected, and some unstressed Atlantic menhaden were observed.

The second winter shutdown occurred on November 24, 1975; OCNGS had been operating at 519 MW and running three circulating water pumps and two dilution pumps. The intake temperature was 7.8°C (46°F); the discharge temperature was 18.9°C (66°F), and the U.S. Route 9 bridge temperature was 10.8°C (51.5°F) at 10:30 p.m. on November 24, 1975. Pumps were shut off as soon as possible after the shutdown and ambient temperature in the discharge canal was achieved by noon on November 25, 1975. A few dead cravelle jack and several stressed bluefish were observed.

On December 12, 1975, the OCNGS began to reduce power, at which time two dilution pumps were removed from service. One circulating water pump was shut off on the 19th, before which OCNGS was generating 543 MW; the other two pumps were shut off on December 20, 1975. One pump remained in service until the OCNGS resumed normal operation on the 21st. On December 19, 1975, the intake temperature was 3.9°C (39°F); the discharge temperature was 17.8°C (64°F), and the U.S. Route 9 bridge temperature was 7.2°C (45°F). After shutdown, on the morning of the 20th, the water temperature at the U.S. Route 9 bridge decreased to 3.5°C (38.3°F) on the surface and 4.0°C (39.2°F) on the bottom. Surveys showed that Atlantic menhaden, winter flounder, Atlantic silverside and white perch were present in Oyster Creek, the largest concentrations in the westernmost lagoon. The estimated mortality, based on beach surveys and bottom trawls, included the following: 100 to 200 bluefish, 25 to 100 Atlantic menhaden, a few winter flounder, blueback herring, searobin, mullet, and northern kingfish. The OCNGS returned to normal operation on December 21, 1975, thus preventing the lagoons from freezing over.

Five days later, on December 26, 1975, OCNGS began to reduce power. Two circulating water pumps were shut off on the 27th, and the third on the 29th. No dilution pumps were operating. On the 26th, OCNGS was operating at 468 MW, the intake temperature was 2.2°C (36°F); the discharge temperature was 15°C (59°F), and the bridge temperature was 5.6°C (42°F). On the morning of the 27th, the temperature at the U.S. Route 9 bridge dropped slightly to 5°C (41°F) on the surface and 3.5°C (38.3°F) on the bottom. No fish were observed in the discharge canal and Oyster

Creek or along the banks. Surveys indicated large numbers of fish were in the Oyster Creek lagoons, apparently unstressed. Silversides, blueback herring, and Atlantic menhaden were the most abundant species collected. Late in the evening of December 27 and early morning of the 28th, 332 dead 27 stressed, and 4 live Atlantic menhaden were observed near the U.S. Route 9 bridge. The temperature, 4.5 to 5°C (40 to 41°F), pH (5.0), and salinity (9 ppt) indicated that a lens of fresh water overlay the more saline Barnegat Bay water. Based upon these observations, it is believed that the synergistic effect of 1) cooler water from the fresh water of Oyster Creek, 2) lower salinity, and 3) lower pH were responsible for the fish killed.

Four shutdowns occurred during 1977; each one was monitored for possible fish kills. No fish were killed as a result of the April 22, 1977, OCNGS shutdown at the beginning of a refueling outage. The OCNGS generated 444 MW and operated four circulating and one dilution pump at that time. At 10:00 p.m. on the 22nd, the intake temperature was 20.6°C (69°F), and the bridge temperature was 23.2°C (73.7°F). By 6:55 a.m. on the morning of the 23rd, the intake temperature decreased to 18.9°C (66°F), and the discharge temperature to 20°C (68°F), during routine sampling, a total of six stressed Atlantic menhaden were observed.

On October 21, 1977, prior to a shutdown, OCNGS was generating 614 MW with four circulating and two dilution pumps in operation. The intake water temperature was 12.2°C (54°F), the discharge temperature was 23.9°C (75°F), and the temperature at the U.S. Route 9 bridge was 16.7°C (62°F). Oyster Creek and the discharge canal were surveyed on the 21st and 22nd. An estimated 120-200 jacks -- blue runner and crevalle, 150 mm to 180 mm long -- were counted and observed dead. Large numbers of jacks were seen swimming without apparent signs of stress in various shallow areas of the discharge canal and Oyster Creek and in Barnegat Bay during that day. No other species appeared to be affected by this outage. In 1975, a similar outage and subsequent mortality of jacks occurred.

On November 14, 1977, OCNGS shut down when it was operating at 588 MW with four circulating and two dilution pumps. The temperatures at the intake, discharge, and at the U.S. Route 9 bridge were 8.6, 19.4 and 15°C (47.5°F, 67°F and 59°F), respectively. Observations of the discharge canal and Oyster Creek indicated that the temperature had not dropped sufficiently to cause thermal shock mortality to the Atlantic menhaden, bluefish, or other species collected there during the week following the shutdown. OCNGS returned to operation on November 15, 1977.

No dead or stressed fish were observed following the shutdown on December 3, 1977. OCNGS was generating 603 MW and operating four circulating and two dilution pumps. Temperatures at the intake, discharge, and U.S. Route 9 bridge, were 6.7, 18.3 and approximately 13.9°C (44°F, 65°F and 57°F), respectively. The bridge temperature had decreased to 10°C (50°F) within 2 1/2 hours. OCNGS returned to operation in the afternoon of the following day.

To minimize the impact of Oyster Creek shutdowns upon the fish in the heated discharge, JCP&L has adopted a plan to operate dilution pumps during the fall to encourage Atlantic menhaden to move out of the discharge canal. This plan has been in effect since 1974. Since 1975, dilution pumps are shut off immediately to reduce the flow of cold water and prolong the cool-down of the discharge canal waters. The reduced amount of water discharged from OCNGS for about 24 hours after a scheduled shutdown is slightly above ambient and this residual heat also mitigates the temperature decrease during the first 24 hours.

3.2.4.5.3 Gas Bubble Disease

Gas bubble disease afflicts fish exposed to water supersaturated with dissolved gases, usually nitrogen and oxygen. Experiments conducted on-site indicate that a few individuals held in heated discharge water have experienced stress as a result of gas bubble disease.

During the December 19, 1975, shutdown, a few Atlantic silversides collected in the thermal discharge showed evidence of gas bubble disease. No evidence was reported to confirm that supersaturated levels of dissolved gases was the cause of death. No specimens of other species of fish found dead exhibited symptoms of this disease. It has been reported that the golden shiner tends to avoid gas-supersaturated waters, except under conditions when water temperature increases of 5°C (9°F) and 10°C (18°F) were associated with the supersaturated conditions. It appears that temperature preference overrides avoidance of supersaturated conditions in the golden shiner; similar behavior may be the cause for the Atlantic silverside mortality (Marcello, et al., 1976).

3.2.4.5.4 Toxic Chemicals

On January 7, 1974, a fish kill incident was attributed to the discharge of chlorine (Wurtz, February 3, 1974). This incident is the only case of a toxic chemical fish kill at OCNGS. About 500 Atlantic menhaden, ranging in size from 8 to 15 in., died. Malfunction of the chlorine injection device resulted in estimated concentrations of 1.0 to 2.5 mg/l free chlorine.

3.2.4.6. Analysis of the Effect of OCNGS on the Fish Community

Dominance of the recent fish community in Barnegat Bay by a few fishes was typical of Barnegat Bay prior to operation of OCNGS (Marcellus, 1972), Great Bay, and other mid-Atlantic estuaries (de Sylva et al., 1962; Richards and Castagna, 1970; Oviatt and Nixon, 1973; McErlean et al., 1973). Some changes in the species composition and relative abundance of fishes have occurred since OCNGS began operation. However, natural variation in the abundance of many populations from year to year was as large as 50 to 100 percent for Barnegat Bay from 1966 to 1970 (Marcellus, 1972) and in Great Bay and adjacent bays from 1972 through 1975. These changes frequently are larger than, and may mask, any changes which may result from OCNGS operation.

Comparisons of the pre-operative years (1966 to 1969) and the operational years (1969 to 70, 1975 to 77) indicated that most changes in the relative abundance of fishes in the bay also were found in other estuaries in New Jersey and apparently were not related to the OCNGS discharge. These comparisons generally were limited to the abundant fishes taken in seine collections at three stations from 1966 to 70 and 1975 to 77 (Tables 3.2-41 to 50). After 1969, catches at the mouth of Oyster Creek were often large because fishes were attracted to the thermal plume.

Catches of the bay anchovy were quite variable at each station and from year to year (Figure 3.2-12). Similar fluctuations were noted for the bay anchovy in seine and trawl catches in Great Bay from 1972 through 1974. Marcellus (1972) did not find any significant difference between annual mean catch in the bay and suggested that environmental factors partially accounted for these fluctuations. The annual mean catch for 1969 to 70 was approximately the same as that for 1967 to 68. The catch at two of the three stations in Barnegat Bay was similar to or greater than the catch there during 1966 to 69, before OCNGS commenced operation.

The annual mean catch of the mummichog has varied little from 1966 to 1977 (Figure 3.2-13). Catches were variable from year to year, but the mean catches from 1975 to 77 were similar to or greater than those from 1966 to 69.

The tidewater silverside was significantly more abundant in 1967 to 68 than in subsequent years. The mean catches from 1969 to 70 and 1975 to 77 were similar to those for 1968 to 69, and this low level of the population after 1968 may reflect a general decline in the population in the last ten years.

Large, natural fluctuations in the population of Atlantic silverside occur in New Jersey estuaries. Marcellus (1972) found a significant difference in the annual mean catch of the Atlantic silverside in Barnegat Bay and large year-to-year variation at all stations (Figure 3.2-15). The mean catch in 1966 to 67 was larger than that in 1967 to 68 because of a large year-class in 1967 and of a misidentification of many tidewater silverside as Atlantic silverside. Catches in 1969 to 70 and 1975 to 76 were similar to 1967 to 68, the least productive year reported by Marcellus. However, the very small catches in 1976 to 77 were possibly due to mortality of individuals during the extremely cold winter of 1976 to 77. A steady decline in the population of this fish was also noted in Great Bay from 1972 (242/seine collection) through 1974 (82/seine collection).

The low number of the fourspine stickleback collected from 1969 to 70 and 1975 to 77 may have resulted from the large, steady decline in the population from 1966 through 1970 (Figure 3.2-16). Although the cause of this decrease is not known, Marcellus (1972) speculated that it may have been caused, in part, by an internal parasite. The fourspine stickleback is usually associated with vegetation. Although Marcellus (1972) did not completely describe the amount of vegetation at these stations, it appears that vegetation was more abundant there from 1966 to 69 than in 1975 to 77. This possible decrease in abundance may account for part of the decline in the catch of this species at these stations because vegetation is an important factor affecting its distribution. Marcellus noted that the catch decreased at the mouth of Oyster Creek in 1969 to 70 because the eelgrass beds there disappeared after OCNGS commenced operation.

Declines in the catch of the northern pipefish have occurred at three stations in the bay since 1966 to 69, but these declines may not reflect a decrease in abundance (Figure 3.2-17). As noted for the fourspine stickleback, the possible decrease in the abundance of eelgrass in the western bay may account for part of the decline in the catch of this species at these stations because vegetation is an important factor affecting its distribution. Furthermore, since the trawl catch of the northern pipefish in Barnegat Bay during 1975 to 76 (0.5/coll.) and 1976 to 77 (0.3) was similar to or greater than the trawl catch (adjusted for differences in tow time) in Little Egg Harbor, New Jersey from 1972 through 1974 (0.15 to 0.25), it does not appear that the population of this species in Barnegat Bay has substantially declined over that in a comparable New Jersey estuary.

The variation in the catch of the silver perch and spot has been large from 1966 through 1977. Although the silver perch was common in the Bay in 1966 to 67 and 1968 to 69, very few were taken from 1975 to 77 (Figure 3.2-18). Marcellus (1972) collected only a few spot from 1966 to 70, but it was abundant recently, especially during 1975 to 76. Similar, large fluctuations of these fishes occurred in Great Bay from 1972 through 1974 and are typical of populations of drums. These large differences probably reflect the reproductive success of different year-classes and may be due to environmental factors.

Marcellus (1972) reported the largest catches of young of the winter flounder in 1967 to 68; after this year the population steadily declined (Figure 3.2-19). A similar decline was found in Great Bay from 1972 through 1974. The population in Barnegat Bay remained low in 1975 to 76, but the number of young increased greatly in 1976 to 77. This fluctuation of the population probably resulted from an environmental factor, such as water temperature, rather than OCNGS operation because a similar number of larvae were produced in 1975 to 76 and 1976 to 77 (Section 4.3.1.3). Jeffries and Johnson (1974) demonstrated that the decline of the winter flounder population in Narragansett Bay from 1968 through 1972 was related to the relatively mild winters during these years. Southern New Jersey has also experienced mild winters in recent years and this phenomenon may explain the recent decline in these populations. This explanation is further supported by the dramatic increase in the number of young produced immediately after the severe winter of 1976 to 77.

Although the northern puffer was very abundant in 1966 to 67, its population decreased sharply from 1967 to 70 (Figure 3.2-20). It remained scarce in the bay, and the decrease was not attributed to the operation of OCNGS. A similar natural decline was noted in other New Jersey bays (Hamer, 1972; Vennel, undated) and in the Delaware Bay sport fishery (Miller, 1978).

Many other factors have probably affected the community of fishes in the bay. Development of residential lagoon systems, the installation of bulkheads along the shore, elimination of wetlands, increased domestic discharges into the bay through ground water, and increased recreational use of the bay have occurred since 1965. The number of predatory fishes (e.g., bluefish, summer flounder) has increased and may be responsible in part for decreases in some forage species. Because these effects are not from a point source, their impact is difficult to evaluate. However, overall degradation of the bay has probably contributed to some of the apparent decreases in the abundance of some fishes.

The largest visible effect of the OCNGS thermal discharge has been mortality from temperature shock, primarily cold shock. The only two incidents of heat shock mortality have occurred under unusual operating or natural conditions. The cause of heat-shock mortality in August 1973 (i.e., cessation of all dilution flow) is unlikely to occur again because OCNGS now operates two dilution pumps during summer. The reduction of dilution flow caused by the shutdown of one of the two dilution pumps should cause the temperature to increase 1.3°C (2.3°F) rather than the 13.1°C (23.6°F) that occurred in 1973 (LMS 1978). Most fishes will not be subject to heat shock because they avoid stressful temperatures in the thermal discharge during summer.

Kills of overwintering fishes either by an OCNGS shutdown or from gradual attrition are of little significance. The Atlantic menhaden, bay anchovy, bluefish, and weakfish are from large populations along the Atlantic coast rather than small, localized populations in the bay. The maximum estimate of the number of the Atlantic menhaden eliminated in a winter kill at OCNGS (1,000,000 fish) was comparable to approximately 20 sets (19 metric tons/set; 50,000 fish/set) of a purse seine by a single commercial fishing boat off the coast of New York or 5 sets (38; 200,000) off North Carolina (Reintjes 1969). The average annual commerical landings in New Jersey were 28,838 metric tons from 1963 through 1970 and 47,788 from 1971 through 1975 (McHugh 1977). If the fish killed at OCNGS were the same size as those taken by the commerical fishery, the loss of 1,000,000 fish (380 metric tons) would represent 0.7 percent of the average commercial harvest in New Jersey from 1972 through 1975. This estimate is probably high because many overwintering Atlantic menhaden were young, and therefore, smaller than the average, commercially harvested fish. A large winter kill of Atlantic menhaden at OCNGS should probably be less extensive than a natural kill of 1,300,000 Atlantic menhaden reported from Chesapeake Bay (Maryland State Fisheries Administration, 1974, 1975). The number of bluefish, weakfish, and bay anchovy killed during winter shutdowns has been small.

Operational changes may have mitigated mortality from cold shock during winter shutdowns. Since 1975, the pumping of dilution water ceased during OCGNS winter shutdowns. Abell and Burton (1977) reported that the likelihood of mortality (to 120 h) of the Atlantic menhaden acclimated to 15°C (59°F) was substantially reduced when a temperature decrease of 10.0°C (18°F) occurred over a period of 6 h. No large mortality of overwintering Atlantic menhaden occurred during two shutdowns in December 1975. However, the lower lethal temperature of young of the Atlantic menhaden is from 2 to 5°C (35.6 to 41°F) (Lewis and Hettler, 1968, unpublished IA data), and when OCNGS shuts down at these bay temperatures, mortality of young may occur regardless of the rate of temperature decrease.

Although the volume of the FRNGS discharge is small (3.16 percent of the water in Oyster Creek and the discharge canal) in relation to the total flow from the OCNGS and the dilution pumps, this discharge may become important during an OCNGS winter shutdown. If OCNGS shuts down, the FRNGS discharge should remain somewhat discrete and areas of lower velocities and warmer water (0.2 to 2.5°C; 0.4 to 4.5°F) may provide refuge for some overwintering fishes. These areas of warmer water may maintain some of the fishes which may reside in other areas of the thermal discharge prior to shutdown and thereby mitigate the effect of cold shock.

3.2.4.7 Incremental Effect of FRNGS

Operational characteristics of FRNGS and its effect on the temperature and salinity of the discharge canal and Oyster Creek were presented in Chapter 1, Appendix A.3, and Appendix B.

With only FRNGS in operation, these temperature and salinity increases will be minimal and should have little effect on fishes. No fishes should be excluded from these areas because they will be near ambient temperature and salinity throughout the year.

The effect of the temperature increase when OCNGS and FRNGS are both in operation should be similar to that discussed for only OCNGS because OCNGS will contribute most (98 percent) of the heat in the thermal discharge. Although little data exist on the ability of fishes to survive rapid increases in salinity, many estuarine fishes tolerate salinities as high as 40 ppt (Gunter, 1945). The number of individuals exposed to the maximum temperature and salinity increase and the time of exposure should be minimal because of the low volume and rapid mixing of the FRNGS discharge.

Cold shock mortality of fishes that reside in the heated discharge during winter has been a chronic occurrence. Although the volume of the FRNGS discharge is small (3.16 percent of the water in Oyster Creek and the discharge canal) in relation to the total flow from OCNGS and the dilution pumps, this discharge may become significant during an OCNGS shutdown. If OCNGS shuts down, the FRNGS discharge will maintain the temperature in Oyster Creek and the discharge canal at 0.6 to 2.5°C (1.1 to 4.5°F) above the bay temperatures and this may mitigate the effect of the shutdown and maintain some overwintering fishes.

3.2.4.8 Summary of Thermal Effects

Collection of fishes from Barnegat Bay from 1975 to 77 indicated that the recent fish community in Barnegat Bay was dominated by a few fishes, and this community was typical of Barnegat Bay prior to operation of OCNGS and of other estuaries, including Great Bay, New Jersey; and other mid-Atlantic estuaries. Some changes in the species composition and relative abundance of fishes have occurred since OCNGS began operation but most of these changes also were found in other New Jersey estuaries. Therefore, it is concluded that the fish community in Barnegat Bay was similar to the community in similar estuaries and the first decision criteria has been met.

No evidence exists that the OCNGS thermal discharge adversely affects the growth or reproductive success of fish. The growth of some bluefish may be greater in the heated discharge possibly because of the abundance of forage fishes. Although Barnegat Bay is a spawning and nursery area for many fishes, these activities occurred throughout the central area of the bay from Cedar Beach to Gulf Point (107.5 million m^3). The exclusion of fishes during summer months from a relatively small area in the discharge canal and Oyster Creek (0.5 million m^3) had little effect on spawning and nursery activities in the Bay. Anadromous herring, which reportedly spawned in the freshwater area of Oyster Creek prior to operation of OCNGS, also reproduce in other tributary streams of Barnegat Bay. The few individuals that wish to use the small remaining freshwater reach of Oyster Creek for spawning will not be blocked from migration along Oyster Creek except during the late stages of spawning, in late May. Therefore, the functioning maintenance of these bay populations should not be harmed. As discussed under the first aspect of the decision criteria, the population of fishes in the bay have been maintained within the range of natural variation found in other mid-Atlantic estuaries.

Neither historical data on the distribution of migratory and resident fishes in the Bay nor predictive data on the extent of the thermal plume in the Bay (LMS, 1978) indicated that fishes will be prevented from dispersing thoughout the Bay or from migrating to their spawning area (i.e., herrings). Except for fishes with a specific habitat preference, both migratory and resident fishes were found throughout the bay. Most movement of fishes occurred from March through May and from September through December. During these months, the LMS thermal models indicate that the thermal plume will not constitute an impediment to the movement of fishes. Fishes will be attracted to the heated water, particularly in the fall, and for some individuals this attraction will delay or stop their migration to the ocean. Only a very small portion of the large coastal populations will be affected, however, and no adverse affect on the overall populations has been seen. Therefore, the third and last criterion has also been satisfied, and the decision criteria for this biotic category have been met.

In addition to the concern expressed in the decision criteria, the effects of stressful conditions associated with the operation of OCNGS and FRNGS were considered. The occurrence of gas bubble disease was rare and not definitely linked to this subsequent mortality of the individuals; therefore it is not deemed an area of further concern. Heat shock mortality should be a problem because most fishes avoid high, stressful temperatures. Mortality of fishes from heat shock has occurred only twice, and both incidents were under unusual natural or operating conditions. The magnitude of these losses was small, and they were insignificant to the local populations.

Most of the fishes attracted to and overwintering in the thermal discharge represented relatively few individuals from large populations along the Atlantic coast, and loss of some or all of these individuals will have little effect on these populations. Because these fishes are confined to Oyster Creek and the discharge canal and are not naturally found in the bay from December through February, their loss will not affect the fish community in the bay. Thus, this concern is of little consequence and the stressful conditions associated with the thermal discharge will not imperil the fish populations in the bay and the final area of concern has been satisfied.

References

Atomic Energy Commission. 1974. Final Environmental Statement, Oyster Creek Nuclear Generating Station. pp 5-35

Abell, P.R., and D.T. Burton. 1977. Cold shocks: the effect of rate of thermal decrease on the mortality of juvenile Atlantic menhaden (Brevoortia tyrannus). Presented at a symposium on energy and environmental stress in aquatic systems, Augusta, Ga., 2-4 Nov. 1977. [Abstr.]

de Sylva, D.P. 1969. Theoretical considerations of the effects of heated effluents on marine fishes. Proc. of the First Nat. Symp. on Thermal Pollution. Vanderbilt Univ. Press, Nashville, Tn. 56 pp.

_____________, F.A. Kalber, Jr., and C.N. Shuster, Jr. 1962. Fishes and ecological conditions in the shore zone of the Delaware River estuary, with notes on other species collected in deeper water. Univ. Del. Mar. Lab. Inf. Ser. Publ. No. 5. 164 pp.

Gunter, G. 1945. Studies on marine fishes of Texas. Publ. Inst. Mar. Sc., Univ. Texas 1(1): 1-190.

Halgen, B.A. [1973]. Phase III - Use Studies. Pages 175-224 in Studies of the upper Barnegat Bay System. Misc. Rept. No. 10m (mimeo). N.J. Dept. of Envir. Prot., Div. of Fish, Game, and Shellfish. Bur. Fish., Nacote Creek Res. Sta.

Hamer, P.E. [1972]. Phase III - Use studies. Pages 115-141 in Studies of the Mullica River-Great Bay estuary. Misc. Rep. No. 6-1 (mimeo). N.J. Dept. of Envir. Prot., Div. of Fish, Game, and Shellfish. Bur. Fish., Nacote Creek Res. Sta.

Jeffries, H.P., and W.C. Johnson. 1974. Seasonal variations of bottom fishes in the Narragansett Bay area: seven-year variations in the abundance of winter flounder (Pseudopleuronectes americanus). J. Fish. Res. Bd. Canada. 31(6): 1057-1066.

Lawler, Matusky and Shelly Engineers. 1978. Simulation of the effluent plumes from the Forked River Nuclear Station. Rept. to Jersey Central Power and Light Co. 71 pp.

Lewis, R.M., and W.F. Hettler, Jr. 1968. Effect of temperature and salinity on the survival of young Atlantic menhaden, Brevoortia tyrannus. Trans. Amer. Fish. Soc. 97(4): 344-349.

Loesch, J.G., and W.A. Lund, Jr. 1977. A contribution to the life history of the blueback herring, Alosa aestivalis. Trans. Amer. Fish. Soc. 106(6): 583-589.

Marcello, R.A., Jr., and R.B. Fairbanks. 1976. Gas bubble disease mortality of Atlantic Menhaden, Brevoortia tyrannus, at a coastal nuclear power plant. Gas Bubble Disease, CONG-741033. pp 75-80.

Marcellus, K.L. 1972. Fishes of Barnegat Bay, New Jersey with particular reference to seasonal influences and possible effects of thermal discharges. Ph.D. Dissertation. Rutgers Univ. 190 pp.

Maryland State Fisheries Administration. 1974. Summary of 1974 fish kills. Dept. Nat. Res., Annapolis, MD.

______________. 1975. Summary of 1975 fish kills. Dept. of Nat. Res., Annapolis, MD.

McClain, J.F. [1973]. Phase I - Fish studies - Pages 1-74 in Studies of the upper Barnegat System. Misc. Rept. No. 10m (mimeo). N.J. Dept. of Envir. Prot. Div. of Fish, Game, and Shellfish. Bur. Fish, Nacote Creek Res. Sta.

McErlean, A.J., S.G. O'Connor, J.A. Mihursky, and C.I. Gibson. 1973. Abundance, diversity, and seasonal patterns of estuarine fish populations. Estuarine and Coastal Mar. Sci. (1973) I: 19-30.

McHugh, J.L. 1967. Estuarine nekton. Pages 581-620 in G. Lauf, ed. Estuaries. Amer. Assoc. Adv. Sci., Publ. No. 83. Wash., D.C.

Miller, R.W. (1978). Marine recreational fishing in Delaware. Del. Div. of Fish and Wildl., Document 40-05/78/01/18. 28 pp.

Milstein, C.B., D.L. Thomas, and Associates. 1976. Ecological studies in the bays and other waterways in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress report for the period January-December 1975. Ichthyological Assoc., Inc., Ithaca, N.Y. 572 pp.

Milstein, C.B., D.L. Thomas and Associates. 1977. Summary of ecological studies for 1972-1975 in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Ichthyological Assoc., Inc., Ithaca, N.Y. 757 pp.

New Jersey Department of Environmental Protection, Division of Environmental Quality, Bureau of Radiation Protection. Undated report. Temporal variations of the Oyster Creek Nuclear Generating Station during 1973 and 1974. Table 6: Reported Fish Kills in Oyster Creek. 1 p.

Oviatt, C.A., and S.W. Nixon. 1973. The demersal fish of Narrangansett Bay: an analysis of community structure, distribution and abundance. Estuarine and Coastal Mar. Sci. (1973)I: 361-378.

Reintjes, J.W. 1969. Synopsis of biological data on the Atlantic menhaden. Brevoortia tyrannus. U.S. Fish and Wildl. Serv., Circ. 320 30 pp.

Reintjes, J.W. 1973. Comments relative to the Oyster Creek menhaden kill, January, 1973, with estimates of the number of dead fish. 2 pp.

____________. Undated report. A final report compilation and correlation analysis of published and unpublished environmental data with distribution, abundance, and movements of young menhaden in mid-Atlantic estuaries. 37 pp.

Richards, C.E., and M. Castagna. 1970. Marine fishes of Virginia's Eastern Shore (inlet and marsh, seaside waters). Chesapeake Sci. 11(4): 235-248.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Bd. Canada 191. 382 pp.

Ross, D.A. August 13, 1973. Letter to I. R. Finfrock. 2 pp.

Tatham, T.R., D.J. Danila, D.L. Thomas, and Associates. 1977. Ecological studies for the Oyster Creek Generating Station. Progress report for the period September 1975-August 1976. Vol. One. Part I. Fin- and shellfish. Ichthyological Assoc., Inc., Ithaca, N.Y.

_____________, _____________, _____________, and _____________. 1978. Preliminary report of ecological studies for the Oyster Creek Generating Station. Progress report for the period September 1976-August 1977. Volume One. Part I. Fin- and shellfish. Ichthyological Assoc., Inc., Ithaca, N.Y.

Thomas, D.L., and C.B. Milstein. 1973. Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress report for the period January-December 1972. Part One. Ichthyological Assoc., Inc., Ithaca, N.Y. 666 pp.

_____________, _____________, T.R. Tatham, R.C. Bieder, D.J. Danila, H.K. Hoff, D.P. Swiecicki, R.P. Smith, G.J. Miller, J.J. Gift, and M.C. Wyllie. 1975. Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress report for the period January-December 1974. Vol. I. Fishes. Ichthyological Assoc., Inc., Ithaca, N.Y. 490 pp.

_____________, _____________, _____________, _____________ F.J. Margraf, and F.A. Swiecicki. 1974. Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress report for the period January-December 1973. Vol. I. Fishes. Ichthyological Assoc., Inc., Ithaca, N.Y. 709 pp.

_____________, _____________, _____________, E. Van Eps., D.K. Stauble, and H.K. Hoff. 1972. Ecological considerations for ocean sites off New Jersey for proposed nuclear generating stations. Vol. One. Part One. Ichthyological Assoc., Inc., Ithaca, N.Y. January 1972. 115 pp.

Vennell, G. [undated]. Use studies of the Great Egg Egg Harbor estuary. Pages 118-156 <u>in</u> Studies of the Great Egg Harbor River and Bay. Misc. Rept. No. 8M (mimeo). N. J. Dept. of Envir. Prot., Div. of Fish, Game, and Shellfish. Bur. Fish., Nacote Creek Res. Sta.

Wurtz, C. B. August 17, 1973. Letter to D.A. Ross.

Wurtz, C.B. 1974. Atlantic menhaden investigations at the Oyster Creek Plant, Final Report. 17 pp.

______________. February 3, 1974. Letter to H.J. Williams.

Younger, Roy. Undated report. January 7, 1974. Fish kill. No pagination.

Zich, H.E. [1977]. The collection of existing information and field investigation of the anadromous clupeid spawning in New Jersey. Misc. Rep. No. 41 (mimeo). N. J. Dept. of Envir. Prot., Div. of Fish, Game, and Shellfish. Bur. Fish, Lebanon, N. J.

TABLE 3.2-1. Register of phytoplankton organisms identified from Barnegat Bay, N. J. April, 1967 to April 1969.

(* = Particularly important species, seasonal dominants or ubiquitous members)

DIATOMS

<u>Achnanthes</u> <u>longipes</u> Agardh
<u>Actinoptychus</u> <u>undulatus</u> (Bailey)
<u>Amphiprora</u> <u>incompta</u> Hohn and Hellerman
<u>A.</u> <u>surirelloides</u> Hendey
<u>Amphora</u> <u>sp</u>.
<u>Asterlonella</u> <u>japonica</u> Cleve. and Moller
<u>Biddulphia</u> spp.
<u>B.</u> <u>arctica</u> (Brightw.)
<u>B.</u> <u>biddulphiana</u> (Smith) Boyer
<u>B.</u> <u>favus</u> (Ehrehberg)
<u>B.</u> <u>granulata</u> Roper
<u>B.</u> <u>vesiculosa</u> Agardh
<u>Campylodiscus</u> <u>sp</u>.
<u>C.</u> <u>fastuosus</u> Ehr.
<u>Cerataulina</u> <u>bergoni</u> H. Peragallo
<u>Chaetoceros</u> <u>spp</u>.
<u>C.</u> <u>approximatus</u> Gran and Angst
<u>C.</u> <u>borealis</u> Bailey
<u>C.</u> <u>curvisetum</u> Cleve.
<u>C.</u> <u>debilis</u> Cleve.
<u>C.</u> <u>decipiens</u> Cleve.
<u>C.</u> <u>dichaeta</u> Ehr.
<u>C.</u> <u>didymus</u> Ehr.
<u>C.</u> <u>frafilis</u> Meunler
<u>C.</u> <u>secundus</u> Cleve.
<u>C.</u> <u>similis</u> Cleve.
<u>C.</u> <u>simplex</u> Ostemfeld
<u>C.</u> <u>subtilis</u> Cleve.
* <u>Cocconeis</u> <u>spp</u>.
<u>Cochlodinium</u> <u>helix</u> (Pouch.) lemm. ex Lebour
<u>Coscinodiscus</u> <u>spp</u>.
<u>C.</u> <u>angstii</u> Gran
<u>C.</u> <u>centralis</u> Ehr.
<u>C.</u> <u>excentricus</u> Ehr.
<u>C.</u> <u>radiatus</u> Ehr.
* <u>Cyclotella</u> <u>of</u> <u>meneghiniana</u> Kutzing
<u>Cymbella</u> <u>spp</u>.
<u>Detonula</u> <u>spp</u>.
* <u>D.</u> <u>confervacea</u> Cleve.
* <u>D.</u> <u>cystifera</u> Gran
<u>Diploneis</u> <u>sp</u>.
<u>D.</u> <u>crabro</u> Ehr.
<u>Ditylium</u> <u>brightwellii</u> (West.)
<u>Eucampia</u> <u>groenlandica</u> Cleve.

E. zodiacus Ehr.
Fragillaria sp.
F. crotonensis Kitton
F. cylindrus Grunow
Grammatophora spp.
Guinardia flaccida (Castr.)
Gyrosigma spp.
Lauderia glacialis (Grun.)
Leptocylindrus sp.
L. danicus Cleve.
L. minimus Gran
Lichmophora sp.
Lithodesmium undulatum Ehr.
Melosira sp.
M. borreri Greville
M. granulata Ehr.
M. juergensil Agardh.
M. nummuloides (Dillw.) Agardh
* Navicula spp.
N. cruciculoides Brockman
N. distans W. Smith
N. (Schizonema) gravelei Agardh
N. monilifera Cleve.
Nitzschia sp.
* N. closterium Ehr.
N. paradoxa Gmelig and van Heurck.
N. seriata Cleve.
Paralia (melosira) sulcata Ehr.
Pinnularia sp.
P. ambigua Cleve.
Pleurosigma sp.
P. fasciola W. Smith
P. formosum W. Smith
P. marinum Donkin
Rhabdonema adriaticum Kutzing
Rhizosolenia sp.
R. alata Brightwell
R. cylindrus Cleve.
R. delicatula Cleve.
R. fragillima ? Bergon
R. semispina Hensen
* R. setigera Brightw.
R. stolterfothii H. Perag.
* Skeletonema costatum (Greville)
Striatella unipunctata Agradh.
Surirella sp.
S. smithii Ralfs
Synedra sp.
S. hennedyana (Greg.)
Tabellaria sp.
Thalassionema frauenfeldii (Grun.)

TABLE 3.2-1 (Continued)

T. nitzchoides Grun.
Thalassiosira spp.
T. condensata (Cleve.)
T. gravida Cleve.
T. hyalina (Grun.)
* T. nordenskioldi Cleve.
T. rotula Meunier
Thallassiothrix longissima Cleve. and Grun.

DINOFLAGELLATES

Amphidinium spp.
A. carteri Hulburt
A. fusiforme Martin
A. sphenoides Wulff
Ceratiium bucephalum ? Cleve.
C. fusus (Ehr.) Clap. and Lach.
C. macroceros Ehr.
C. minutum Jorgensen
* Ceratiium tripos Ehr.
Dinophysis sp.
D. acuminate Clap. and Lach.
D. acuta Ehr.
D. ovum Schutt
Dipolopsalis lenticular Bergh
Glenodinium sp.
G. danicum Paulsen
G. foliaceum Stein
Goniodoma sp.
Gonyaulax sp.
* G. digitale (Pouchet)
G. polygramma Stein
G. scrippsae Kofoid
* G. spinifera (Clap. and Lach.)
G. tricantha Jorgensen
Gymnodinium spp.
* G. incoloratum Conrad
G. nelsoni Martin
G. punctatum Pouchet
* G. splendens Lebour
Gyrodinium spp.
G. dominans Hulburt
G. pellucidum (Wulff)
G. pingue (Schutt) Kofoid and Swezy
Gyrodinium resplendens Hulburt
Hemidinium sp.
Massartia sp.
Nematodium sp.
N. armatum (Dogiel) Lebour
Noctiluca scintillans Macartney

TABLE 3.2-1 (Continued)

- <u>Ostreopsis monotis</u>
- <u>Peridinium spp.</u>
- <u>P. brevipes</u> Paulsen
- <u>P. clandicans</u> Paulsen
- <u>P. depressum</u> Bailey
- <u>P. excavatum</u> Martin
- <u>P. granii</u> Ostenfeld
- * <u>P. Leonis</u> Paviilard
- <u>P. pallidum</u> Ostenfeld
- <u>R. roseum</u> Paulsen
- <u>P. triquetra</u> (Stein)
- * <u>P. trochoideum</u> (Stein)
- * <u>Peridinopsis rotunda</u> Lebour
- <u>Polykrikos sp.</u>
- <u>P. barnegatensis</u> Martin
- <u>P. bartmanni</u> Zimmerman
- <u>P. kofoidi</u> Chatton
- * <u>Prorcentrum Micans</u> Ehr.
- * <u>P. redfieldi</u> Bursa
- <u>P. scutellum</u> Schroeder
- * <u>P. triangulatum</u> Martin
- <u>Spirodinium fissum</u> Levander

OTHER FLAGELLATE FORMS

- <u>Bipedomonas sp.</u>
- <u>Calycomonas gracilis</u> (Lohmann) Wulff
- <u>Carteria sp.</u>
- <u>Chlamydomonas spp.</u>
- <u>Chroomonas sp.</u>
- * <u>Cryptomonas spp.</u>
- <u>Distephanus speculum</u> (Ehr.) Haeckel
- <u>Ebria tripertita</u> (Schumann) Lemmermann
- * <u>Euglena spp.</u>
- * <u>Eutreptia sp.</u>
- <u>Ochromonas sp.</u>
- <u>Pyramimonas sp.</u>
- <u>P. tetrarhynchus</u> Schmarda
- <u>P. torta</u> Conrad
- <u>Scherefflia dubia</u> Pascher

OTHER FORMS

- <u>Merismopedia sp.</u>
- <u>Aphanothece sp.</u>
- <u>Lyngbya sp.</u>
- <u>Nannochloris sp.</u>
- <u>Oscillatoria spp.</u>
- <u>Pediastrum sp.</u>
- <u>Phormidium sp.</u>
- <u>Scenedesmus quadricandata</u> (Turpin)
- <u>Spirulina sp.</u>

TABLE 3.2-2 SURFACE WATER TEMPERATURE AT FIVE BAY STATIONS FROM MARCH 1969 TO DECEMBER 1970. DATA FROM MOUNTFORD (1971).

TEMPERATURE IN °C

	STATION					
DATE	1	2	3	4	5	MEAN
3/16/69	2.8	2.8	3.9	3.1	2.8	3.1
4/13/69	11.0	12.1	12.2	12.2	12.3	12.0
5/24/69	17.0	17.1	17.5	16.9	17.0	17.1
6/10/69	20.9	21.1	21.6	21.4	21.3	21.3
6/29/69	25.0	24.8	25.0	24.9	24.9	24.9
7/10/69	23.6	23.2	23.2	23.2	23.3	23.3
7/27/69	23.3	23.3	23.0	22.6	22.7	23.0
8/8/69	25.9	25.7	25.4	26.0	26.2	25.8
8/17/69	25.9	25.8	25.5	25.9	25.6	25.7
9/11/69	19.7	20.0	21.9	21.2	21.6	20.9
9/23/69	18.1	18.0	19.0	17.6	17.4	18.0
10/7/69	16.8	16.8	17.5	16.8	17.2	17.0
10/25/69	9.3	8.8	9.4	9.1	8.9	9.1
11/18/69	6.1	5.8	6.9	6.7	7.2	6.5
12/7/69	-0.3	0.0	7.7	0.8	0.7	1.8
12/21/69	-0.2	1.8	5.8	0.8	0.8	1.8
1/10/70	0.0	0.7	4.9	-0.1	----	1.4
1/27/70	0.6	0.3	6.6	0.5	0.0	1.6
2/1/70	1.4	1.4	2.4	1.0	0.4	1.3
2/22/70	1.0	1.4	1.4	1.1	1.1	1.2
3/15/70	2.9	3.1	3.1	4.2	3.5	3.4

TABLE 3.2-2 (CONTINUED)

SURFACE WATER TEMPERATURE AT FIVE BAY STATIONS FROM MARCH 1969 TO DECEMBER 1970. DATA FROM MOUNTFORD (1971).

TEMPERATURE IN °C

DATE	STATION 1	2	3	4	5	MEAN
4/16/70	7.6	7.5	7.8	8.2	6.7	7.6
5/28/70	16.8	17.4	20.4	18.1	17.5	18.1
6/17/70	22.0	24.5	27.2	20.5	20.1	22.9
6/30/70	21.6	23.4	25.0	21.0	21.0	22.4
7/13/70	23.8	23.7	28.2	23.9	23.8	24.7
7/23/70	22.9	22.5	28.8	22.3	23.5	22.0
8/14/70	24.3	24.5	29.5	25.4	25.6	25.9
9/1/70	23.3	22.9	27.1	23.0	23.7	24.0
9/18/70	22.7	22.8	22.5	22.1	22.5	22.5
10/6/70	15.5	16.0	22.9	17.3	17.6	17.9
10/20/70	12.1	12.5	12.0	12.6	12.8	12.4
11/17/70	9.5	9.2	15.3	9.7	10.5	10.8
12/1/70	6.2	6.5	13.8	7.6	7.8	10.4

TABLE 3.2-3

SURFACE SALINITY AT FIVE BAY STATIONS FROM MARCH, 1969 TO DECEMBER, 1970. DATA FROM MOUNTFORD (1971)

SALINITY IN ppt

	STATION					
DATE	1	2	3	4	5	MEAN
3/16/69	24.0	24.7	25.2	26.3	26.5	25.3
4/13/69	23.6	23.9	24.1	24.8	25.3	24.3
5/24/69	24.3	25.2	21.3	26.6	26.0	24.7
6/10/69	27.0	27.0	26.7	28.3	28.1	27.4
6/29/69	24.9	25.8	25.1	25.7	26.2	25.5
7/10/69	25.0	25.3	25.8	25.9	26.3	25.7
7/27/70	22.9	23.9	24.3	25.1	24.4	24.1
8/8/69	17.1	19.0	18.2	22.5	22.3	19.8
8/17/69	19.4	20.1	20.5	22.9	23.8	21.3
9/11/69	19.2	20.3	21.1	23.4	24.0	21.6
9/23/69	21.5	24.2	23.2	24.6	24.6	23.6
10/7/69	22.0	22.9	22.0	23.9	24.4	23.0
10/25/69	23.1	25.4	24.1	25.9	26.1	24.9
11/18/69	19.1	18.4	19.0	22.0	22.8	20.3
12/7/69	21.0	21.2	22.4	24.7	25.0	22.9
12/21/69	20.8	21.4	21.0	22.2	23.2	21.7
1/10/70	19.1	20.8	19.4	18.1	----	19.4
1/27.70	25.8	21.9	21.3	20.0	10.2	19.8
2/1/70	24.7	16.5	22.3	25.0	25.2	22.7
2/22/70	21.5	21.5	21.7	22.8	23.5	22.2
3/15/70	21.3	21.9	22.1	23.1	25.5	22.8

TABLE 3.2-3 (CONTINUED)

SURFACE SALINITY AT FIVE BAY STATIONS FROM MARCH, 1969 TO DECEMBER, 1970. DATA FROM MOUNTFORD (1971)

SALINITY IN ppt

	STATION					
DATE	1	2	3	4	5	MEAN
4/16/70	18.0	18.8	18.3	20.4	23.7	19.8
5/28/70	19.1	19.7	20.3	20.6	21.5	20.2
6/17/70	20.3	21.2	19.0	22.4	23.6	21.3
6/30/70	20.3	21.6	21.5	23.6	23.8	22.2
7/13/70	20.2	21.5	22.2	20.9	22.9	21.5
7/23/70	19.5	20.3	21.1	22.1	23.6	21.3
8/14/70	23.9	25.0	24.4	25.5	25.6	24.9
9/1/70	24.8	25.2	24.1	25.2	25.4	24.9
9/18/70	26.3	27.3	27.7	29.5	29.5	28.1
10/6/70	25.5	26.7	26.7	28.4	27.1	26.9
10/20/70	24.4	25.8	25.7	28.7	27.9	26.5
11/17/70	23.0	23.6	23.3	24.7	24.6	23.8
12/1/70	23.0	23.2	22.4	24.4	24.7	23.5

TABLE 3.2-4 SURFACE WATER TEMPERATURE AND SALINITY AT SITES 6 AND 7 (INTAKE AND DISCHARGE CANALS) DURING 1970. DATA FROM MOUNTFORD (1971).

TEMPERATURE IN °C; SALINITY IN ppt

DATE	STATION	TEMPERATURE	SALINITY
2/22/70	6	1.4	----
	7	3.2	----
3/15/70	6	2.9	----
	7	11.4	----
4/16/70	6	7.7	----
	7	14.1	----
5/28/70	6	17.3	20.3
	7	25.4	19.3
6/17/70	6	22.5	20.8
	7	31.0	17.3
6/30/70	6	23.7	21.7
	7	27.3	20.1
7/13/70	6	24.9	21.8
	7	32.2	19.4
7/23/70	6	22.5	22.2
	7	31.2	20.3
8/14/70	6	24.5	25.0
	7	30.5	24.1
9/1/70	6	22.6	24.3
	7	28.7	23.8
9/18/70	6	22.6	26.7
	7	23.2	26.2
10/6/70	6	16.1	28.0
	7	25.0	26.5
10/20/70	6	12.8	25.9
	7	12.5	25.2
11/17/70	6	9.4	24.3
	7	18.7	22.1
12/1/70	6	6.1	23.4
	7	15.0	21.5

TABLE 3.2-5. Seasonal distribution of the 66 most abundant diatom taxa (indicated by asterisk) and many less abundant diatom taxa in the intake and discharge canals. Taxa are listed as showing no substantial seasonal fluctuations or according to the season or seasons in which they achieved proportional maxima in the canals. Data from Hein (1977).

Entire Year Generally

*Asterionella formosa
Diploneis smithii var. rhombica
*Eunotia exigua
*Frustulia rhomboides var. saxonica
*Grammatophora oceanica var. macilenta
*Navicula lanceolata
*Nitzschia distans
*Nitzschia kutzingiana
*Synedra tabulata var. acuminata

Winter

*Chaetoceros atlanticus
Licmophora sp. 2
*Navicula pseudincerta
*Pinnularia subcapitata var. hilseana
*Sceletonema costatum
Synedra pulchella

Spring

Achnanthes longipes
*Amphipleura rutilans
Asterionella japonica
Cocconeis sp. 2
Cyclotella sp. 2
Gyrosigma spenceri
*Licmophora communis
Navicula directa
*Nitzschia bergii
*Nitzschia pellucida
*Synedra investiens
*Tabellaria flocculosa

Spring and Summer

*Achnanthes clevei
*Achnanthes fimbriata
Achnanthes hauckiana
Cocconeis placentula var. euglypta
*Cocconeis scutellum

TABLE 3.2-5 (Continued)

Cyclotella sp. 1
Eunotia pectinalis var. minor
Gyrosigma diaphanum
Melosira fausta
Navicula digitoradiata
*Navicula pseudony
*Navicula sp. 1
*Navicula sp. 3
Thalassiosira decipiens

Summer

Achnanthes sp. 2
*Amphipleura micans
*Amphora angusta
Amphora exigua
*Cocconeis disculoides
Cocconeis disculus
*Cocconeis placentula
*Cocconeis placentula var. intermedia
*Cocconeis pseudodiruptoides
*Cocconeis scutellum var. parva
*Cocconeis scutellum var. speciosa
*Cocconeis scutellum var. stauroneiformis
Cocconeis sp. 3
Diploneis bombus var. egena
Diploneis sp. 1
*Eunotia arcus
Eunotia bidentula
*Eunotia flexuosa
Eunotia sp. 1
Eunotia sp. 2
*Frustulia rhomboides var. amphipleuroides
Gyrosigma fasciola
Gyrosigma peisonis
Gyrosigma rectum
*Hyalodiscus scoticus
*Licmophora abbreviata
Licmophora hyalina
*Licmophora paradoxa
Licmophora sp. 1
*Mastogloia pumila
Melosira granulata
*Melosira italica
Melosira sulcata
*Melosira sp. 2
*Melosira sp. 3
*Navicula complanata
Navicula gastrum var. remotestriata

TABLE 3.2-5 (Continued)

*Navicula perpendicularis
*Navicula sp. 6
*Nitzschia communis var. abbreviata
*Nitzschia dissipata
*Nitzschia filiformis var. ignorata
Nitzschia frustulum var. perpusilla
Nitzschia punctata var. coarctata
Nitzschia sigma var. intercedens
Nitzschia socialis
Nitzschia thermalis var. minor
*Pinnularia abaujensis
*Pinnularia mesolepta
*Trachyneis aspera var. pulchella

Fall

*Amphora coffeaeformis var. borealis
*Amphora dannfeltii
Navicula granulata
*Neidium bisulcatum var. ?
*Nitzschia dissipata var. media
*Nitzschia longissima var. reversa
Nitzschia subtilis
*Nitzschia sp. 1
*Stauroneis sp. 1

Spring and Fall

*Amphiprora angustata
Amphora laevis var. perminuta
Eunotia praerupta
Enotia pseudopectinalis
*Enotia repens var. acruata
Fragilaria floridana
Gyrosigma wansbeckii
*Melosira nummuloides
*Navicula ammophila fo. minuta
*Navicula delicatula
Navicula scopulorum var. perlonga
*Nitzschia closterium
*Surirella recedens

TABLE 3.2-6 CHLOROPHYLL a CONCENTRATIONS AT FIVE BAY STATIONS FROM APRIL TO DECEMBER, 1970. SEE FIGURE 3.2-1 FOR STATION LOCATIONS. DATA FROM MOUNTFORD (1971).

CHLOROPHYLL a in mg/l

	STATION					
DATE	1	2	3	4	5	MEAN
4/16/70	8.5	8.7	9.1	8.2	9.2	8.6
	8.5	9.1	9.1	4.8	10.7	
5/28/70	8.0	5.0	7.0	5.5	5.7	6.0
	6.1	6.0	5.5	5.8	5.2	
6/17/70	8.3	7.9	9.8	7.0	6.6	7.7
	7.1	8.0	9.5	7.7	5.3	
6/30/70	9.1	9.1	7.8	8.0	9.1	8.6
	9.9	8.6	7.1	9.6	7.6	
7/13/70	10.5	9.6	11.2	11.6	10.2	10.6
	10.0	10.4	12.0	11.2	9.0	
7/23/70	8.3	7.0	6.8	5.4	4.8	6.4
	8.8	6.4	6.4	5.0	4.8	
8/14/70	6.5	11.6	7.6	6.2	3.2	7.2
	7.3	10.8	6.8	5.4	6.4	
9/1/70	7.5	7.6	5.0	5.2	7.0	6.5
	7.0	7.1	4.8	6.8	7.2	
9/18/70	9.9	7.6	6.4	4.8	4.6	6.7
	9.1	6.5	6.5	4.6	---	
10/6/70	4.5	3.9	5.8	3.6	5.4	4.6
	4.5	3.8	5.4	3.8	5.5	
10/20/70	4.8	4.5	5.5	3.0	3.4	4.1
	4.7	4.2	5.6	2.8	2.9	
11/17/70	14.5	8.8	11.9	10.7	11.9	11.3
	8.6	7.4	11.9	12.0	15.1	
12/1/70	2.9	2.9	4.0	5.8	4.2	3.8
	2.8	2.6	3.6	6.0	3.6	

TABLE 3.2-7 MEAN CHLOROPHYLL a CONCENTRATIONS AT FIVE BAY STATIONS FROM APRIL TO DECEMBER 1970. DATA FROM MOUNTFORD (1971).

CHLOROPHYLL a IN mg/l

	STATION				
DATE	1	2	3	4	5
4/16/70-12/1/70	7.6	7.1	7.4	6.6	6.7

TABLE 3.2-8 CHLOROPHYLL a CONCENTRATIONS AT STATIONS 6 AND 7 (INTAKE AND DISCHARGE CANALS) FROM JUNE 1969 TO DECEMBER 1970. DATA FROM MOUNTFORD (1971).

CHLOROPHYLL a in mg/1

	STATION	
DATE	6	7
6/10/69	2.0	4.0
6/29/69	----	13.2
7/10/69	23.9	22.8
7/27/69	22.5	31.0
8/8/69	11.2	15.8
8/17/69	15.0	18.3
9/11/69	0.5	2.1
10/7/69	5.0	3.5
10/25/69	3.4	3.0
11/18/69	4.6	5.8
12/7/69	5.0	10.2
12/21/69	10.1	10.0
1/10/70	7.1	5.7
2/1/70	26.7	21.0
2/22/70	27.3	15.5
3/15/70	3.8	4.5
4/16/70	11.2	5.3
5/28/70	5.7	7.0

TABLE 3.2-8 (CONTINUED)

CHLOROPHYLL a CONCENTRATIONS AT STATIONS 6 AND 7 (INTAKE AND DISCHARGE CANALS) FROM JUNE 1969 TO DECEMBER 1970. DATA FROM MOUNTFORD (1971).

CHLOROPHYLL a in mg/1

	STATION	
DATE	6	7
6/17/70	8.8	12.4
6/30/70	7.3	6.9
7/13/70	11.2	7.4
7/23/70	6.0	4.6
8/14/70	9.0	6.0
9/1/70	7.6	6.0
9/18/70	7.9	8.2
10/6/70	5.1	6.7
10/20/70	5.5	4.2
11/17/70	14.7	15.5
12/1/70	3.1	1.3

TABLE 3.2-9 GROSS PRODUCTIVITY AT FIVE BAY STATIONS FROM MAY TO DECEMBER, 1970. SEE FIGURE 3.2-1 FOR STATION LOCATIONS. DATA FROM MOUNTFORD (1971).

PRODUCTIVITY IN mg $O_2/m^3/hr$

DATE	STATION 1	2	3	4	5	MEAN
5/28/70	94.8	136.0	154.3	162.0	140.0	138.0
	189.0	89.0	125.2	152.0	138.0	
6/17/70	312.0	254.0	221.0	206.0	172.0	247.1
	333.0	301.0	253.0	236.0	183.0	
6/30/70	457.0	498.0	455.0	396.0	384.0	443.9
	519.0	537.0	415.0	396.0	382.0	
7/13/70	410.0	240.0	260.0	360.0	250.0	281.2
	220.0	260.0	190.0	352.0	270.0	
7/23/70	298.0	237.0	401.0	236.0	191.0	263.8
	250.0	227.0	341.0	261.0	196.0	
8/14/70	444.0	670.0	507.0	741.0	343.0	527.9
	427.0	640.0	496.0	542.0	469.0	
9/1/70	323.0	326.0	210.0	271.0	283.0	273.1
	298.0	275.0	184.0	287.0	274.0	
9/18/70	349.0	370.0	259.0	270.0	247.0	288.6
	239.0	344.0	324.0	265.0	219.0	
10/6/70	70.6	385.0	103.0	52.1	76.3	124.9
	145.0	117.0	197.0	33.7	69.3	
10/20/70	178.0	84.0	43.2	68.7	36.1	74.9
	87.0	68.9	43.8	63.3	76.8	
11/17/70	234.0	134.0	196.0	165.0	292.0	200.0
	165.0	127.0	188.0	177.0	322.0	
12/1/70	52.3	58.8	50.2	98.7	77.7	72.5
	48.3	53.2	70.4	119.0	96.5	

TABLE 3.2-10 MEAN GROSS PRODUCTIVITY AT FIVE BAY STATIONS FROM MAY TO DECEMBER 1970. DATA FROM MOUNTFORD (1971).

PRODUCTIVITY IN mg $O_2/m^3/hr$

	STATION				
DATE	1	2	3	4	5
5/28/70-12/1/70	256.0	268.0	237.0	246.3	216.2

TABLE 3.2-11 GROSS PRODUCTIVITY, NET PRODUCTIVITY, AND RESPIRATION AT STATIONS 1 THROUGH 4 IN 1971 AND 1972. DATA FROM LOVELAND AND OTHERS (1972).

PRODUCTIVITY IN mg $O_2/m^3/hr$

DATE	STATION	GROSS PRODUCTIVITY	NET PRODUCTIVITY	RESPIRATION
8/4/71	1	533.0	256.0	277.0
	2	437.0	264.0	173.0
	3	329.0	168.0	161.0
	4	424.0	193.0	231.0
9/9/71	1	520.0	396.0	124.0
	2	313.0	157.0	156.0
	3	229.0	60.0	169.0
	4	267.0	218.0	49.0
10/11/71	1	166.0	23.0	143.0
	2	142.0	7.0	135.0
	3	146.0	26.0	120.0
	4	133.0	56.0	77.0
11/11/71	1	278.0	-82.0	360.0
	2	9.0	-135.0	144.0
	3	190.0	28.0	162.0
	4	139.0	55.0	84.0
4/18/72	1	70.0	-6.0	76.0
	2	56.0	60.0	-4.0
	3	84.0	43.0	41.0
	4	63.0	28.0	35.0
5/11/72	1	163.0	131.0	32.0
	2	133.0	76.0	57.0
	3	136.0	101.0	35.0
	4	115.0	78.0	37.0
6/28/72	1	124.0	38.0	86.0
	2	160.0	78.0	82.0
	3	161.0	4.0	157.0
	4	205.0	133.0	72.0
7/27/72	1	356.0	280.0	76.0
	2	578.0	489.0	89,0
	3	385.0	296.0	89.0
	4	380.0	284.0	96.0

TABLE 3.2-12 MEAN GROSS AND NET PRODUCTIVITY AT FOUR BAY STATIONS IN 1971 AND 1972. NET PRODUCTIVITY IN PARENTHESES. DATA FROM LOVELAND AND OTHERS (1972).

PRODUCTIVITY IN $mg_2\ O_2/m^3/hr$

		STATION			
YEAR	NO. OF SAMPLES	1	2	3	4
1971	16	374.3 (148.3)	225.3 (73.3)	223.5 (70.5)	240.8 (130.5)
1972	16	178.3 (110.8)	231.8 (175.8)	191.5 (111.0)	190.8 (131.0)

TABLE 3.2-13 GROSS PRODUCTIVITY, NET PRODUCTIVITY, AND RESPIRATION AT STATIONS 6 AND 7 (INTAKE AND DISCHARGE CANALS) FROM 1970 TO 1972. DATA FROM MOUNTFORD (1971) AND LOVELAND AND OTHERS (1972).

PRODUCTIVITY IN mg $O_2/m^3/hr$

DATE	STATION	GROSS PRODUCTIVITY	NET PRODUCTIVITY	RESPIRATION
7/23/70	6	232.0	141.5	90.5
	7	229.0	114.0	115.0
8/14/70	6	569.0	87.0	482.0
	7	386.0	.0	348.0
9/1/70	6	194.0	24.0	170.0
	7	151.0	0.0	151.0
9/18/70	6	404.0	298.0	106.0
	7	371.0	352.0	19.0
10/6/70	6	126.0	32.9	93.1
	7	-74.3	0.0	74.3
10/20/70	6	85.2	42.9	42.6
	7	259.0	59.0	200.0
11/17/70	6	310.0	259.3	50.7
	7	272.0	175.6	96.4
12/1/70	6	60.0	48.0	12.0
	7	58.5	15.1	43.4
8/4/71	6	372.0	410.0	38.0
	7	416.0	46.0	370.0
9/9/71	6	200.0	52.0	148.0
	7	94.0	2.0	92.0
10/11/71	6	158.0	10.0	148.0
	7	164.0	16.0	148.0
11/11/71	6	262.0	-32.0	294.0
	7	-66.0	-138.0	72.0

TABLE 3.2-13 (Continued)

GROSS PRODUCTIVITY, NET PRODUCTIVITY, AND RESPIRATION AT STATIONS 6 AND 7 (INTAKE AND DISCHARGE CANAL) FROM 1970 TO 1972. DATA FROM MOUNTFORD (1971) AND LOVELAND AND OTHERS (1972).

DATE	STATION	GROSS PRODUCTIVITY	NET PRODUCTIVITY	RESPIRATION
4/18/72	6	52.0	12.0	40.0
	7	74.0	40.0	34.0
5/11/72	6	142.0	88.0	54.0
	7	192.0	140.0	52.0
6/28/72	6	114.0	42.0	72.0
	7	254.0	182.0	72.0
7/27/72	6	332.0	252.0	80.0
	7	326.0	254.0	72.0

TABLE 3.2-14 MEAN GROSS AND NET PRODUCTIVITY AT STATIONS 6 AND 7 (INTAKE AND DISCHARGE CANALS) FROM 1970 TO 1972. NET PRODUCTIVITY IN PARENTHESES. DATA FROM MOUNTFORD (1971) AND LOVELAND AND OTHERS (1972).

PRODUCTIVITY IN mg $O_2/m^3/hr$

		STATION		
YEAR	NO. OF SAMPLES	6	7	DIFFERENCE
1970	8	247.5 (116.7)	206.5 (89.5)	41.0 (27.2)
1971	4	248.0 (110.0)	152.0 (-18.5)	96.0 (128.5)
1972	4	160.0 (98.5)	211.5 (154.0)	51.5 (55.5)

TABLE 3.2-15. Distribution patterns of some diatom taxa in the intake and discharge canals grouped according to their relative abundance between the canals. Taxa in each group do not necessarily have their maxima in the same seasons, and those with an asterisk are among the 66 most abundant. Data from Hein (1977).

Taxa with No Apparent Seasonal or Thermal Distribution Patterns

Amphora exigua
*Cocconeis scutellum var. speciosa
*Grammatophora oceanica var. macilenta
*Navicula lanceolata
*Navicula sp. 1
*Nitzschia distans
*Nitzschia longissima var. reversa
*Nitzschia pellucida
*Synedra tabulata var. acuminata

Taxa with Maxima Restricted to Various Seasons with Same Abundance in Both Canals During Maxima (No Thermal Effects Evident)

*Achnanthes clevei
Achnanthes sp. 2
*Amphipleura rutilans
*Amphiprora angustata
Amphora laevis var. perminuta
*Cocconeis placentula
*Cocconeis scutellum var. parva
Gyrosigma diaphanum
Gyrosigma fasciola
*Licmophora communis
*Melosira nummuloides
*Melosira sp. 3
*Navicula ammophila fo. minuta
*Navicula complanata
Navicula directa
Navicula gastrum var. remotestriata
*Sceletonema costatum

Taxa with Maxima Restricted to Various Seasons But More Abundant in the Intake Canal Than the Discharge Canal During Maxima (Possible Thermal Effects)

Achnanthes hauckiana
Achnanthes longipes
*Chaetoceros atlanticus
*Cocconeis disculoides
Cocconeis placentula var. euglypta
*Cocconeis pseudodiruptoides

TABLE 3.2-15 (Continued).

*Cocconeis scutellum
*Cocconeis scutellum var. stauroneiformis
Cyclotella sp. 1
*Melosira italica
Melosira sulcata
Navicula scopulorum var. perlonga
*Nitzschia dissipata var. media
Nitzschia punctata var. coarctata
*Synedra investiens
Thalassiosira decipiens

Taxa with Maxima Restricted to Various Seasons But More Abundant in the Discharge Canal Than the Intake Canal During Taxons' Maxima (Possible Thermal Effects)

*Amphipleura micans
*Amphora coffeaeformis var. borealis
*Mastogloia pumila
*Navicula delicatula
*Navicula pseudincerta
*Nitzschia communis var. abbreviata
*Nitzschia filiformis var. ignorata
Nitzschia sigma var. intercedens
*Stauroneis sp. 1

Taxa for Which the Maxima Occurred at Different Times But Similar Temperatures in the Intake and Discharge Canals

*Amphora angusta
*Amphora dannfeltii
Asterionella japonica
*Cocconeis placentula var. intermedia
Cyclotella sp. 2
Diploneis bombus var. egena
Diploneis smithii var. rhombica
Diploneis sp. 1
Gyrosigma wansbeckii
Licmophora hyalina
Melosira granulata
*Nitzschia closterium
Nitzschia frustulum var. perpusilla
*Nitzschia kutzingiana
Nitzschia socialis
Nitzschia subtilis
Synedra pulchella
*Trachyneis aspera var. pulchella

TABLE 3.2-16 DIATOM COMMUNITY PARAMETERS RECORDED IN THE INTAKE AND DISCHARGE CANALS. S=THE NUMBER OF TAXA ENCOUNTERED, N=THE TOTAL NUMBER OF VALVES COUNTED, H"=THE INFORMATION MEASURE DIVERSITY INDEX, R'=THE REDUNDANCY INDEX. DATA FROM HEIN (1977)

DATE	LOCATION	S	N	H"	R'
12/19/75	Intake	59	513	3.35	0.54
	Discharge	53	510	3.83	0.41
1/28/76	Intake	--	---	----	----
	Discharge	39	527	2.41	0.63
2/28/76	Intake	42	536	3.46	0.42
	Discharge	39	519	3.30	0.44
3/29/76	Intake	51	514	4.24	0.31
	Discharge	52	519	4.14	0.33
4/30/76	Intake	80	527	5.03	0.27
	Discharge	53	515	4.12	0.34
6/3/76	Intake	88	510	5.65	0.17
	Discharge	56	520	4.70	0.23
7/5/76	Intake	67	539	4.75	0.28
	Discharge	68	510	5.08	0.21
8/2/76	Intake	94	515	5.89	0.14
	Discharge	51	525	4.48	0.25
9/7/76	Intake	60	513	4.91	0.21
	Discharge	52	519	4.58	0.24
10/3/76	Intake	57	516	4.39	0.31
	Discharge	54	512	4.15	0.34
10/31/76	Intake	61	521	4.62	0.28
	Discharge	21	515	1.20	0.80
12/5/76	Intake	44	524	2.97	0.54
	Discharge	43	514	3.18	0.49
MEANS	Intake	63.9	520.7	4.48	0.32
	Discharge	48.4	517.1	3.77	0.39
STANDARD DEVIATIONS	Intake	17.0	9.8	0.93	0.13
	Discharge	11.7	5.4	1.10	0.18

TABLE 3.2-17 DEGREE OF DIFFERENCE VALUES (Dhk) BETWEEN DIATOM COMMUNITIES IN THE INTAKE AND DISCHARGE CANALS. IF Dhk=1, THE SAME SPECIES ARE PRESENT IN BOTH COMMUNITIES IN THE SAME PROPORTIONS. IF Dhk=2, THERE ARE NO TAXA IN COMMON. DATA FROM HEIN (1977).

DATE	Dhk VALUE
12/19/75	1.105
1/28/76	-----
2/28/76	1.057
3/29/76	1.036
4/30/76	1.166
6/3/76	1.219
7/5/76	1.167
8/2/76	1.331
9/7/76	1.174
10/3/76	1.237
10/31/76	1.353
12/5/76	1.097

TABLE 3.2-18 Seasonal heat dissipation of the FRNGS[1]

Tem erature in °F & (°C)

Season	Barnegat Bay Temperature	Peak Condenser Discharge Temperature[3]	Blow own Temper ture Above ay Temper ture	Blowdown T mperature A ove Bay T mperature[4]	Blowdown Temperature Above Bay Temperature[5]
Spring	56.7 (13.7)	79.7 (26.5)	21.0 (11.7)	3.6 (2.0)	1.3 (0.7)
Summer	73.6 (23.1)	96.6 (35.9)	15.8 (8.	2.7 (1.5)	1 0 (0.6)
Fall	56.7 (13.7)	79.7 (26.5)	23.9 (13.3)	4.1 (2.3)	1.4 (0.8)
Winter	43.1 (6.2)	66.1 (18.9)	26.7 (14.8)	4.6 (2.6)	1.6 (0.9)
Peak	82.0 (27.8)	105.0 (40.6)	15.4 (8.5)	2 7 (1.5)	0.9 (0.5)

NOTES:

(1) Salinity concentration of 1.5 X ient bay salinity.

(2) After Devine (1974). See page 5-1 for difications to this table

(3) OCNGS operating at full power.

(4) OCNGS not operating but after mixing with e circulating water pump (115,000 gpm).

(5) OCNGS not operating but after mixing with one circulating water pump (115,000 gpm) and one dilution pump (260,000 gpm).

TABLE 3 2-19 Seasonal heat dissipation of the FRNGS[1]

Temperature in °F & (°C)

Season	Barnegat Bay Temperature[2]	Peak Condenser Discharge Temperature[3]	Blowdown Temperature Above Bay Temperature	Blowdown Temperature Above Bay Temperature[4]	Blowdown Temperature Above Bay Temperature[5]	Blowdown Temperature Above Bay Temperature[6]
Spring	56.7 (13.7)	79.7 (26.5)	21.0 (11.7)	1.0 (0.6)	0.7 (0.4)	0.5 (0.3)
Summer	73.6 (23.1)	96.6 (35.9)	15.8 (8.8)	0.8 (0.4)	0.5 (0.3)	0.4 (0.2)
Fall	56.7 (13.7)	79.7 (26.5)	23.9 (13.3)	1.2 (0.7)	0.8 (0.4)	0.6 (0.3)
Winter	43.1 (6.2)	66.1 (18.9)	26.7 (14.8)	1.3 (0.7)	0.9 (0.5)	0.6 (0.3)
Peak	82.0 (27.8)	105.0 (40.6)	15.4 (8.5)	0.8 (0.4)	0.5 (0.3)	0.4 (0.2)

NOTES:

(1) Salinity concentration of 1.5 X ambient bay salinity.

(2) After Devine (1974). See page 5-1 for modifications to this table.

(3) OCNGS operating at full power.

(4) OCNGS operating and after mixing with four circulating water pumps (460,000 gpm) and two service water pumps (12,000 gpm).

(5) OCNGS operating and after mixing with four circulating water pumps (460,000 gpm), two service water pumps (12,000 gpm), and one dilution pump (260,000 gpm).

(6) OCNGS operating and after mixing with four circulating water pumps (460,000 gpm), two service pumps (12,000 gpm), and two dilution pumps (520,000 gpm).

TABLE 3.2-20. Combined thermal discharge of the OCNGS and the FRNGS[1]

Temperature in °F & (°C)

Season	Barnegat Bay Temperature[2]	OCNGS Peak Condenser Discharge Temperature[3]	Discharge Temperature Above Bay Temperature	Discharge Temperature Above Bay Temperature[4]	Discharge Temperature Above Bay Temperature[5]	Discharge Temperature Above Bay Temperature[6]
Spring	56.7 (13.7)	79.7 (26.5)	21.0 (11.7)	22.3 (12.4)	14.7 (8.2)	10.9 (6.1)
Summer	73.6 (23.1)	96.6 (35.9)	15.9 (8.8)	22.1 (12.3)	14.5 (8.1)	10.8 (6.0)
Fall	56.7 (13.7)	79.7 (26.5)	23.9 (13.3)	22.5 (12.5)	14.8 (8.2)	11.0 (6.1)
Winter	43.1 (6.2)	66.1 (18.9)	26.7 (14.8)	22.6 (12.5)	14.9 (8.3)	11.0 (6.1)
Peak	82.0 (27.8)	105.0 (40.6)	15.4 (8.5)	22.1 (12.3)	14.5 (8.1)	10.8 (6.0)

NOTES:

(1) Salinity concentration of 1.5 X ambient bay salinity.

(2) After Devine (1974). See page 5-1 for modifications to this table.

(3) OCNGS operating at full power.

(4) Includes discharge of the OCNGS four circulating water pumps (460,000 gpm) and two service water pumps (12,000 gpm), mixed with blowdown of the FRNGS (21,600 gpm).

(5) Includes discharge of the OCNGS - four circulating water pumps (460,000 gpm), two service water pumps (12,000 gpm), and one dilution pump (260,000 gpm), mixed with blowdown of the FRNGS (21,600 gpm).

(6) Includes discharge of the OCNGS - four circulating water pumps (460,000 gpm), two service water pumps (12,000 gpm), and two dilution pumps (520,000 gpm), mixed with the blowdown of the FRNGS (21,600 gpm).

TABLE 3.2-21. Temperature characteristics for growth (photosynthesis or cell division) of selected phytoplankton species found in Barnegat Bay, New Jersey.

Species	Temperature °F (°C)	Qualifying Statement	Reference
Skeletonema costatum	41.0-86.0 (5.0-30.0)	Range of growth in varying nutrient solutions and light concentrations under laboratory conditions	Curl and McLeod (1961)
	68.0 (20.0)	Optimum growth in varying nutrient concentrations at 10,000 Lux under laboratory conditions	Curl and McLeod (1961)
	60.8-78.8 (16.0-26.0)	Range of maximum growth at 0.075-0.04 + Langlies (ly)/minute of light under laboratory conditions	Jitts and others (1964)
	68.0 (20.0)	Optimum growth at 0.25 ly/minute of light under laboratory conditions	Jitts and others (1964)
	42.8-82.4 (6.0-28.0)	Range of any growth at 0.005-0.4 + ly/minute of light under laboratory conditions	Jitts and others (1964)
	68.0 (20.0)	Temperature at which photosynthesis was at a maximum in all nutrient solutions tested	Curl and McLeod (1961)
	35.1-84.2 (1.7-29.0)	Present in Chesapeake Bay, Virginia throughout the year: Range of temperatures associated with salinities between 10.8 ppt and 33.8 ppt.	Mulford and Norcross (1971)
	98.6 - 104.0 (37.0-40.0)	Highest temperatures tolerated.	Jitts and others (1964)

TABLE 3.2-21 Con nued

Species	Temperature °F (°C)	Qualifying Statement	Reference
Amphidinium carteri	73.4-78.8 (23.0-26.0)	Range of maximum growth at 0.1-0.4 + ly/minute of light under laboratory conditions	Jitts and others (1964)
	75.2 (24.0)	Optimum growth at 0.30 ly/minute of light under laboratory conditions	Jitts and others (1964)
	64.4-91.4 (18.0-33.0)	Range for any growth at 0.05-0.4 + ly/minute of light under laboratory conditions	Jitts and others (1964)
Prorocentrum micans	71.6-82.4 (22.0-28.0)	Optimum growth range	Ukeles (1961)
Nannochloris atomus	50.0-86.0 (10.0-30.0)	Range of any recorded growth under laboratory conditions	Ryther (1954)
	59.0-77.0 (15.0-25.0)	Optimum growth range under laboratory conditions	Ryther (1954)
Chaetoceros curvisetum	64.4-68.0 (18.0-20.0)	Range for optimum growth	Ryther (1954)

TABLE 3.2-21 (Continued).

Species	Temperature °F (°C)	Qualifying Statement	Reference
Thalasslosira nordenskioldii	52.7-57.2 (11.5-14.0)	Range of maximum growth at 0.02-0.15 ly/minute of light under laboratory conditions	Jitts and others (1964)
	55.4 (13.0)	Optimum growth at 0.075 ly/minute of light under laboratory conditions	Jitts and others (1964)
	66.2-68.0 (19.0-20.0)	Range of any growth at 0.005-0.5 + ly/minute of light under laboratory conditions	Jitts and others (1964)
Detonula confervacea	35.6-53.6 (2.0-12.0)	Mean daily cell division rate increases significantly between these temperatures	Smayda (1969)
	60.8-62.6 (16.0-17.0)	Growth ceases	Smayda (1969)

TABLE 3.2-22. Seasonal salinity of the OCNGS and the FRNGS discharges.[7]

Salinity in ppt

Season	Barnegat Bay Salinity[1]	FRNGS Blowdown Salinity[2]	Blowdown Salinity Above Bay Salinity[3]	Total Discharge Salinity[4]	Blowdown Salinity Above Bay Salinity[5]	Total Discharge Salinity[6]
Spring	22.1	33.2	5.7	24.0	2.0	22.8
Summer	25.4	38.1	6.6	27.6	2.3	26.2
Fall	21.5	32.3	5.6	23.4	1.9	22.2
Winter	21.4	32.1	5.5	23.2	1.9	22.0
Peak	30.0	45.0	7.8	32.6	2.7	30.9

NOTES:

(1) Mean bay salinities from September 1975 to September 1976. After Ichthyological Associates (1977).

(2) Salinity concentration of 1.5 X ambient bay salinity.

(3) OCNGS not operating but after mixing with one circulating water pump (115,000 gpm).

(4) Combined salinity of the OCNGS discharge and FRNGS blowdown (3) after mixing.

(5) OCNGS not operating but after mixing with one circulating water pump (115,000 gpm) and one dilution pump (260,000 gpm).

(6) Combined salinity of OCNGS discharge and FRNGS blowdown (5) after mixing.

(7) See page 5-1 for modifications to this table.

TABLE 3 2-23 Seasonal salinity of the OCNGS and FRNGS discharges [5]

Salinity in ppt

Season	Barnegat Bay Salinity[1]	FRNGS Blowdown Salinity[2]	Blowdown Salinity Above Bay Salinity[3]	Total Discharge Salinity[4]
Spring	22.1	33.2	1.1	22.4
Summer	25.4	38.1	1.2	25.8
Fall	21.5	32.3	1.0	21.8
Winter	21.4	32.1	1.0	21.7
Peak	30.0	45.0	1.4	30.5

NOTES:

(1) Mean bay salinities from September 1975 to September 1976. After Ichthyological Associates (1977).

(2) Salinity concentration of 1.5 X ambient bay salinity

(3) OCNGS operating and after mixing with four circulating water pumps (460,000 gpm), two service water pumps (12,000 gpm), and one dilution pump (260,000 gpm).

(4) C bined salinity of the OCNGS discharge and FRNGS blowdown after mixing

(5) See page 5-1 for modifications to this table

TABLE 3.2-24. Seasonal salinity of the OCNGS and FRNGS discharges.[5]

Salinity in ppt

Season	Barnegat Bay Salinity[1]	FRNGS Blowdown Salinity[2]	Blowdown Salinity Above Bay Salinity[3]	Total Discharge Salinity[4]
Spring	22.1	33.2	0.8	22.4
Summer	25.4	38.1	0.9	25.7
Fall	21.5	32.3	0.8	21.7
Winter	21.4	32.1	0.8	21.6
Peak	30.0	45.0	1.1	30.4

NOTES:

(1) Mean bay salinities from September 1975 to September 1976. After Ichthyological Associates (1977).

(2) Salinity concentration of 1.5 X ambient bay salinity.

(3) OCNGS operating and after mixing with four circulating water pumps (460,000 gpm), two service water pumps (12,000 gpm), and two dilution pumps (520,000 gpm).

(4) Combined salinity of the OCNGS discharge and FRNGS blowdown after mixing.

(5) See page 5-1 for modifications to this table.

ɔle 3.2-25 Average monthly density (n m^{3}) of numerous and important microzooplankton at two stations (#3 and #23) not affected by the thermal plume of the Oyster Creek Generating Station. Forked River, New Jersey from September 1975 through August 1976. NE = not enumerated.

Form	Sta. #	September[a]	October	November	December	January	February	March	April	May	June	July	August	Year
Copepod nauplii	3	3,198	6,133	9,875	27,200	NS	42,936	16,405	79,373	29,506	73,606	78,757	27,651	39,144
	23	6,120	3,451	11,157	17,129	NS	214,351	154,067	38,334	14,573	55,512	25,450	12,529	54,655
Rotifers	3	11,502	353	259	27,266	NS	29,915	0	11,285	28,336	11,540	731	2,074	11,176
	23	2,081	57	6,567	87,624	NS	227,064	1,950	11,250	26,631	1,900	0	3,697	36,670
Barnacle larvae	3	173	873	490	1,895	NS	150	524	20,084	5,696	1,186	355	116	3,137
	23	14	123	43	391	NS	74	14	1,967	2,104	2,399	574	36	773
Polychaete larvae	3	820	311	1,225	457	NS	112	125	16,917	13,897	6,079	4,936	2,208	4,627
	23	273	770	469	744	NS	308	627	26,348	14,707	12,909	3,634	2,384	6,290
Polydora spp.	3	0	37	0	0	NS	0	0	14,322	7,886	2,486	620	262	2,561
	23	0	43	0	173	NS	0	78	12,249	7,065	7,284	155	218	2,727
Copepods	3	915	2,854	8,491	,095	NS	14,274	22,871	30,820	3,922	33,316	43,044	23,336	18,902
	23	808	1,047	7,350	,938	NS	29,971	47,793	5,869	1,994	12,308	16,600	2,551	13,442
<u>Acartia clausi</u>	3	NE	5	94	79	NS	11,324	14,278	9,792	216	156	0	0	3,594
	23	NE	0	0	396	NS	19,956	15,283	104	27	0	0	0	3,577
<u>Acartia tonsa</u>	3	NE	170	961	1,823	NS	52	0	40	0	3,543	5,130	2,919	1,464
	23	NE	15	858	2,723	NS	0	1,435	0	0	1,377	650	280	734
<u>Acartia</u> spp.	3	NE	854	5,081	3,080	NS	2,516	4,801	18,976	2,011	6,262	9,134	6,813	5,953
	23	NE	324	2,351	5,099	NS	8,783	42,991	4,479	520	7,655	6,350	997	7,955
<u>Oithona colcarva</u>	3	NE	310	522	301	NS	0	78	72	53	1,124	4,190	5,356	1,201
	23	NE	106	634	149	NS	0	546	0	0	485	1,050	427	340
<u>Oithona</u> spp.	3	0	65	834	246	NS	0	0	40	262	663	9,862	7,098	1,907
	23	0	15	858	50	NS	0	356	0	131	128	1,300	494	333
Gastropod larvae	3	2,312	1,123	311	42	NS	0	0	220	3,909	2,581	1,946	905	1,103
	23	3,814	308	574	33	NS	0	0	680	5,008	964	3,574	18	1,116
Total Bivalve larvae	3	1,565	1,468	10,092	258	NS	39	0	3,947	5,962	5,527	1,136	1,999	3,043
	23	1,013	334	36	74	NS	0	28	8,003	2,250	7,715	966	925	2,033
<u>Mulinia lateralis</u>	3	0	0	0	0	NS	0	0	0	0	0	0	25	3
	23	0	0	7	0	NS	0	0	0	104	285	50	113	56
<u>Mercenaria mercenaria</u>	3	0	0	0	0	NS	0	0	0	0	0	0	0	0
	23	0	0	0	0	NS	0	0	104	0	0	0	0	10
Cyphonaute larvae	3	313	356	18	40	NS	0	0	1,544	553	691	3,630	1,156	799
	23	14	1,373	0	0	NS	0	14	3,879	234	435	1,205	460	760
Meroplankton	3	.0,574	4,675	2,284	3,609	NS	352	649	43,720	32,917	21,752	20,273	11,784	14,202
	23	5,272	3,407	1,133	1,428	NS	432	20,515	42,322	23,412	32,129	11,506	7,097	14,338
Holoplankton	3	915	9,393	18,642	60,561	NS	87,124	39,276	121,575	61,765	119,817	122,606	53,061	69,382
	23	9,008	4,554	25,074	113,691	NS	471,386	203,816	55,452	43,274	70,204	42,050	18,777	104,828
Total Microzooplankton	3	21,489	14,068	20,925	64,170	NS	87,475	39,924	165,295	94,682	141,569	142,879	64,845	83,582
	23	14,280	7,962	26,207	115,119	NS	471,818	224,331	97,774	66,686	102,333	53,556	25,874	119,169

[a] Most holoplankton enumerated in this. Densities are not included totals.

Table 3.2-26 The mean density[a] of the dominant (> 5%) forms of macrozooplankton in the intake canal to the Oyster Creek Generating Station at water temperatures below 18 C (October through March) and above 18 C (April through September) from March 1976 through March 1977.

Below 18 C	Mouth South Branch of Forked River	Route 9 Bridge
Neomysis americana	44,056	38,893
Sarsia spp.	26,050	23,328
Rathkea octopunctata	20,553	23,326
Crangon septemspinosa (zoeae)	11,104	9,296
Total Macrozooplankton	120,387	117,388

Above 18 C	Mouth South Branch of Forked River	Route 9 Bridge
Xanthidae zoeae	46,355	88,153
Amphipoda	18,906	26,120
Crangon septemspinosa (zoeae)	11,073	4,305
Neomysis americana	10,398	22,087
Total Macrozooplankton	109,404	169,700

[a] $n/1000\ m^3$

Table 3.2-27 Alphabetical listing by scientific name of all vertebrate species collected by fish and impingement programs from September 1975 through August 1977.

Alosa aestivalis - Blueback herring
Alosa pseudoharengus - Alewife
Alosa sapidissima - American shad
Alutera schoepfi - Orange filefish
Ammodytes sp. - Sand lance
Anchoa hepsetus - Striped anchovy
Anchoa mitchilli - Bay anchovy
Anguilla rostrata - American eel
Apeltes quadracus - Fourspine stickleback
Astroscopus guttatus - Northern stargazer
Bairdiella chrysura - Silver perch
Brevoortia tyrannus - Atlantic menhaden
Bufo fowleri - Fowler's toad
Caranx crysos - Blue runner
Caranx hippos - Crevalle jack
Centropristis striata - Black sea bass
Chaetodipterus faber - Atlantic spadefish
Chaetodon ocellatus - Spotfin butterflyfish
Chasmodes bosquianus - Striped blenny
Chilomycterus schoepfi - Striped burrfish
Clupea harengus - Atlantic herring
Conger oceanicus - Conger eel
Cynoscion regalis - Weakfish
Cyprinodon variegatus - Sheepshead minnow
Dactylopterus volitans - Flying gurnard
Dasyatis sayi - Bluntnose stingray
Dorosoma cepedianum - Gizzard shad
Engraulis eruystole - Silver anchovy
Esox niger - Chain pickerel
Etropus microstomus - Smallmouth flounder
Fistularia tabacaria - Bluespotted cornetfish
Fundulus heteroclitus - Mummichog
Fundulus majalis - Striped killifish
Gasterosteus aculeatus - Threespine stickleback
Gobiosoma bosci - Naked goby
Gobiosoma ginsburgi - Seaboard goby
Hippocampus erectus - Lined seahorse
Hyporhamphus unifasciatus - Halfbeak
Hypsoblennius hentzi - Feather blenny
Lactophys triqueter - Smooth trunkfish
Leiostomus xanthurus - Spot
Lepomis gibbosus - Pumpkinseed
Lucania parva - Rainwater killifish
Lutjanus griseus - Gray snapper
Malaclemys terrapin - Diamondback terrapin
Membras martinica - Rough silverside
Menidia beryllina - Tidewater silverside
Menidia menidia - Atlantic silverside
Menticirrhus saxatilis - Northern kingfish
Micropogon undulatus - Atlantic croaker
Monacanthus hispidus - Planehead filefish
Morone americana - White perch
Morone saxatilis - Striped bass
Mugil cephalus - Striped mullet
Mugil curema - White mullet
Mustelus canis - Smooth dogfish
Mycteroperca microlepis - Gag
Myoxocephalus aenaeus - Grubby
Notemigonus crysoleucas - Golden shiner
Opsanus tau - Oyster toadfish
Paralichthys dentatus - Summer flounder
Peprilus triacanthus - Butterfish
Pomatomus saltatrix - Bluefish
Prionotus carolinus - Northern searobin
Prionotus evolans - Striped searobin
Pseudopleuronectes americanus - Winter flounder
Rachycentron canadum - Cobia
Rissola marginata - Striped cusk-eel
Scophthalmus aquosus - Windowpane
Selar crumenophthalmus - Bigeye scad
Selene vomer - Lookdown
Sphoeroides maculatus - Northern puffer
Sphyraena borealis - Northern sennet
Squalus acanthias - Spiny dogfish
Stenotomus chrysops - Scup
Strongylura marina - Atlantic needlefish
Symphurus plagiusa - Blackcheek tonguefish
Syngnathus fuscus - Northern pipefish
Syngnathus louisianae - Chain pipefish
Synodus foetens - Inshore lizardfish
Tautog onitis - Tautog
Tautogolabrus adspersus - Cunner
Trachinotus falcatus - Permit
Trinectes maculatus - Hogchoker
Urophycis chuss - Red hake
Urophycis regius - Spotted hake
Vomer setapinnis - Atlantic moonfish

Table 3.2-28. Alphabetical listing by common name of all vertebrates collected by fish and impingement programs from September 1975 through August 1977.

Alewife - Alosa pseudoharengus
American eel - Anguilla rostrata
American shad - Alosa sapidissima
Atlantic croaker - Micropogon undulatus
Atlantic herring - Clupea harengus
Atlantic menhaden - Brevoortia tyrannus
Atlantic moonfish - Vomer setapinnis
Atlantic needlefish - Strongylura marina
Atlantic silverside - Menidia menidia
Atlantic spadefish - Chaetodipterus faber
Bay anchovy - Anchoa mitchilli
Bigeye scad - Selar crumenophthalmus
Black sea bass - Centropristis striata
Blackcheek tonguefish - Symphurus plagiusa
Blueback herring - Alosa aestivalis
Bluefish - Pomatomus saltatrix
Bluerunner - Caranx crysos
Bluespotted cornetfish - Fistularia tabacaria
Bluntnose stingray - Dasyatis sayi
Butterfish - Peprilus triacanthus
Chain pickerel - Esox niger
Chain pipefish - Syngnathus louisianae
Cobia - Rachycentron canadum
Conger eel - Conger oceanicus
Crevalle jack - Caranx hippos
Cunner - Tautogolabrus adspersus
Diamondback terrapin - Malaclemys terrapin
Feather blenny - Hypsoblennius hentzi
Flying gurnard - Dactylopterus volitans
Fourspine stickleback - Apeltes quadracus
Fowler's toad - Bufo fowleri
Gag - Mycteroperca microlepis
Gizzard shad - Dorosoma cepedianum
Golden shiner - Notemigonus crysoleucas
Gray snapper - Lutjanus griseus
Grubby - Myoxocephalus aenaeus
Halfbeak - Hyporhamphus unifasciatus
Hogchoker - Trinectes maculatus
Inshore lizardfish - Synodus foetens
Lined seahorse - Hippocampus erectus
Lookdown - Selene vomer
Mummichog - Fundulus heteroclitus
Naked goby - Gobiosoma bosci
Northern kingfish - Menticirrhus saxatilis
Northern pipefish - Syngnathus fuscus
Northern puffer - Sphoeroides maculatus
Northern searobin - Prionotus carolinus
Northern sennet - Sphyraena borealis,
Northern stargazer - Astroscopus guttatus
Orange filefish - Aluterus schoepfi
Oyster toadfish - Opsanus tau
Permit - Trachinotus falcatus
Planehead filefish - Monacanthus hispidus
Pumpkinseed - Lepomis gibbosus
Rainwater killifish - Lucania parva
Red hake - Urophycis chuss
Rough silverside - Membras martinica
Sand lance - Ammodytes sp.
Scup - Stenotomus chrysops
Seaboard goby - Gobiosoma ginsburgi
Sheepshead minnow - Cyprinodon variegatus
Silver anchovy - Engraulis eurystole
Silver perch - Bairdiella chrysura
Smallmouth flounder - Etropus microstomus
Smooth dogfish - Mustelus canis
Smooth trunkfish - Lactophrys triqueter
Spiny dogfish - Squalus acanthias
Spot - Leiostomus xanthurus
Spotfin butterflyfish - Chaetodon ocellatus
Spotted hake - Urophycis regius
Striped anchovy - Anchoa hepsetus
Striped bass - Morone saxatilis
Striped blenny - Chasmodes bosquianus
Striped burrfish - Chilomycterus schoepfi
Striped cusk-eel - Rissola marginata
Striped killifish - Fundulus majalis
Striped mullet - Mugil cephalus
Striped searobin - Prionotus evolans
Summer flounder - Paralichthys dentatus
Tautog - Tautoga onitis
Threespine stickleback - Gasterosteus aculeatus
Tidewater silverside - Menidia beryllina
Weakfish - Cynoscion regalis
White mullet - Mugil curema
White perch - Morone americana
Windowpane - Scophthalmus aquosus
Winter flounder - Pseudopleuronectes americanus

Table 3.2-29 Percent increase (+) or decrease (-) in the mean density of the numerous and important microzooplankton between the mouth of the discharge canal (Sta. 17) and the condenser discharge of the Oyster Creek Generating Station from April through August 1976.

Form	Condenser Discharge	Mouth of Oyster Creek	% Difference
Total microzooplankton	97,413	92,910	- 5
Copepod nauplii	42,187	34,064	- 19
Rotifers	6,385	12,974	+ 103
Acartia clausi	4,338	3,632	- 16
Acartia tonsa	1,463	618	- 57
Acartia spp.	8,504	3,283	- 61
Oithona colcarva	740	1,778	+ 140
Oithona similis	26	0	- 100
Oithona spp.	10,433	2,489	- 76
Paracalanus crassirostris	1,718	8,478	+ 394
Polychaete larvae	6,493	3,738	- 42
Total bivalve larvae	2,064	1,533	- 25
Mulinia lateralis	313	799	+ 155
Barnacle larvae	13,897	3,849	- 72
Gastropod larvae	1,484	2,521	+ 70
Cyphonaute larvae	34	1,240	+3547

Table 3.2-30 Comparison of mean density of common and important macrozooplankton between the intake canal (sta. 6) and discharge canal (50) from March 1976 through March 1977.

		Mean Density (No./1000m³)		
Form	Months Analysed	Intake Canal	Discharge Canal	Percent Difference
Xanthidae zoeae	March 1976, October through March	-	-	-
	April through September	88,153	49,488	-44
Neomysis americana		38,893	13,683	-65
		25,087	1,806	-93
Unidentified Amphipoda	"	2,721	3,164	+14
		18,156	3,643	-80
Sarsia spp.	"	23,328	10,202	-56
		-	-	-
Rathkea octopunctata	"	23,326	3,952	-83
		-	-	-
Crangon septemspinosa zoeae	"	9,296	4,950	-47
		4,305	1,746	-59
Ampelisca spp.		-	-	-
		7,964	580	-93
Oxyurostylis smithi		1,098	87	-92
		6,429	1,118	-83
Palaemonetes spp. zoeae		-	-	-
		1,994	8,600	+77
Polychaete larvae		4,830	1,029	-79
		922	114	-88
Caprellidea		98	15	-85
		3,024	933	-69
Mysidopsis bigelowi	"	919	319	-65
		2,107	550	-74
Leucon americanus		596	595	0
		2,263	1,097	-51
Edotea triloba		101	169	+40
		1,886	295	-84
Mnemiopsis leidyi	"	-	-	-
		430	136	-68
Nereis spp. epitokes	"	-	-	-
		383	107	-72
Callinectes sapidus megalopae		-	-	-
		223	64	-71

Table 3.2-31 Comparison of mean density of common and important ichthyoplankton between the intake canal (sta. 6) and discharge canal (50) from March 1976 through March 1977.

Form	Months Analysed	Mean Density (n/m^3) Intake Canal	Discharge Canal	Percent Difference
Pseudopleuronectes americanus larvae	March 1976, March 1977	14.158	4.394	-69
Ammodytes sp. larvae	"	2.867	1.589	-45
Anchoa mitchilli eggs	May through August 1976	59.632	19.174	-68
Anchoa mitchilli larvae and juveniles	July through October 1976	2.750	1.156	-58
Gobiidae larvae	May through September 1976	0.908	0.530	-42
Syngnathus fuscus juveniles	"	0.357	0.048	-86
Atherinidae larvae and juveniles	"	0.068	0.038	-44

Table 3.2-32 TOTAL NUMBER OF SPECIMENS TAKEN BY 4.9-m TRAWL FROM SEPTEMBER 1975 THROUGH AUGUST 1977 IN BARNEGAT BAY.

SPECIES	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	TOTALS
DASYATIS SAYI	2	-	-	-	-	-	-	-	-	-	5	-	7
ANGUILLA ROSTRATA	15	3	1	2	-	8	11	10	35	26	10	9	130
CONGER OCEANICUS	-	1	-	2	-	-	-	-	-	-	-	-	3
ALOSA AESTIVALIS	-	1	-	32	1	-	16	28	-	1	-	-	79
ALOSA PSEUDOHARENGUS	-	1	-	9	-	-	7	4	-	-	-	-	21
ALOSA SAPIDISSIMA	-	-	-	3	-	-	15	2	-	-	-	-	20
BREVOORTIA TYRANNUS	7	4	55	55	21	9	3	-	1	2	3	9	169
CLUPEA HARENGUS	-	-	-	-	-	-	6	454	33	1	-	-	494
ETRUMEUS TERES	-	-	1	-	-	-	-	-	-	-	-	-	1
ANCHOA HEPSETUS	2	-	-	-	-	-	-	-	-	-	-	-	2
ANCHOA MITCHILLI	4795	10070	3559	539	-	-	129	4776	6081	3607	7193	3188	43937
SYNODUS FOETENS	-	1	2	-	-	-	-	-	-	-	1	-	4
OPSANUS TAU	34	26	17	1	3	1	1	4	9	17	46	44	203
UROPHYCIS REGIUS	-	-	-	-	-	-	4	17	7	-	-	-	28
RISSOLA MARGINATA	9	2	-	3	2	-	-	1	6	1	2	9	35
STRONGYLURA MARINA	1	-	-	-	-	-	-	-	-	-	-	-	1
CYPRINODON VARIEGATUS	-	-	-	-	-	1	-	-	-	-	-	-	1
FUNDULUS HETEROCLITUS	-	2	1	1	1	1	2	1	-	-	-	-	9
LUCANIA PARVA	-	2	-	-	-	-	-	-	-	-	-	-	2
MENIDIA BERYLLINA	-	-	-	-	-	3	-	-	-	-	-	-	3
MENIDIA MENIDIA	2	14	1361	773	9	9	177	41	18	4	9	31	2448
APELTES QUADRACUS	8	4	4	322	170	991	2599	179	36	59	8	4	4384
FISTULARIA TABACARIA	1	-	-	-	-	-	-	-	-	-	-	1	2
HIPPOCAMPUS ERECTUS	2	-	-	1	-	-	-	1	-	1	-	-	5
SYNGNATHUS FUSCUS	8	31	47	48	1	5	37	54	57	37	15	20	360
MORONE AMERICANA	-	1	3	7	-	1	3	-	-	1	-	-	16
CENTROPRISTIS STRIATA	13	7	4	-	-	-	-	-	1	6	1	10	42
POMATOMUS SALTATRIX	4	6	9	12	-	-	-	-	1	5	12	12	61
CARANX HIPPOS	-	2	1	-	-	-	-	-	-	-	53	10	66
SELENE VOMER	19	41	13	2	-	-	-	-	-	-	1	3	79
STENOTOMUS CHRYSOPS	-	2	-	-	-	-	-	-	-	4	-	1	7
BAIRDIELLA CHRYSURA	18	13	-	-	-	-	-	-	-	3	-	2	36
CYNOSCION REGALIS	42	16	4	1	-	-	-	1	3	2	14	185	268
LEIOSTOMUS XANTHURUS	333	101	24	21	-	-	-	7	2	556	1354	514	2912
MENTICIRRHUS SAXATILIS	2	1	-	-	-	-	-	-	-	-	-	1	4
MICROPOGON UNDULATUS	5	5	1	-	-	-	-	-	-	-	-	-	11
CHAETODON OCELLATUS	-	2	-	-	-	-	-	-	-	-	-	-	2
TAUTOGA ONITIS	12	12	15	7	-	6	1	9	9	6	5	9	91
TAUTOGOLABRUS ADSPERSUS	-	1	1	-	-	-	1	-	1	2	-	-	6
SPHYRAENA BOREALIS	-	1	-	-	-	-	-	-	-	-	-	1	2
CHASMODES BOSQUIANUS	3	2	3	1	1	1	-	-	-	-	-	1	12
HYPSOBLENNIUS HENTZI	2	1	1	1	-	-	-	-	-	1	-	1	7
AMMODYTES SP.	-	-	214	192	-	-	28	30	-	-	-	-	464
GOBIOSOMA SP.	-	-	-	-	-	-	1	-	-	-	-	-	1
GOBIOSOMA BOSCI	8	32	17	39	7	14	6	2	3	1	1	4	134
GOBIOSOMA GINSBURGI	1	-	1	3	1	-	1	-	-	-	-	-	7
PEPRILUS TRIACANTHUS	2	1	-	-	-	-	-	-	1	1	1	1	7
PRIONOTUS CAROLINUS	-	-	-	-	-	-	-	-	-	-	-	7	7
PRIONOTUS EVOLANS	11	4	7	-	-	-	-	-	-	-	2	13	37
ETROPUS MICROSTOMUS	5	5	4	15	1	-	-	-	-	-	-	-	30
PARALICHTHYS DENTATUS	1	4	1	1	-	-	-	8	6	8	5	12	46
SCOPHTHALMUS AQUOSUS	-	-	1	1	-	-	1	5	2	-	-	1	11
PSEUDOPLEURONECTES AMERICANUS	11	16	17	59	5	19	85	54	31	272	205	26	800
TRINECTES MACULATUS	13	8	3	2	-	-	13	3	5	6	14	14	81
MONACANTHUS HISPIDUS	-	1	-	-	-	-	-	-	-	-	-	-	1
SPHOEROIDES MACULATUS	5	-	-	-	-	-	-	-	1	3	3	6	18
CRANGON SEPTEMSPINOSA	3	425	845	10556	438	2079	5051	3826	2051	334	66	131	25805
CALLINECTES SAPIDUS	92	133	89	124	24	71	254	267	513	324	386	308	2585
TOTAL SPECIMENS	5491	11005	6326	12835	685	3219	8452	9784	8913	5291	9415	4568	86004
TOTAL TAXA	35	41	33	32	15	16	25	25	25	29	26	33	58
TOTAL COLLECTIONS	64	64	64	64	37	56	64	64	64	64	64	64	733

Table 3.2-33 TOTAL NUMBER OF SPECIMENS TAKEN BY 12.2-m SEINE FROM SEPTEMBER 1975 THROUGH AUGUST 1977 IN BARNEGAT BAY.

SPECIES	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	TOTALS
ANGUILLA ROSTRATA	13	-	-	-	-	-	-	11	3	3	3	6	39
CONGER OCEANICUS	-	-	-	1	-	-	-	-	-	-			1
ALOSA AESTIVALIS	-	-					-	1	-	-	-	-	1
BREVOORTIA TYRANNUS	-	-	-	-	-	-	-	-	-	4	2	1	7
CLUPEA HARENGUS	-	-	-	-	-	-	-	12	5	-	-	-	17
ANCHOA HEPSETUS	98	11	-	-	-	-	-	-	-	-	-	-	109
ANCHOA MITCHILLI	1089	324	315	1	-	-	116	12889	204	641	512	833	16924
SYNODUS FOETENS	-	-	-	-	-	-	-	-	-	-	1	1	2
OPSANUS TAU	14	4	-	-	-	-	-	-	1	12	36	134	201
UROPHYCIS REGIUS	-	-	-	-	-	-	-	1	-	-	-	-	1
RISSOLA MARGINATA	-	4	2	-	-	-	-	1	28	21	8	3	67
STRONGYLURA MARINA	10	-	1	-	-	-	-	-	8	11	41	6	77
CYPRINODON VARIEGATUS	-	2	5	4	1	1	11	9	-	1	-	-	34
FUNDULUS DIAPHANUS	-	-	-	-	-	-	-	1	2	1	-	-	4
FUNDULUS HETEROCLITUS	12	58	59	25	11	28	90	140	20	23	42	45	553
FUNDULUS MAJALIS	-	4	7	22	-	4	4	84	-	2	1	7	135
LUCANIA PARVA	6	3	-	1	-	-	-	1	1	1	-	1	14
MENIDIA BERYLLINA	1	68	-	11	32	92	248	165	22	17	14	4	674
MENIDIA MENIDIA	1799	1188	1935	1533	94	120	2721	3701	364	537	2724	1247	17963
APELTES QUADRACUS	82	72	8	74	22	30	79	19	21	-	18	46	471
GASTEROSTEUS ACULEATUS	-	-	-	-	-	-	-	-	-	1	-	-	1
FISTULARIA TABACARIA	-	-	-	-	-	-	-	-	-	-	-	1	1
HIPPOCAMPUS ERECTUS	-	-	-	1	-	-	-	-	-	-	-	1	2
SYNGNATHUS FUSCUS	27	25	12	4	1	-	12	10	39	13	39	65	247
MORONE AMERICANA	2	1	4	-	-	-	-	2	-	1	-	-	10
CENTROPRISTIS STRIATA	9	-	-	-	-	-	-	-	-	-	-	2	11
LEPOMIS GIBBOSUS	-	4	-	-	-	-	-	-	-	-	-	-	4
POMATOMUS SALTATRIX	1	3	5	-	-	-	-	-	-	16	8	5	38
CARANX HIPPOS	-	7	-	-	-	-	-	-	-	-	87	16	110
SELENE VOMER	4	1	-	-	-	-	-	-	-	-	2	3	10
TRACHINOTUS CAROLINUS	-	-	-	-	-	-	-	-	-	-	3	1	4
TRACHINOTUS FALCATUS	5	3	6	-	-	-	-	-	-	-	7	14	35
LUTJANUS GRISEUS	-	2	-	-	-	-	-	-	-	-	-	-	2
BAIRDIELLA CHRYSURA	2	-	5	-	-	-	-	-	-	-	1	9	17
CYNOSCION REGALIS	1	-	-	-	-	-	-	-	-	-	2	13	16
LEIOSTOMUS XANTHURUS	8	6	1	-	-	-	-	-	23	163	220	56	477
MENTICIRRHUS SAXATILIS	7	7	1	-	-	-	-	-	-	-	-	5	20
MICROPOGON UNDULATUS	-	1	3	1	-	-	-	-	-	-	-	-	5
TAUTOGA ONITIS	1	-	-	-	-	-	-	-	-	-	-	4	5
MUGIL CEPHALUS	3	-	1	-	-	-	-	-	-	1	2	3	10
MUGIL CUREMA	11	8	1	1	-	-	-	10	3	16	5	5	60
ASTROSCOPUS GUTTATUS	-	-	-	-	-	-	-	-	-	-	1	2	3
CHASMODES BOSQUIANUS	1	1	-	-	-	-	-	-	-	-	3	2	7
HYPSOBLENNIUS HENTZI	-	-	-	-	-	-	-	-	-	-	-	2	2
AMMODYTES SP.	-	-	-	1	-	-	2	2	-	-	-	-	5
GOBIOSOMA BOSCI	29	2	1	1	-	-	-	1	6	3	7	15	65
GOBIOSOMA GINSBURGI	-	-	-	-	-	-	-	-	-	-	-	4	4
PRIONOTUS EVOLANS	6	1	1	-	-	-	-	-	-	-	-	5	13
ETROPUS MICROSTOMUS	1	8	1	-	-	-	-	-	-	-	-	-	10
PSEUDOPLEURONECTES AMERICANUS	1	3	1	-	-	-	1	1	15	83	37	23	165
TRINECTES MACULATUS	3	-	-	-	-	-	-	-	-	-	2	-	5
LACTOPHRYS TRIQUETER	-	1	-	-	-	-	-	-	-	-	-	-	1
SPHOEROIDES MACULATUS	1	-	-	-	-	-	-	-	-	-	-	6	7
CRANGON SEPTEMSPINOSA	95	318	1057	4837	390	1354	2886	1212	598	36	370	1000	14153
CALLINECTES SAPIDUS	208	145	37	36	-	-	39	62	143	231	298	547	1746
TOTAL SPECIMENS	3550	2285	3469	6554	551	1629	6209	18335	1506	1838	4496	4143	54565
TOTAL TAXA	32	31	24	17	7	7	12	22	19	24	30	39	55
TOTAL COLLECTIONS	46	46	46	46	30	38	46	46	46	46	46	46	528

Table 3.2-34 TOTAL NUMBER OF SPECIMENS TAKEN BY 45.7-m SEINE FROM SEPTEMBER 1976 THROUGH AUGUST 1977 IN BARNEGAT BAY.

SPECIES	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	TOTALS
ANGUILLA ROSTRATA	-	2	-	-	-	-	1	2	1	10	6	4	26
ALOSA AESTIVALIS	-	-	-	1069	-	-	10	-	9	-	3	-	1091
ALOSA PSEUDOHARENGUS	-	-	-	-	-	-	8	-	9	-	1	-	18
ALOSA SAPIDISSIMA	-	-	-	-	-	-	-	1	-	-	-	-	1
BREVOORTIA TYRANNUS	-	2	15	-	-	-	-	-	1	-	-	1	19
ANCHOA HEPSETUS	-	1	1	-	-	-	-	-	-	-	-	-	2
ANCHOA MITCHILLI	-	3	-	-	-	-	-	86	24	183	24	25	345
SYNODUS FOETENS	1	-	-	-	-	-	-	-	-	-	-	-	1
OPSANUS TAU	-	17	1	-	-	-	1	-	1	3	3	48	74
RISSOLA MARGINATA	-	14	5	1	-	-	-	-	2	1	-	-	23
STRONGYLURA MARINA	-	24	197	-	-	-	-	-	-	2	-	6	229
CYPRINODON VARIEGATUS	-	2	2	4	-	-	-	-	-	-	-	-	8
FUNDULUS HETEROCLITUS	-	6	2	2	1	-	2	9	1	-	2	1	26
FUNDULUS MAJALIS	-	1	2	17	4	-	-	15	-	-	-	-	39
MEMBRAS MARTINICA	-	-	-	-	-	-	-	-	-	1	1	-	2
MENIDIA BERYLLINA	-	2	-	-	-	-	-	-	-	-	-	-	2
MENIDIA MENIDIA	-	55	72	444	2	2	1096	161	185	12	29	28	2086
APELTES QUADRACUS	-	-	-	1	-	-	-	2	5	-	1	1	10
FISTULARIA TABACARIA	-	1	-	-	-	-	-	-	-	-	-	-	1
SYNGNATHUS FUSCUS	-	18	2	-	-	-	-	12	45	15	13	35	140
MORONE AMERICANA	-	3	3	3	-	2	2	3	3	1	-	-	20
CENTROPRISTIS STRIATA	3	28	1	-	-	-	-	-	-	-	-	-	32
POMATOMUS SALTATRIX	-	50	7	-	-	-	-	-	-	32	38	22	149
CARANX CRYSOS	-	5	-	-	-	-	-	-	-	-	-	-	5
CARANX HIPPOS	-	137	-	-	-	-	-	-	-	-	-	1	138
SELAR CRUMENOPHTHALMUS	-	17	-	-	-	-	-	-	-	-	-	-	17
SELENE VOMER	-	4	-	-	-	-	-	-	-	-	1	9	14
BAIRDIELLA CHRYSURA	7	9	13	-	-	-	-	-	-	-	-	2	31
CYNOSCION REGALIS	1	-	-	-	-	-	-	-	-	-	-	-	1
LEIOSTOMUS XANTHURUS	22	64	125	5	-	-	-	1	3	2	216	122	560
TAUTOGA ONITIS	7	17	4	-	-	-	-	-	-	4	3	1	36
MUGIL CEPHALUS	-	5	-	-	-	-	-	-	-	-	-	67	72
MUGIL CUREMA	-	9	-	-	-	-	-	-	-	-	-	42	51
SPHYRAENA BOREALIS	-	1	-	-	-	-	-	-	-	-	-	-	1
ASTROSCOPUS GUTTATUS	-	1	-	-	-	-	-	-	-	-	-	-	1
CHASMODES BOSQUIANUS	3	2	-	-	-	-	-	-	-	-	-	-	5
HYPSOBLENNIUS HENTZI	-	12	-	-	-	-	-	-	-	-	-	-	12
GOBIOSOMA BOSCI	-	1	-	-	-	-	-	-	-	1	-	-	2
PRIONOTUS EVOLANS	-	-	-	-	-	-	-	-	-	-	1	-	1
ETROPUS MICROSTOMUS	-	12	9	5	-	-	-	-	-	-	-	-	26
PARALICHTHYS DENTATUS	-	-	-	-	-	-	-	2	-	3	13	2	20
SCOPHTHALMUS AQUOSUS	-	-	-	-	-	-	-	2	4	2	-	-	8
PSEUDOPLEURONECTES AMERICANUS	3	5	10	17	1	1	13	10	137	387	49	1	634
TRINECTES MACULATUS	-	-	-	-	-	-	-	4	-	-	3	-	7
SYMPHURUS PLAGIUSA	-	-	-	1	-	-	-	-	-	-	-	-	1
SPHOEROIDES MACULATUS	1	-	-	-	-	-	-	-	-	-	2	3	6
CHILOMYCTERUS SCHOEPFI	-	-	-	-	-	-	-	-	-	-	1	-	1
CRANGON SEPTEMSPINOSA	-	5	17	1266	9	16	249	233	61	18	2	31	1907
CALLINECTES SAPIDUS	11	45	25	11	-	-	4	10	25	51	142	85	409
CALLINECTES SIMILIS	-	-	-	-	-	-	-	-	-	-	-	1	1
TOTAL SPECIMENS	59	580	513	2846	17	21	1386	553	516	728	554	538	8311
TOTAL TAXA	10	35	20	14	5	4	10	16	17	18	22	23	50
TOTAL COLLECTIONS	1	12	12	12	4	4	12	12	12	12	12	12	117

Table 3.2-35 TOTAL NUMBER OF SPECIMENS TAKEN BY GILL NET FROM SEPTEMBER 1975 THROUGH AUGUST 1976 IN BARNEGAT BAY.

SPECIES	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	TOTALS
MUSTELUS CANIS	-	-	-	-	-	-	-	-	-	-	-	2	2
ALOSA AESTIVALIS	2	-	4	-	-	1	-	1	-	-	-	-	8
ALOSA PSEUDOHARENGUS	-	-	2	-	-	1	23	12	1	-	-	-	39
BREVOORTIA TYRANNUS	3	24	11	60	-	-	12	42	15	38	36	35	276
CLUPEA HARENGUS	-	-	-	-	-	-	6	-	-	-	-	-	6
MORONE AMERICANA	1	-	-	-	-	1	-	1	-	-	2	-	5
MORONE SAXATILIS	-	-	-	-	-	-	-	1	-	-	-	-	1
POMATOMUS SALTATRIX	21	6	1	-	-	-	-	-	51	4	7	37	127
CARANX HIPPOS	-	-	-	-	-	-	-	-	-	-	-	1	1
BAIRDIELLA CHRYSURA	2	-	-	-	-	-	-	-	-	-	-	-	2
CYNOSCION REGALIS	-	-	-	-	-	-	-	-	13	19	1	-	33
LEIOSTOMUS XANTHURUS	1	-	-	-	-	-	-	-	-	-	23	33	57
MENTICIRRHUS SAXATILIS	2	-	-	-	-	-	-	-	1	-	-	-	3
MICROPOGON UNDULATUS	1	-	-	-	-	-	-	-	-	-	-	-	1
TAUTOGA ONITIS	-	1	-	1	-	-	-	-	-	-	-	-	2
PSEUDOPLEURONECTES AMERICANUS	-	1	-	-	-	-	-	-	-	-	-	-	1
SPHOEROIDES MACULATUS	-	-	-	-	-	-	-	-	-	1	-	-	1
MALACLEMYS TERRAPIN	-	-	-	-	-	-	-	-	-	-	1	-	1
CALLINECTES SAPIDUS	29	4	-	-	-	-	-	2	8	32	52	50	177
TOTAL SPECIMENS	62	36	18	61	0	3	41	59	89	94	122	158	743
TOTAL TAXA	9	5	4	2	0	3	3	6	6	5	7	6	19
TOTAL COLLECTIONS	11	7	7	7	7	7	7	7	7	7	7	7	88

Table 3.2-36 Major species of fishes and macroinvertebrates passed through the dilution pumps, by season, based on the impingement of organisms at the Oyster Creek Generating Station's traveling screens from September 1975 through August 1977.

		Ambient Temp. (C) Range[a]	Delta T (mortality ≥ 30%)
March-June	Alosa aestivalis	2-4,6-14	-, >7.7[c]
	Alosa pseudoharengus	6-8,11-14	-
	Brevoortia tyrannus	5-9	10.9[b]
	Anchoa mitchilli	7-22	9.4[c]
	Menidia menidia	7-14	-
	Syngnathus fuscus	8-13	-
	Crangon septemspinosa	12-20	14[b]
	Callinectes sapidus	16-20,25-29	13.3[c],12.7[c]
July-September	Anchoa mitchilli	18-22	10-10.8[b]
	Pomatomus saltatrix	20-22	10[b]
	Cynoscion regalis	18-25	-
	Leiostomus xanthurus	23-27	-
	Callinectes sapidus	20-27	12.7[c]
October-December	Brevoortia tyrannus	5-10	12-15[b]
	Anchoa mitchilli	11-18	4.5[b]
	Rissola marginata	7-9	-
	Menidia menidia	1-8	>12.1[c]
	Syngnathus fuscus	5-10	>9.8[c]
	Leiostomus xanthurus	6-11	-
	Etropus microstomus	4-7	-
	Callinectes sapidus	12-20	>5.9[c]
January-March	Alosa aestivalis	0-5	-
	Pseudopleuronectes americanus	0,5-8	16.3[b,d]
	Crangon septemspinosa	0,5-7	13.5[b]

a. Ambient temperature during periods of greatest impingement (Tatham et al. 1978a).
b. Based on data reported by Tatham et al. (1978a).
c. Based on data reported by Tatham et al. (1977a).
d. Based on increasing acclimation temperature.

TABLE 3.2-37. Water temperatures and perating conditions of the OCNGS prior to shutdown (January 1970 - August 1977)

OUTAGE DATES	DATE-TIME OF DATA	TEMPERATURE °C (°F) INTAKE	DISCHARGE	ΔT	ELECTRICAL OUTPUT MWe	NO. OF PUMPS IN OPERATION CIRCULATING	DILUTION
<u>1970</u>							
1/31-2/12	1/31	4.4 (40)	14.4 (58)	10.0 (18)	537	4	
4/19-5/21	4/18	15.0 (59)	23.3 (74)	8.3 (15)	532	4	
10/16-10/29	10/16	21.7 (71)	29.4 (85)	7.8 (14)	513	4	
<u>1971</u>							
1/25-1/28	1/25 8^{30}	2.2 (36)	11.7 (53)	9.4 (17)	564	3	-
2/12-2/19	2/12 16^{30}	5.6 (42)	15.0 (59)	9.4 (17)	563	3	-
3/3-3/5	3/3 12^{35}	7.8 (46)	17.2 (63)	9.4 (17)	565	3	-
9/18-11/11	9/17 8^{30}	25.6 (78)	36.1 (97)	10.6 (19)	505	4	1
11/16-11/21	11/16 8^{30}	8.3 (47)	18.9 (66)	10.6 (19)	421	3	1
<u>1972</u>							
1/28-2/2[a]	1/28 00^{30}	1.7 (35)	10.6 (51)	8.9 (16)	370	3	-
5/1-6/20	5/1 20^{30}	18.3 (65)	33.3 (92)	15.0 (27)	600	3	-
8/9-8/15	8/9 2^{30}	26.1 (79)	38.3 (101)	12.2 (22)	630	3	1

TABLE 3.2-37 (Continued).

OUTAGE DATES	DATE-TIME OF DATA	TEMPERATURE °C (°F) INTAKE	DISCHARGE	ΔT	ELECTRICAL OUTPUT MWe	NO. OF PUMPS IN OPERATION CIRCULATING	DILUTION
1972 (Cont.)							
11/11-11/13	11/10 8^{30}	12.8 (55)	24.4 (76)	11.7 (21)	649	4	1
12/29-12/31[a]	12/29 4^{30}	4.4 (40)	16.7 (62)	12.2 (22)	616	4	-
1973							
1/1-1/13	(Outage Continued)						
2/18[a]	2/18 10^{30}	1.1 (34)	11.7 (53)	10.6 (19)	560	4	-
4/14-6/4	4/13 12^{30}	8.9 (48)	21.1 (70)	12.2 (22)	605	4	-
7/21-7/25	7/20 8^{30}	27.8 (82)	40.0 (104)	12.2 (22)	550	4	1
9/8-10/5	9/8 12^{30}	26.1 (79)	37.8 (100)	11.7 (21)	550	4	1
8/8[a]	8/8 12^{30}	28.3 (83)	41.1 (106)	12.8 (23)	605	4	1
* 1974							
1/12-1/20[a]	1/12 00^{30}	1.7 (35)	11.7 (53)	10.0 (18)	450	4	1
3/7-3/11	3/7 04^{30}	11.7 (53)	26.7 (80)	9.4 (17)	630	3	1
4/13-6/29	4/12 20^{30}	14.4 (58)	23.3 (74)	8.9 (16)	605	3	1
10/8-10/15	10/8 00^{30}	13.9 (57)	30.0 (86)	16.1 (29)	596	3	3
11/11-11/15	11/11 14^{30}	10.0 (50)	15.6 (60)	5.6 (10)	150	3	-

* 1970-74 temperature data are daily maximums

TABLE 3.2-38. Known fish at the OCNGS since the initiation of plant operation until present (Roche, 1976 - Revised 1977).

DATE	NUMBER	SPECIES	SIZE RANGE	PROBABLE CAUSE	INTAKE TEMPERATURE °C(°F)
1/29/72	100,000-1,000,000	Atlantic menhaden	76-127 mm	Thermal Shock	1.7 (35) (1230 pm)
1/5-1/8/73	18,000-1,200,000	Atlantic menhaden	102-356 mm	"	5.6 (42) (1800 pm, 1/5)
	20	Bay anchovy	--	"	
2/16-2/21/73	Several Thousand	Atlantic menhaden	--	"	4.4 (40) (1230 am)
8/9/73	2,000-4,000	Atlantic menhaden	127-356 mm	"	28.9 (84) (830 pm)
1/7/74	500	Atlantic menhaden	203-280 mm	Chlorine	3.3 (38) (430 pm)
1/11-1/15/74	9,900-180,000	Atlantic menhaden	102-356 mm	Thermal Shock	1.7 (35) (830 pm)
	100-3,600	Bluefish	228-356 mm	"	
2/4/75	100	Atlantic menhaden	--		3.3 (38) (0030 am)
	50-100	Bluefish	--	"	
11/24/75	7-100	Cravelle jack	--		8.9 (48) (0030 am)
12/29/75	15-100	Atlantic menhaden	100-250 mm	"	2.8 (37) (740 am)
	3-200	Bluefish	90-170 mm	"	
12/27/75	350	Atlantic menhaden	120-150 mm	pH	2.2 (36) (1000 pm)
10/21/77	120-200	Blue runner Cravelle jacks		Thermal Shock	12.2 (54) (1 am)

TABLE 3.2-39. Number of Atlantic menhaden caught in 13 trawl surveys, August 1972 to January 1974 (Wurtz, 1974).

Station	Temperature Range At Intake Canal °C (°F)[1]	Rt. 9 Bridge In Oyster Creek	Mouth Of Oyster Creek	Forked River West Of Mouth[2]	Intake Canal[2]	Stouts Creek (Control)
1972						
Aug 31-Sept 1	26.7-27.8 (80-82)	0	0	0	0	0
Sept 29-30	21.1-22.3 (70-73)	0	0	0	0	0
Oct 24-25	13.3-15 (56-59)	0	0	0	0	0
Nov 6, 13, 15-17	8.9-11.1 (48-52)	0	0	4	0	0
Dec 27-28	6.1-6.7 (43-44)	205	2	0	0	0
1973						
Jan 25-26	5.0-5.6 (41-42)	3	1	0	0	0
Apr 9-10	11.1-13.3 (52-56)	58	80	47	1	13
May 30-31	18.9-21.7 (66-71)	1	1	0	0	1
Jul 30-31	26.7 (80)	7	0	1	0	1
Sept 27-28	18.9 (66)	1	2	4	0	0
Oct 30-31	12.8-13.9 (55-57)	2	1	0	2	13
Nov 29-30	8.9-12.8 (48-55)	5	1	0	0	0
1974						
Jan 24-25	5.0-5.6 (41-42)	1	7	0	0	0
TOTAL (465)		283	95	56	3	28

[1] These temperatures are considered ambient temperatures
[2] Area affected by recirculation of thermal plume 5 percent of time or less (Woodward-Clyde, 1975).

TABLE 3.2-40. Actual number of Atlantic menhaden collected from OCNGS intake screens, Barnegat Bay, Forked River and Oyster Creek from September 1975 through August 1976 (Ichthyological Associates, 1977).

1975	Mean Intake Temperature °C(°F)	OCNGS	Barnegat Bay	Forked River	Oyster Creek	Total
September	20.1 (68.2)	5	0	3	0	8
October	16.4 (61.5)	3	18	5	1	27
November	11.8 (53.2)	24	9	1	2	36
December	4.4 (39.9)	2903	0	2	65	2970
1976						
January[2]	0.6 (33.0)	0	0	0	1	1
February	4.1 (39.4)	0	0	0	0	0
March	8.9 (48.0)	27	3	0	10	40
April	14.3 (57.7)	287	15	11	16	329
May	20.0 (68.0)	290	15	1	0	306
June	25.8 (78.4)	222	27	3	13	265
July	26.7 (80.0)	1447	31	7	3	1488
August	26.6 (79.9)	156	30	6	7	199
Total		5364	148	39	118	5669

[1] Intake temperature considered ambient bay temperature.

[2] OCNGS shutdown Dec. 27, 1975 - Mar. 3, 1976.

TABLE 3.2-41. The relationship between the number of fish killed during an outage at OCNGS and the duration of temperature decrease at the U.S. Route 9 bridge (Oyster Creek) to ambient temperature (intake temperature).

Date	Maximum number of fish killed	Ambient temperature °C(°F)	Duration of temperature decrease at the Rt. 9 bridge to ambient temperature (hours)
1-5 to 1-8-73 (12-29-72)	1.2×10^6	(40 --- 35)[1] 4.4 ---1.7	11
1-29-72 (1-28)	1.0×10^6	1.7 (35)[2]	11[3]
1-11 to 1-15-74	1.8×10^5	1.7 (35)	8 1/4
2-16 to 2-21-73 (2-18)	5.0×10^2	1.1 (34)[4]	16
12-27-75	4.0×10^2	2.2 (36)	8
12-19-75	3.0×10^2	5.6 (42)	9
2-4-75	2.0×10^2	3.3 (38)	16
10-21-77[5]	2.0×10^2	12.2 (54)	10.5
11-24-75	1.0×10^2	8.9 (48)	13

1 Air temperature dropped from 30°F to 15°F in 26 h (1-7 to 1-8).

2 Air temperature dropped from 30.4°F to 10.7°F in 42 h (12-27 to 12-29-72).

3 D. R. Weigle (personal communication 9-30-77).

4 Air temperature dropped from 47°F to 11°F in 48 h (2-15 to 2-17-73).

5 Fish killed were blue runner and cravelle jacks - (<u>Caranx</u> sp.)
All other fish kills involved Atlantic menhaden (almost exclusively - Table 3.2-38).

Table 3.2-42 Catch (n/coll) of the ten most abundant fishes taken Marcellus (1972) at his Station 3. Forked River mouth.

Species	1969 Nov 29	1969 Dec 5	1970 eb 18	eb 25	Mar 10	Mar 25	Apr 10	Apr 29	May 15	May 28	Jun 11	Jun 30	Jul 14	Aug 4	Aug 28	ep 11	ep 28	Oct 8
Clupea harengus	-	0.1	-	-	-	-	10.3	-	2.4	0.3	-	-	-	-	-	-	-	-
Anchoa mitchilli	-	-	-	-	-	-	-	-	8.6	180.3	122.0	10.4	5.4	-	27.7	0 9	9.9	-
Fundulus heteroclitus	-	-	0.1	0.7	-	-	0.6	1.1	1.1	0.4	4.0	0.6	0.4	-	-	-	0.1	-
Menidia beryllina	-	-	0.1	-	0.3	0.9	14.4	1.1	0.6	0.1	4.3	0.9	-	-	-	-	-	-
Menidia menidia	3.3	27.1	1.1	-	0.1	-	10.0	19.7	7.7	10.4	47.3	135.9	15.4	5.4	13.6	31.9	13.9	51.7
Apeltes quadracus	0.4	0.6	-	1.6	0.1	-	1.0	3.0	2.3	1.9	4.1	4.9	1.9	-	0.3	1.1	0.1	0.6
Syngnathus fuscus	-	-	-	-	-	-	0.7	2.6	4.9	3.1	0.6	-	1.0	1.6	0.9	0.3	0.1	0.4
Bairdiella chrysura	-	-	-	-	-	-	-	-	-	0.4	-	0.4	-	8.7	13.4	7.1	10.4	46.7
Pseudopleuronectes americ n s	-	-	-	-	-	-	-	-	-	0.1	0.1	-	-	-	-	-	-	-
Sphoeroides maculatus	-	-	-	-	-	-	-	-	-	0.1	0.3	0.4	-	0.4	-	0.1	0.1	-

Table 3.2-43 Catch (n/coll) of the ten most abundant fishes taken by Marcellus (1972) at his Station 5. Oyster Creek mouth, New Jersey.

Species	1969 Dec 5	1970 Feb 18	Feb 25	Mar 10	Mar 25	Apr 10	Apr 29	May 15	May 28	Jun 11	Jun 30	Jul 14	Jul 29	Aug 4	Aug 28	Sep 11	Sep 28	Oct 3
Clupea harengus	0.1	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Anchoa mitchilli	-	-	-	-	-	-	-	3.6	4.4	-	0.4	0.7	2.3	2.6	0.3	-	-	-
Fundulus heteroclitus	0.3	-	26.9	-	28.9	0.3	1.7	0.1	0.1	-	-	0.1	0.4	-	0.3	-	-	0.1
Menidia beryllina	-	-	41.4	22.7	257.3	6.1	0.6	-	0.3	2.0	0.7	-	-	-	-	-	-	-
Menidia menidia	149.9	36.7	58.4	4.3	33.4	140.4	56.7	1.9	2.0	100.9	125.4	31.3	9.7	3.4	3.1	-	0.3	0.7
Apeltes quadracus	0.1	0.4	0.7	0.3	0.1	-	0.1	-	-	-	-	-	-	-	-	-	-	-
Syngnathus fuscus	-	-	-	-	-	0.1	0.3	-	1.0	0.1	0.1	0.7	1.4	0.3	0.4	0.1	-	-
Bairdiella chrysura	-	-	-	-	-	-	-	-	-	-	0.3	-	8.4	-	-	0.4	-	-
Pseudopleuronectes americanus	0.1	-	-	-	-	0.6	0.1	-	0.1	-	-	-	-	-	-	-	-	-
Sphoeroides maculatus	-	-	-	-	-	-	-	0.1	-	0.1	0.3	-	-	-	0.1	-	-	-

Table 3.2-44 Catch (n/coll) of the ten most abundant fishes taken by Marcellus (1972) at his Station 7, Sands Point Harbor, New Jersey.

	1969		1970																
	Nov	Dec	Feb	Feb	Mar	Mar	Apr	Apr	May	May	Jun	Jun	Jul	Jul	Aug	Aug	Sep	Sep	Oct
Species	23	5	12	25	10	25	10	29	14	28	15	30	15	28	4	26	10	28	8
Clupea harengus	-	0.3	-	-	-	-	1.3	-	-	-	-	-	-	-	-	-	-	-	-
Anchoa mitchilli	-	-	-	-	-	-	-	-	-	-	4.0	0.1	-	-	55.4	-	-	0.1	-
Fundulus heteroclitus	0.3	0.1	-	-	-	0.1	0.3	0.1	0.1	-	-	-	-	-	0.3	-	-	0.1	-
Menidia beryllina	0.3	-	0.7	0.7	-	-	-	-	-	-	0.3	0.1	-	-	-	-	-	-	-
Menidia menidia	0.4	0.3	2.3	2.4	0.1	0.8	4.9	0.1	-	8.6	3.6	25.3	37.0	38.1	38.7	1.4	1.9	-	6.9
Apeltes quadracus	0.3	0.6	0.3	0.1	0.1	-	0.1	0.3	-	0.1	0.6	-	0.1	-	1.6	-	0.4	-	0.7
Syngnathus fuscus	-	-	-	-	-	0.1	0.6	0.7	1.6	2.3	0.3	0.3	1.4	2.9	0.7	4.6	2.0	1.0	0.7
Bairdiella chrysura	-	-	-	-	-	-	-	-	0.3	-	-	-	0.1	1.3	3.4	0.1	-	-	2.0
Pseudopleuronectes americanus	0.3	-	-	-	-	0.1	0.3	0.3	0.1	-	-	0.4	-	-	-	0.1	0.6	-	0.3
Sphoeroides maculatus	-	-	-	-	-	-	-	-	-	3.3	1.3	2.4	-	0.1	-	-	-	-	0.7

Table 3.2-45 Cat h (n/coll) f the t n most abundant fishes ta by M el us (1972) at h s Station 8, D ible Cr ew J sey

	1		1970										
	Nov	Dec	Feb	Feb	[illegible]ar	Mar	Jun	Ju	Jul	Jul	Aug	Aug	[illegible]ep
Species	23	5	12	27	10	25	15		15	23	4	31	14
Clupea harengus	-	-	-	-	-	-	-		-	-	-	-	-
Anchoa mitchilli	-	-	-	-	-	-	-		-	-	-	-	-
Fundulus heteroclitus	0.7	-	-	-	0.7	0.1	3.1	1.1	1.1	0.4	0.1	-	-
Menidia beryllina	-	0.3	0.6	0.1	11.7	0.3	0.3	0.1	-	-	-	-	-
Menidia menidia	-	0.3	0.6	0.3	2.9	0.4	75.1	268.6	69.9	22.9	41.9	7.1	1 7.4
Apeltes quadracus	1.3	1.3	0.1	0.1	1.4	0.6	26.7	24.0	16.9	18.0	2.0	3.4	4.4
Syngnathus fuscus	-	-	-	-	-	-	1.4	5.6	7.6	5.0	2.7	3.9	2.6
Bairdiella chrysura	-	-	-	-	-	-	-	0.1	1.9	2.0	-	-	-
Pseudopleuronectes american s	-	-	-	-	-	-	-	0.9	0.1	0.3	-	-	-
Sphoeroides maculatus	-	-	-	-	-	-	1.1	3.3	1.4	3.9	0.9	0.4	-

Table 3.2-46 Catch (n/coll) of the most abundant fishes taken by seine at I. A. Station 4, Forked River mouth, New Jersey from September 1975 through August 1977.

	1975							1976								
Species	Sep 23	Oct 8	Oct 20	Nov 4	Nov 17	Dec 4	Dec 15	Jan 29	Feb 13	Feb 25	Mar 10	Mar 24	Apr 14	Apr 30	May 14	May 28
Anchoa mitchilli	72.0	-	21.0	-	-	-	-	-	-	-	-	-	-	-	0.5	-
Fundulus heteroclitus	-	-	0.5	-	-	-	-	-	-	0.5	-	6.0	6.0	6.0	-	0.5
Menidia beryllina	-	-	-	-	-	-	-	-	0.5	-	-	27.5	5.5	1.0	0.5	1.5
Menidia menidia	2.0	21.0	32.5	6.0	4.5	-	31.5	0.5	1.0	1.5	1.5	158.5	5.5	5.5	4.5	8.0
Apeltes quadracus	-	-	-	-	-	-	-	-	0.5	-	-	0.5	-	-	-	-
Syngnathus fuscus	0.5	0.5	0.5	-	-	-	-	-	-	-	-	1.0	-	-	-	-
Leiostomus xanthurus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pseudopleuronectes americanus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

able 3.2-46 (cont.)

	1976										1977					
Species	Jun 9	Jun 23	Jul 14	Jul 26	Aug 4	Aug 18	Sep 21	Oct 19	Nov 9	Dec 16	Mar 7	Apr 14	May 5	Jun 13	Jul 20	Aug 9
Anchoa mitchilli	28.5	21.0	1.0	4.5	4.0	0.5	1.5	0.5	-	-	-	-	-	-	1.5	38.5
Fundulus heteroclitus	-	-	-	3.5	4.5	-	-	7.0	-	-	-	10.5	0.5	-	-	-
Menidia beryllina	-	-	-	-	-	-	-	2.5	-	-	0.5	4.5	-	-	-	-
Menidia menidia	6.0	16.0	17.5	51.0	16.5	21.5	4.5	3.5	-	-	-	2.0	-	-	4.5	166.0
Apeltes quadracus	-	-	-	-	0.5	-	-	-	0.5	-	-	1.0	-	-	0.5	-
Syngnathus fuscus	0.5	-	-	-	-	-	1.5	0.5	-	-	-	0.5	3.0	-	1.5	2.5
Leiostomus xanthurus	1.5	11.5	0.5	5.5	2.0	-	1.5	-	-	-	-	-	-	-	3.0	-
Pseudopleuronectes americanus	0.5	-	-	0.5	1.0	-	0.5	-	-	-	-	-	-	16.5	-	-

Table 3.2-47 Catch (n/coll) of the most abundant fishes taken by seine at I. A. 17, Oyster Creek mouth, New Jersey from September 1975 through August 1977.

	1975								1976									
Species	Sep 11	Sep 23	Oct 8	Oct 20	Nov 4	Nov 17	Dec 4	Dec 15	Jan 7	Jan 29	Feb 13	Feb 25	Mar 10	Mar 24	Apr 14	Apr 30	May 14	May 28
Anchoa mitchilli	-	-	-	73.0	153.0	-	-	-	-	-	-	-	-	-	4372.0	11.0	1.5	1.0
Fundulus heteroclitus	1.0	-	-	0.5	-	0.5	-	0.5	-	0.5	-	1.0	-	-	-	-	-	0.5
Menidia beryllina	-	-	-	-	-	-	-	-	-	2.0	5.0	2.5	0.5	24.0	4.0	1.5	-	1.0
Menidia menidia	25.0	1.0	9.0	0.5	21.5	42.0	115.5	20.5	-	14.5	0.5	20.5	-	222.0	1050.5	532.5	4.5	1.0
Apeltes quadracus	-	0.5	-	-	-	-	-	2.0	-	4.0	0.5	1.5	0.5	0.5	-	0.5	-	-
Syngnathus fuscus	-	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0	1.0	-
Leiostomus xanthurus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pseudopleuronectes americanus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3.2-47 (cont.)

	1976										1977							
Species	Jun 9	Jun 23	Jul 14	Jul 26	Aug 4	Aug 18	Sep 21	Oct 19	Nov 9	Dec 16	Jan 25	Feb 14	Mar 7	Apr 14	May 5	Jun 13	Jul 20	Aug 9
Anchoa mitchilli	0.5	-	3.0	12.5	0.5	8.0	0.5	0.5	-	-	-	-	-	-	-	-	[illegible]	-
Fundulus heteroclitus	-	-	1.5	-	-	5.0	-	1.5	-	-	-	0.5	-	2.0	0.5	0.5	-	0.5
Menidia beryllina	-	-	-	-	-	-	-	1.5	-	-	-	0.5	-	7.0	-	-	-	-
Menidia menidia	18.0	0.5	64.0	11.0	9.0	7.5	-	2.0	38.5	23.0	-	0.5	-	0.5	0.5	-	93.0	20.0
Apeltes quadracus	-	-	-	1.0	-	1.0	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus fuscus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.5
Leiostomus xanthurus	4.5	1.5	-	3.0	-	0.5	-	-	-	-	-	-	-	-	-	-	-	0.5
Pseudopleuronectes americanus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.0	-	-

Table 3.2-48 Catch (n/coll) of the most abundant fishes taken by seine at I. A. Station 20, Sands Point Harbor, New Jersey from September 1975 through August 1976.

	1975							
Species	Sep 11	Sep 23	Oct 8	Oct 20	Nov 4	Nov 17	Dec 4	Dec 15
Anchoa mitchilli	-	231.0	-	4.5	-	-	-	-
Fundulus heteroclitus	-	-	-	2.5	-	10.0	-	-
Menidia beryllina	-	-	-	-	-	-	-	1.5
Menidia menidia	116.0	12.0	40.0	21.5	33.5	154.5	8.5	66.0
Apeltes quadracus	-	1.0	-	0.5	-	1.5	-	4.0
Syngnathus fuscus	1.5	-	2.0	-	-	-	-	-
Leiostomus xanthurus	-	-	-	-	-	-	-	-
Pseudopleuronectes americanus	-	-	-	-	-	-	-	-

Table 3.2-48 (cont.)

	1976														
Species	Jan 29	Feb 13	Feb 25	Mar 10	Mar 24	Apr 14	Apr 30	May 14	May 28	Jun 9	Jun 23	Jul 14	Jul 26	Aug 4	Aug 18
Anchoa mitchilli	-	-	-	-	-	1.0	0.5	0.5	2.5	6.0	-	28.5	-	-	84.0
Fundulus heteroclitus	-	-	-	-	3.5	-	1.0	-	-	-	-	-	1.5	2.5	-
Menidia beryllina	6.5	3.5	2.0	0.5	3.0	21.0	2.0	-	3.0	1.5	-	-	4.5	-	-
Menidia menidia	2.5	0.5	-	0.5	62.5	27.0	5.5	2.5	3.0	1.0	9.0	26.5	68.0	69.5	49.0
Apeltes quadracus	-	-	-	-	-	1.5	0.5	1.5	-	-	-	0.5	-	-	0.5
Syngnathus fuscus	-	-	-	-	-	-	1.0	2.5	-	1.0	1.0	1.0	0.5	4.0	1.0
Leiostomus xanthurus	-	-	-	-	-	-	-	-	-	1.0	7.0	24.9	2.5	3.5	-
Pseudopleuronectes americanus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3.2-49 Catch (n/coll) of the most abundant fishes taken by seine at I. A. 23, Double Creek mouth, New Jersey from September 1975 through August 1977.

Species	1975 Sep 11	1975 Sep 23	1975 Oct 8	1975 Oct 20	1975 Nov 4	1975 Nov 17	1975 Dec 4	1975 Dec 15	1976 Jan 7	1976 Jan 29	1976 Feb 13	1976 Feb 25	1976 Mar 10	1976 Mar 24	1976 Apr 14	1976 Apr 30
Anchoa mitchilli	-	18.5	-	8.0	-	-	-	-	-	-	-	-	-	-	-	-
Fundulus heteroclitus	-	4.0	-	-	-	0.5	-	1.5	-	-	-	-	-	3.0	8.0	0.5
Menidia beryllina	-	-	-	-	-	-	-	-	-	-	0.5	-	-	16.0	6.5	2.0
Menidia menidia	76.0	2.0	78.0	5.0	261.5	2.5	0.5	0.5	-	0.5	1.0	-	1.0	8.0	19.5	56.0
Apeltes quadracus	1.0	37.0	-	32.0	-	0.5	-	2.0	-	-	-	-	1.5	0.5	0.5	-
Syngnathus fuscus	-	-	0.5	2.0	0.5	-	-	-	-	-	-	-	0.5	-	0.5	-
Leiostomus xanthurus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pseudopleuronectes americanus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3.2-49 (cont.)

Species	1976 May 14	1976 May 28	1976 Jun 9	1976 Jun 23	1976 Jul 14	1976 Jul 26	1976 Aug 4	1976 Aug 18	1976 Oct 19	1976 Nov 9	1976 Dec 16	1977 Mar 7	1977 Apr 14	1977 May 5	1977 Jun 13	1977 Jul 20	1977 Aug 9
Anchoa mitchilli	-	-	1.0	3.0	16.5	1.0	-	46.0	-	-	-	-	-	-	-	1.5	-
Fundulus heteroclitus	-	3.5	-	0.5	-	1.5	-	-	3.5	-	0.5	1.5	12.0	0.5	0.5	2.0	-
Menidia beryllina	-	2.0	-	5.0	-	-	-	-	28.0	-							
Menidia menidia	0.5	3.5	14.5	31.5	49.5	28.0	29.5	16.0	0.5	-			9.5	-	-	60.0	53.0
Apeltes quadracus	3.0	4.0	-			2.0	-	8.0	-	-	0.5				-	-	-
Syngnathus fuscus	0.5	2.0	-	-	1.5	2.0	1.5	4.5	-						-	0.5	2.5
Leiostomus xanthurus			2.0	11.5	10.0	6.5	3.5	10.5	-						-	-	-
Pseudopleuronectes americanus	-	-	-	-	1.5	1.0	3.0	3.0	-						0.5	-	-

Table 3.2-50 Annual mean number per collection, per cent of total catch, and rank of fishes commonly taken by seine from November 1966 through October 1970 (Marcellus 1972) and from September 1975 through August 1977.

	Forked River Mouth																	
	1966 - 1967			1967 - 1968			1968 - 1969			1969 - 1970			1975 - 1976			1976 - 1977		
	n/coll	%	rank	n/coll	%	rank	n/coll	%	rank	n/coll	%	rank	n/coll	%	rank	n/coll	%	rank
Anchoa mitchilli	22.0	20.0	3	23.5	22.0	3	53.1	34.3	1	20.3	37.0	2	7.0	22.8	2	4.2	30.7	1
Fundulus heteroclitus	0.2	0.2	9	0.4	0.4	9	0.2	0.1	12	0.5	0.9	9	1.3	4.1	4	1.8	13.1	3
Menidia beryllina	a	a	a	30.3	28.5	2	1.4	0.9	7	1.3	2.3	5	1.7	5.4	3	0.8	5.5	6
Menidia menidia	28.1	25.5	2	33.1	31.1	1	52.3	33.8	2	21.9	40.0	1	18.8	61.5	1	2.6	19.0	2
Apeltes quadracus	32.5	29.5	1	12.1	11.4	4	9.2	5.9	4	1.3	2.4	4	0.1	0.2	9.5	0.2	1.5	8
Syngnathus fuscus	2.4	2.1	7	2.5	2.4	5	1.7	1.1	6	0.9	1.6	6	0.2	0.5	7	0.9	6.2	5
Bairdiella chrysura	10.1	9.1	4	2.0	1.9	6	32.3	20.8	3	5.6	10.2	3	< 0.1	< 0.1	18	-	-	-
Leiostomus xanthurus	-	-	-	-	-	-	-	-	-	-	-	-	1.0	3.1	5	0.5	3.3	7
Pseudopleuronectes americanus	0.3	0.3	8	0.1	0.1	12	0.2	0.1	11	< 0.1	< 0.1	21	0.1	0.3	8	1.7	12.4	4
Sphoeroides maculatus	3.3	3.0	6	0.3	0.3	10	0.6	0.4	8	0.1	0.1	15	-	-	-	-	-	-
All fishes	110.3	-	-	106.5	-	-	154.8	-	-	54.8	-	-	30.5	-	-	13.7	-	-

Table 3.2-50 (cont.)

	Oyster Creek Mouth																	
	1966 - 1967			1967 - 1968			1968 - 1969			1969 - 1970			1975 - 1976			1976 - 1977		
	n/coll	%	rank	n/coll	%	rank	n/coll	%	rank	n/coll	%	rank	n/coll	%	rank	n/coll	%	rank
Anchoa mitchilli	4.9	5.2	4	3.9	10.4	3	22.1	30.0	2	0.8	1.1	7	193.2	66.1	1	0.6	3.0	4
Fundulus heteroclitus	0.6	0.7	9	1.3	3.5	5	0.8	1.1	6	3.3	4.4	3	0.5	0.2	8	0.4	2.1	5
Menidia beryllina	a	a	a	1.1	2.8	7	0.8	1.1	5	18.6	24.8	2	1.7	0.6	3	0.8	3.8	3
Menidia menidia	54.9	57.9	1	19.2	51.8	1	40.6	44.1	1	42.8	56.8	1	91.3	31.2	2	15.1	77.2	1
Apeltes quadracus	9.6	10.1	3	5.6	15.1	2	3.4	4.6	3	0.1	0.1	14	0.5	0.2	7	-	-	-
Syngnathus fuscus	1.1	1.2	7	0.9	2.5	9	0.8	1.1	7	0.3	0.4	10	0.1	< 0.1	14	0.1	0.4	11.5
Bairdiella chrysura	4.1	3.4	5	0.3	0.7	11	2.4	3.2	4	0.5	0.7	8	< 0.1	< 0.1	25	-	-	-
Leiostomus xanthurus	< 0.1	0.1	21	-	-	-	-	-	-	-	-	-	0.4	0.1	10	< 0.1	0.2	14.5
Pseudopleuronectes americanus	1.2	1.3	6	1.2	3.3	6	0.8	1.0	8	0.1	0.1	16	-	-	-	1.1	5.7	2
Sphoeroides maculatus	14.0	14.8	2	1.3	3.6	4	0.4	0.5	9	< 0.1	< 0.1	18	< 0.1	< 0.1	25	< 0.1	0.2	14.5
All fishes	94.9	-	-	37.0	-	-	73.7	-	-	75.4	-	-	292.3	-	-	19.6	-	-

Table 3.2-50 (cont.)

	Sands Point Harbor																	
	1966 - 1967			1967 - 1968			1968 - 1969			1969 - 1970			1975 - 1976			1976 - 1977		
	n/coll	%	rank	n/coll	%	rank	n/coll	%	rank	n/coll	%	rank	n/coll	%	rank	n/coll	%	rank
Anchoa mitchilli	8.4	8.7	3	1.3	2.0	6	50.9	41.4	1	3.1	20.3	2	15.6	27.6	2		Not Sampled	
Fundulus heteroclitus	2.1	2.2	4	0.4	0.5	10	0.5	0.4	10	0.1	0.7	8	1.3	2.3	5			
Menidia beryllina	a	a	a	10.8	16.6	3	10.1	8.2	3	0.1	0.7	8	2.1	3.8	3			
Menidia menidia	64.1	66.7	1	28.0	43.2	1	46.4	37.7	2	9.1	58.7	1	33.9	60.0	1			
Apeltes quadracus	17.2	17.9	2	17.1	26.3	2	5.4	4.4	4	0.3	1.8	6	0.5	0.9	7			
Syngnathus fuscus	1.4	1.4	5	1.4	2.2	5	1.9	1.6	6	1.0	6.5	3	0.7	1.1	6			
Bairdiella chrysura	0.8	0.8	6	0.2	0.3	11	4.5	3.6	5	0.4	2.4	5	< 0.1	< 0.1	17.5			
Leiostomus xanthurus	< 0.1	< 0.1	21	-	-	-	-	-	-	-	-	-	1.7	3.0	4			
Pseudopleuronectes americanus	0.2	0.3	9	2.3	3.6	4	1.3	1.1	7	0.1	0.9	7	-	-	-			
Sphoeroides maculatus	0.2	0.2	10	0.9	1.3	8	0.6	0.5	8	0.4	2.7	4	0.1	0.1	11			
All fishes	96.1	-	-	64.9	-	-	122.9	-	-	15.5	-	-	56.4	-				

Table 3.2-50 (cont.)

	Double Creek Mouth																	
	1966 - 1967			1967 - 1968			1968 - 1969			1969 - 1970			1975 - 1976			1976 - 1977		
	n/coll	%	rank	n/coll	%	rank	n/coll	%	rank	n/coll	%	rank	n/coll	%	rank	n/coll	%	rank
Anchoa mitchilli	0.3	0.3	11	1.6	2.3	6	0.1	0.1	11	-	-	-	3.9	8.9	2	0.2	0.8	8
Fundulus heteroclitus	1.4	1.5	6	2.3	3.2	4	0.6	0.6	17	0.6	1.0	7	0.9	2.0	6	2.3	8.7	4
Menidia beryllina	a	a	a	2.6	3.6	3	6.0	6.1	3	1.0	1.7	5	1.3	3.0	5	3.1	11.9	3
Menidia menidia	54.3	59.5	1	28.9	40.5	2	78.9	80.2	1	47.5	76.1	1	30.0	68.4	1	14.3	54.9	1
Apeltes quadracus	22.4	24.5	2	29.0	40.6	1	7.2	7.3	2	7.7	12.3	2	3.8	8.6	3	0.1	0.2	9.5
Syngnathus fuscus	1.0	1.1	7	1.2	1.7	7	1.3	1.3	5	2.2	3.5	3	0.8	1.9	7	0.3	1.3	6
Bairdiella chrysura	3.5	3.8	4	0.1	0.2	14	0.1	0.1	10	0.3	0.5	8	-	-	-	-	-	-
Leiostomus xanthurus	-	-	-	-	-	-	-	-	-	-	-	-	1.6	3.7	4			
Pseudopleuronectes americanus	0.3	0.3	9	2.2	3.1	5	2.1	2.1	4	0.1	0.2	11	0.4	0.8	8	0.1	0.2	9.5
Sphoeroides maculatus	4.1	4.5	3	0.1	0.1	9	0.8	0.8	6	1.6	2.6	4	-	-				
All fishes	91.3	-	-	71.4	-	-	98.4	-	-	62.4	-	-	43.8	-		26.1		

[a] Marcellus (1972) noted that he misidentified M. beryllina as M. menidia during the first six months of study, resulting in an underestimate of the former and an overestimate of the latter in 1966-67.

FIGURE 3.2-1. Phytoplankton sampling stations of Mountford (1969b, 1971) and Loveland and others (1969, 1970, 1971, 1972).

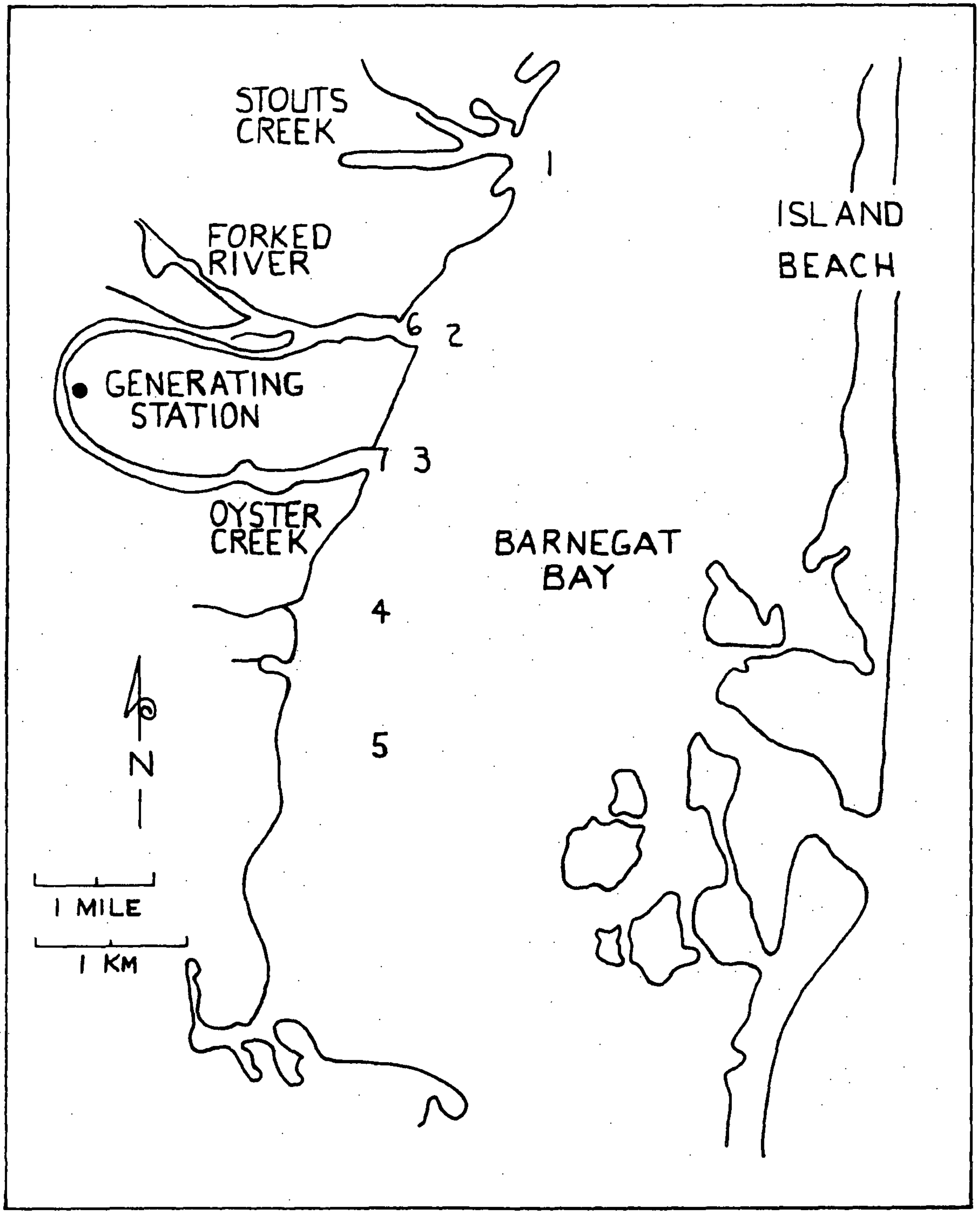

STOUTS CREEK
1
FORKED RIVER
ISLAND BEACH
6
2
GENERATING STATION
7
3
OYSTER CREEK
BARNEGAT BAY
4
5
N
1 MILE
1 KM

FIGURE 3.2-1

FIGURE 3.2-2. Diatom sampling stations of Hein (1977).

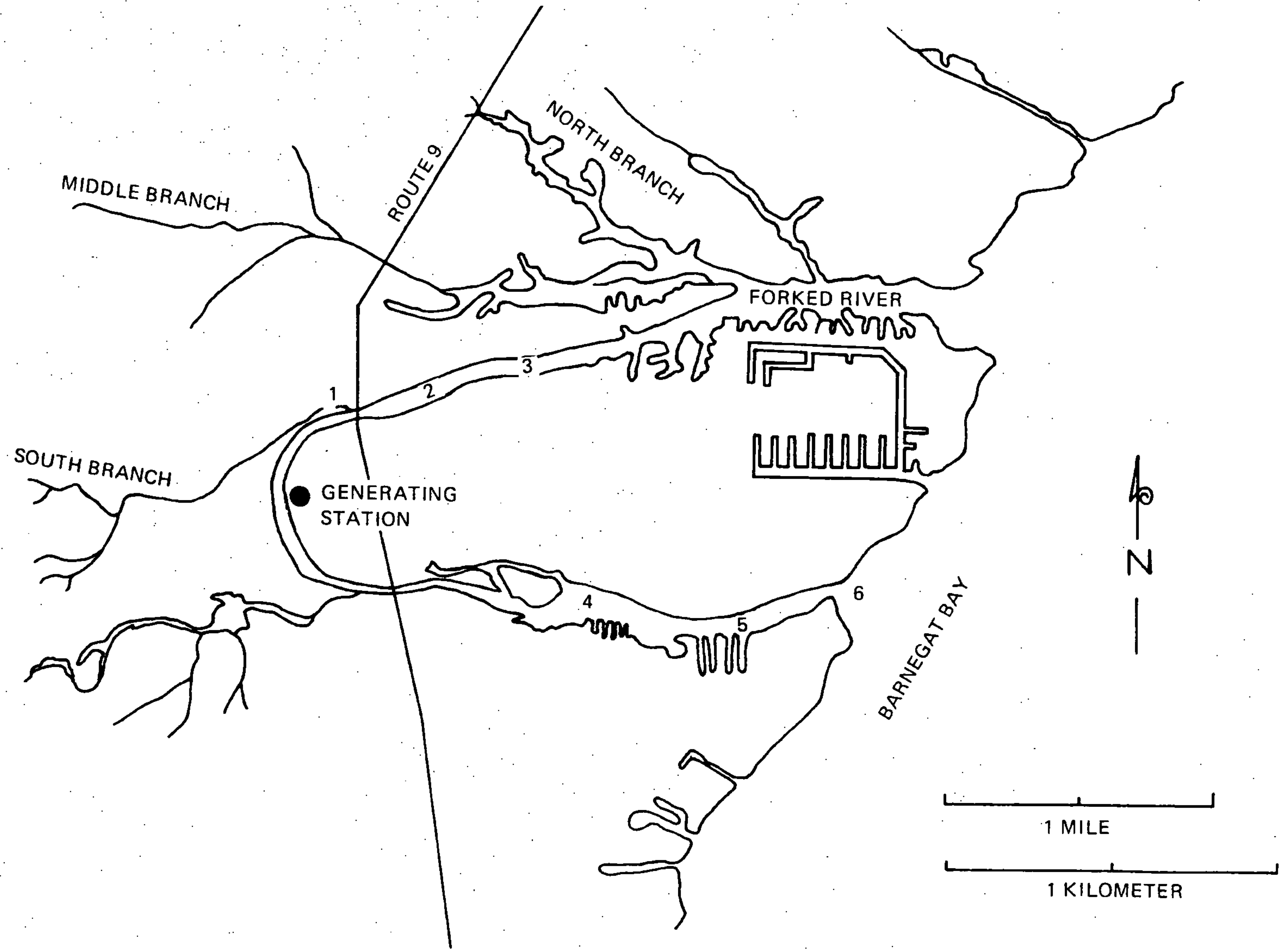

MIDDLE BRANCH
ROUTE 9
NORTH BRANCH
FORKED RIVER
SOUTH BRANCH
GENERATING STATION
1
2
3
4
5
6
BARNEGAT BAY
N
1 MILE
1 KILOMETER

FIGURE 3.2-2

FIGURE 3.2-3. Four year occurrence histogram for selected phytoplankton in Barnegat Bay. From Mountford (1971).

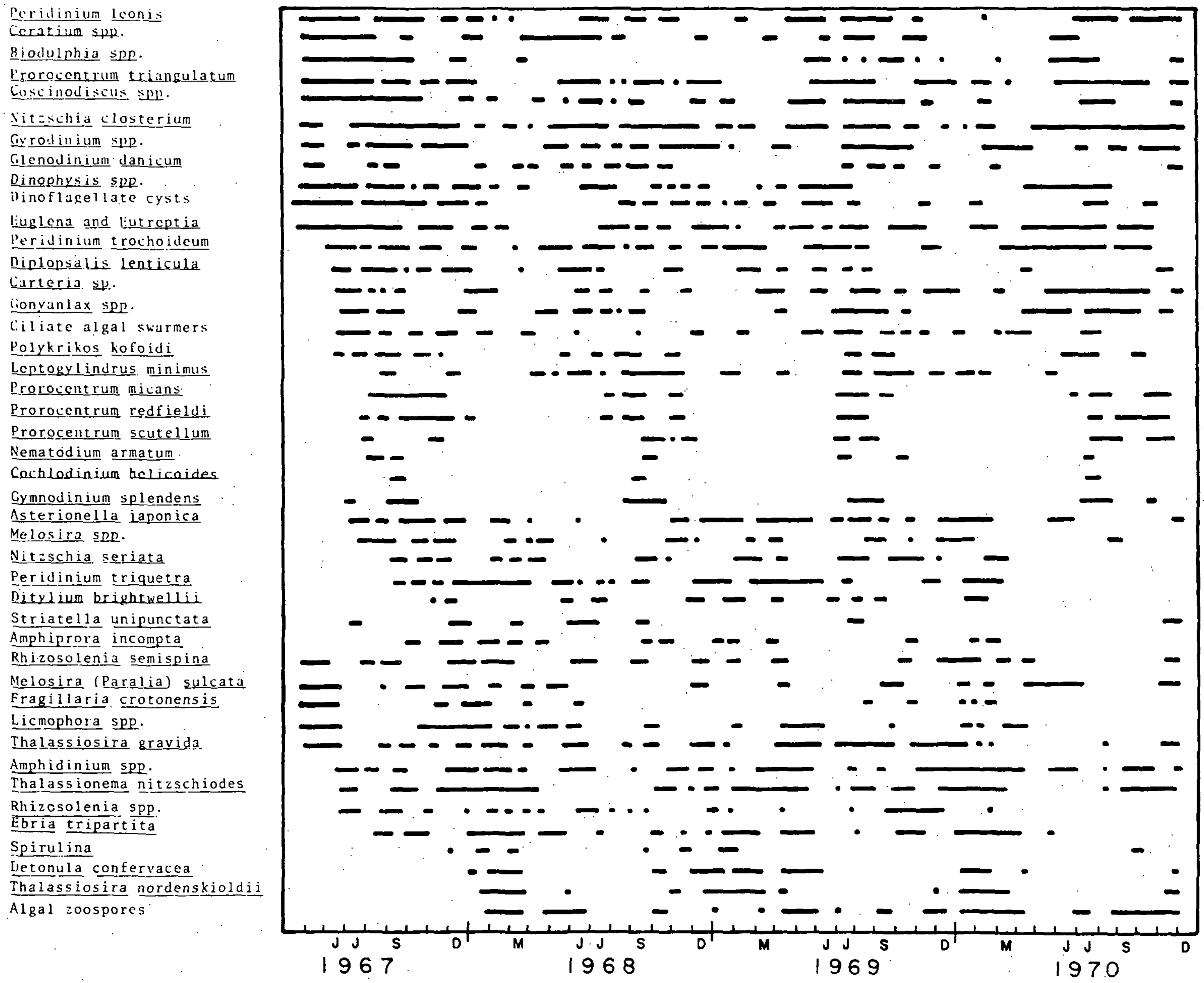
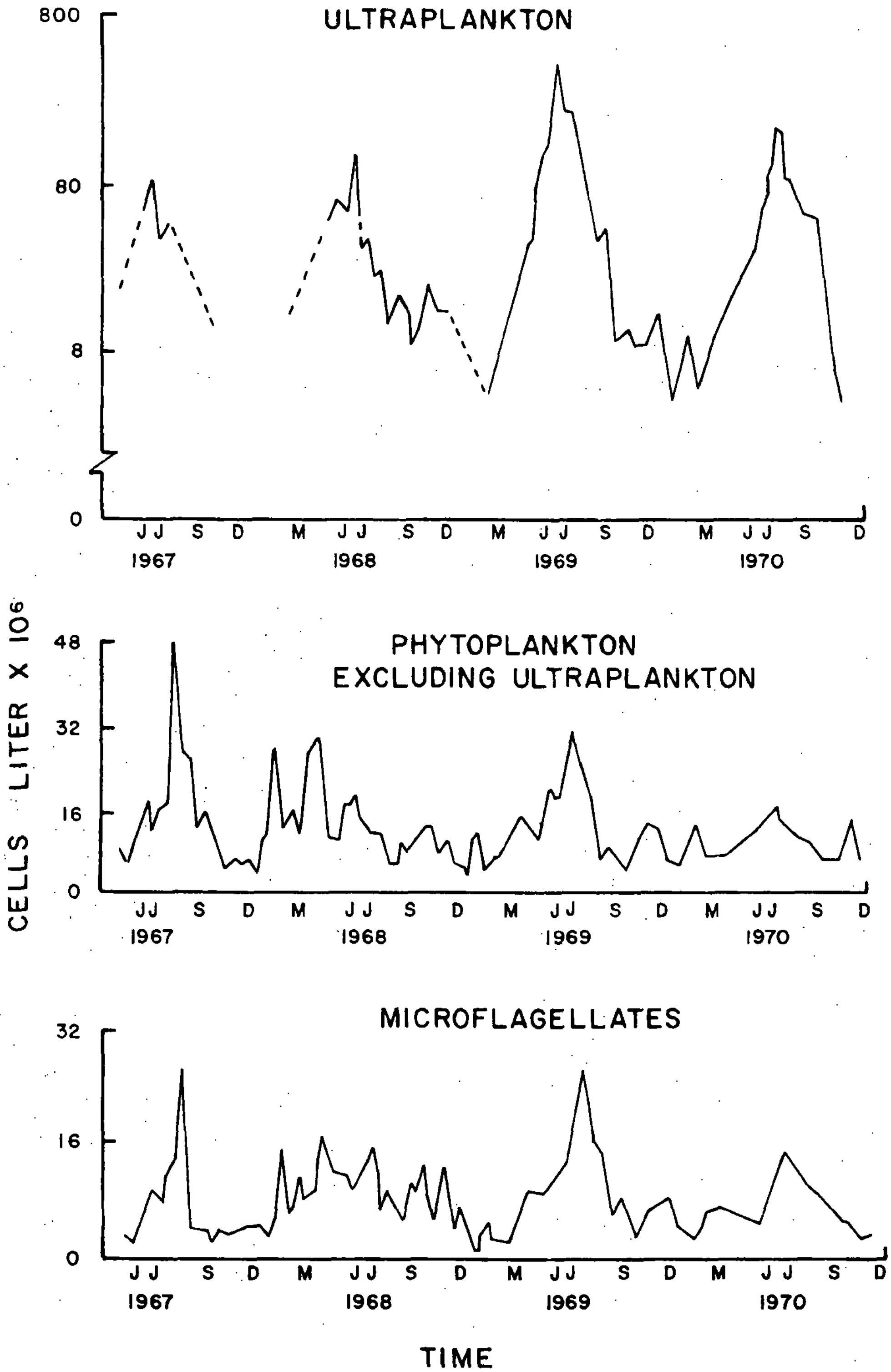

Peridinium leonis
Ceratium spp.
Biodulphia spp.
Prorocentrum triangulatum
Coscinodiscus spp.
Nitzschia closterium
Gyrodinium spp.
Glenodinium danicum
Dinophysis spp.
Dinoflagellate cysts
Euglena and Eutreptia
Peridinium trochoideum
Diplopsalis lenticula
Carteria sp.
Gonyaulax spp.
Ciliate algal swarmers
Polykrikos kofoidi
Leptocylindrus minimus
Prorocentrum micans
Prorocentrum redfieldi
Prorocentrum scutellum
Nematodium armatum
Cochlodinium helicoides
Gymnodinium splendens
Asterionella japonica
Melosira spp.
Nitzschia seriata
Peridinium triquetra
Ditylium brightwellii
Striatella unipunctata
Amphiprora incompta
Rhizosolenia semispina
Melosira (Paralia) sulcata
Fragillaria crotonensis
Licmophora spp.
Thalassiosira gravida
Amphidinium spp.
Thalassionema nitzschiodes
Rhizosolenia spp.
Ebria tripartita
Spirulina
Detonula confervacea
Thalassiosira nordenskioldii
Algal zoospores
J J S D M J J S D M J J S D M J J S D
1967
1968
1969
1970

FIGURE 3.2-3

FIGURE 3.2-4. Phytoplankton abundance in Barnegat Bay from 1967 to 1970. Modified from Mountford (1971).



ULTRAPLANKTON
800
80
8
0
J J S D M J J S D M J J S D M J J S D
1967
1968
1969
1970
CELLS LITER X 10^6
PHYTOPLANKTON
EXCLUDING ULTRAPLANKTON
48
32
16
0
J J S D M J J S D M J J S D M J J S D
1967
1968
1969
1970
MICROFLAGELLATES
32
16
0
J J S D M J J S D M J J S D M J J S D
1967
1968
1969
1970
TIME

FIGURE 3.2-4

FIGURE 3.2-5. Mean chlorophyll *a* concentrations at five sampling stations in Barnegat Bay in 1969 and 1970. Data from Mountford (1971).

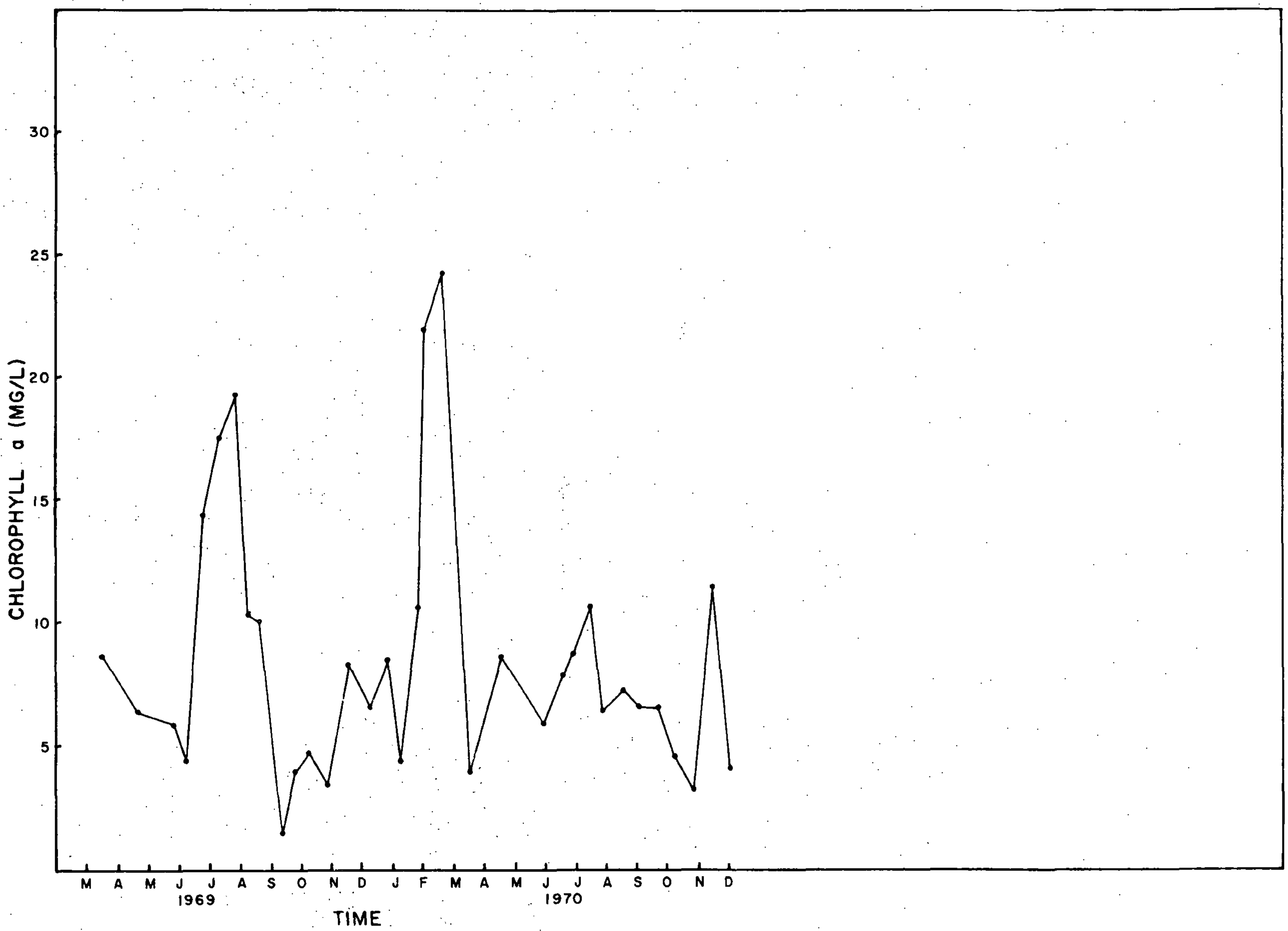

CHLOROPHYLL a (MG/L)
30
25
20
15
10
5
M A M J J A S O N D J F M A M J J A S O N D
1969
1970
TIME

FIGURE 3.2-5

FIGURE 3.2-6. Chlorophyll *a* concentrations at the intake and discharge canals of the OCNGS in 1969 and 1970. Data from Mountford (1971).

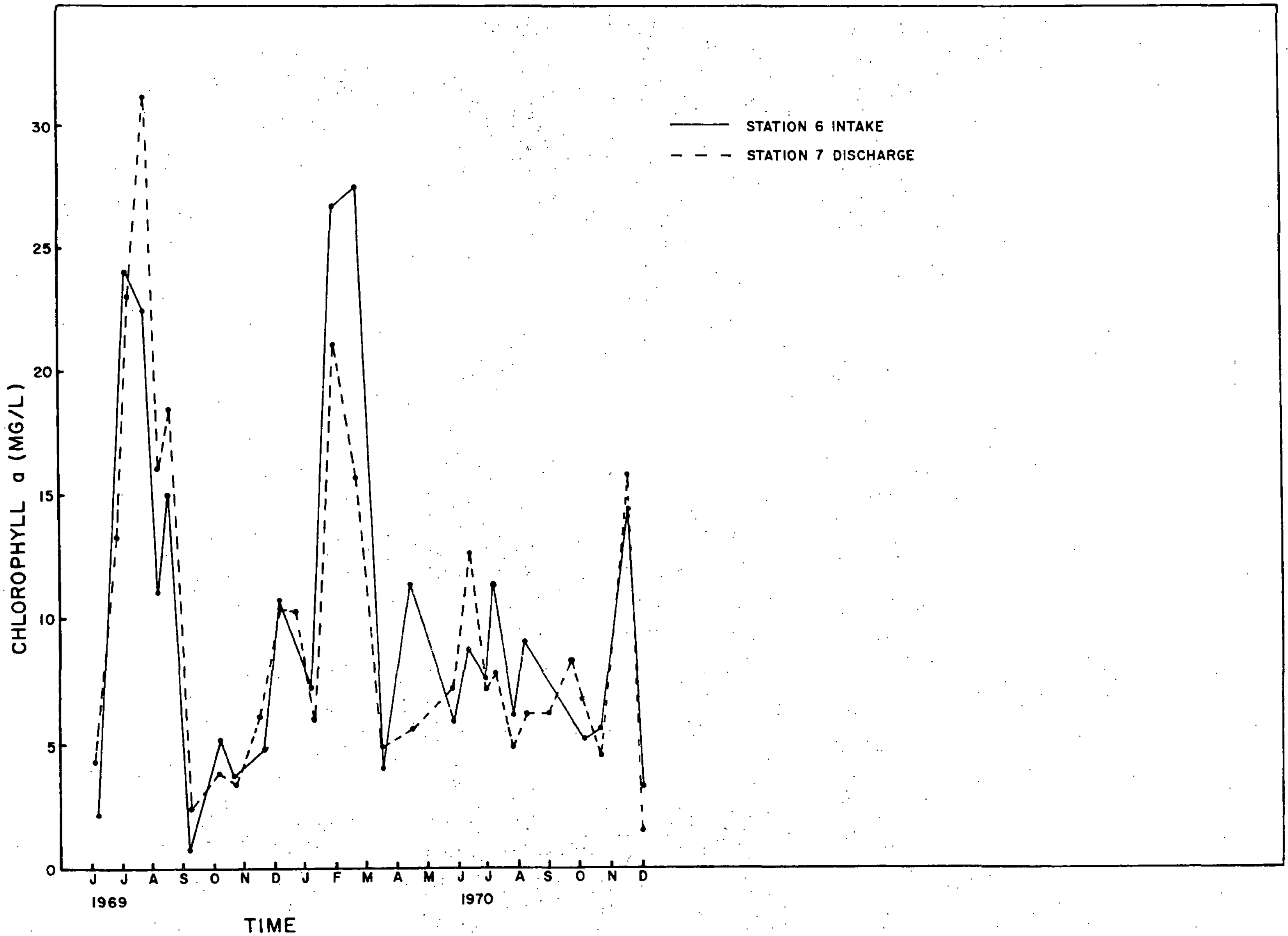
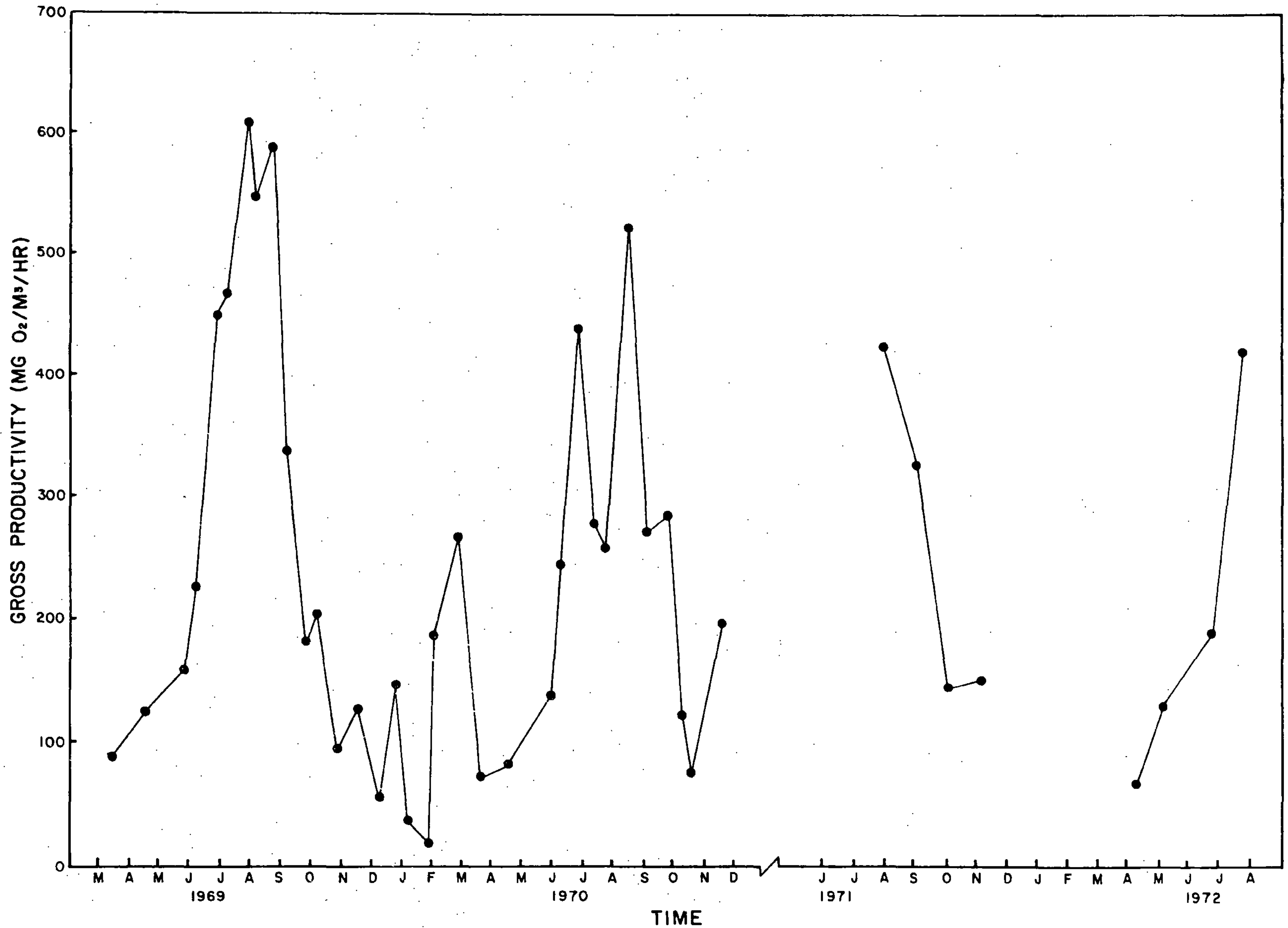

STATION 6 INTAKE
STATION 7 DISCHARGE
CHLOROPHYLL a (MG/L)
0
5
10
15
20
25
30
J J A S O N D J F M A M J J A S O N D
1969
1970
TIME

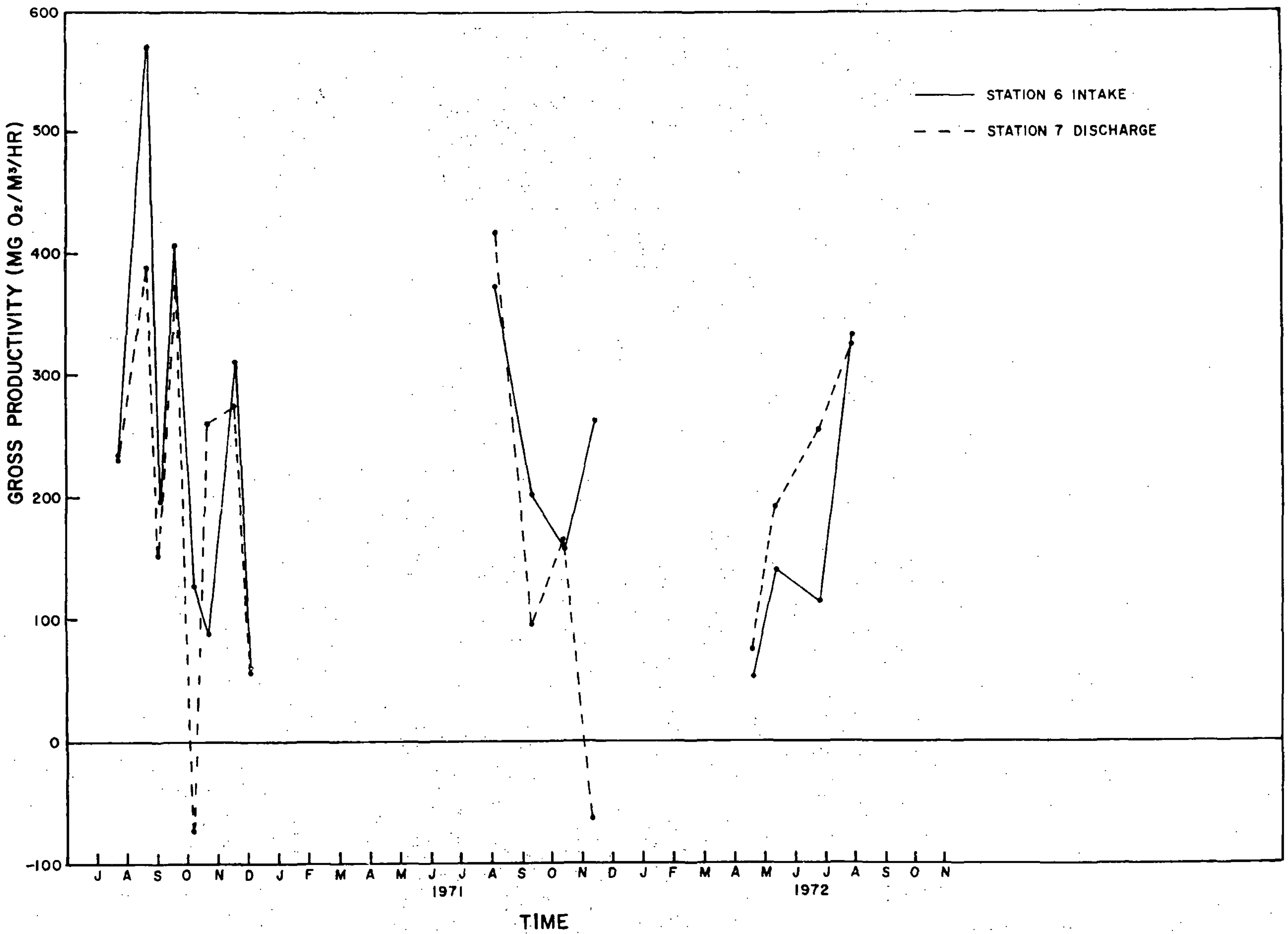
FIGURE 3.2-6

FIGURE 3.2-7. Mean gross productivity at five stations in Barnegat Bay in 1969 and 1970 and at four stations in 1971 and 1972. Data from Mountford (1971) and Loveland and others (1972).


GROSS PRODUCTIVITY (MG O2/M3/HR)
700
600
500
400
300
200
100
0
M A M J J A S O N D J F M A M J J A S O N D
J J A S O N D J F M A M J J A
1969
1970
1971
1972
TIME

IGURE 3.2-7

FIGURE 3.2-8. Gross productivity at the intake and discharge canals of the OCNGS in 1970, 1971, and 1972. Data from Mountford (1971) and Loveland and others (1972).



STATION 6 INTAKE
STATION 7 DISCHARGE
GROSS PRODUCTIVITY (MG O_2/M^3/HR)
600
500
400
300
200
100
0
-100
J A S O N D J F M A M J J A S O N D J F M A M J J A S O N
1971
1972
TIME

FIGURE 3.2-8

FIGURE 3.2-9. Generalized sediment distribution in Barnegat Bay (after Kennish and Olsson 1975); Approximate location of benthic invertebrate sampling stations (+); areal extent of thermal plume (1.5°F ΔT) as measured at the sediment surface (-----).

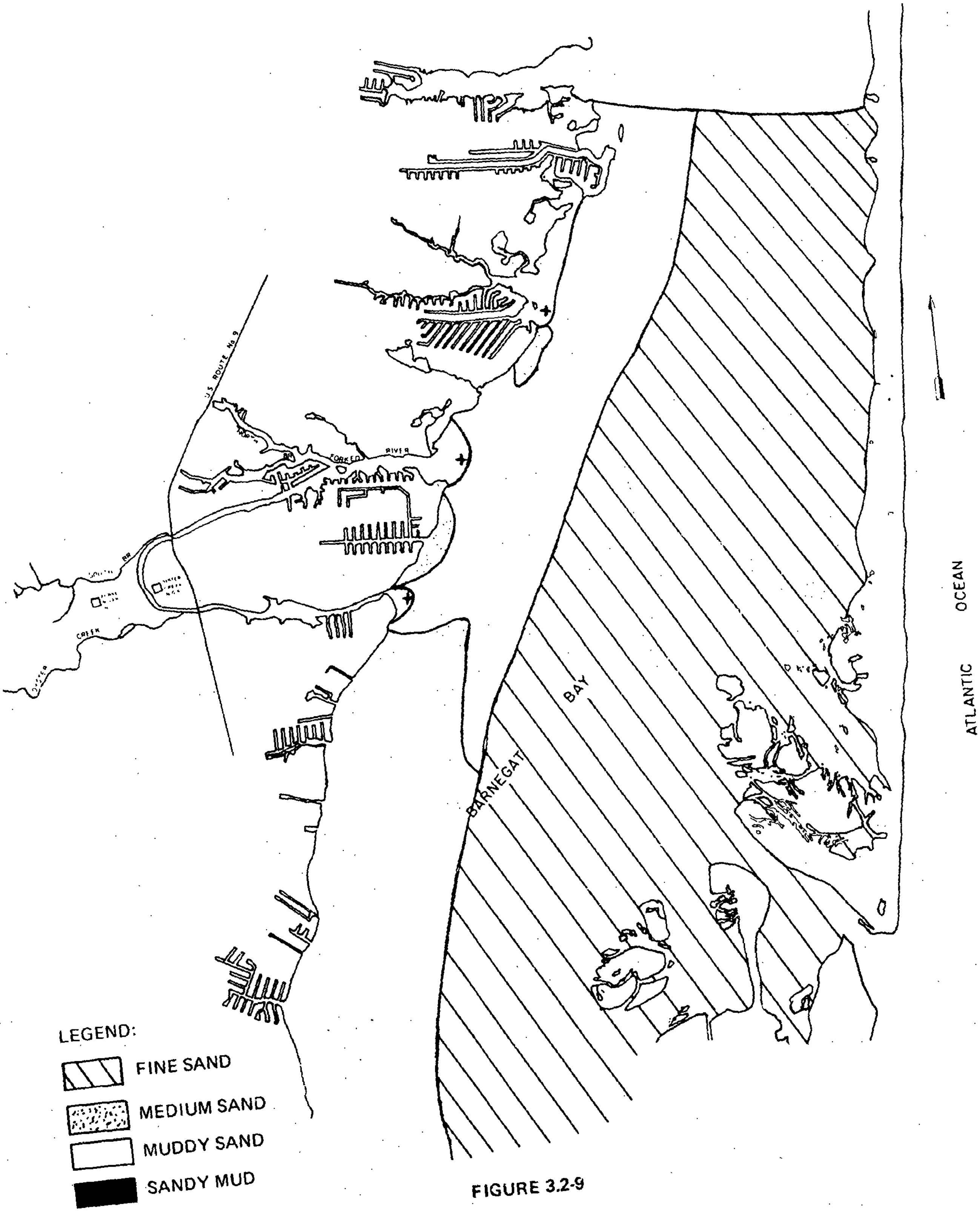

U.S. ROUTE No. 9
FORKED RIVER
BARNEGAT BAY
ATLANTIC OCEAN
LEGEND:
FINE SAND
MEDIUM SAND
MUDDY SAND
SANDY MUD

FIGURE 3.2-9

FIGURE 3.2-10. Mean number of individuals/m^2 vs. time.

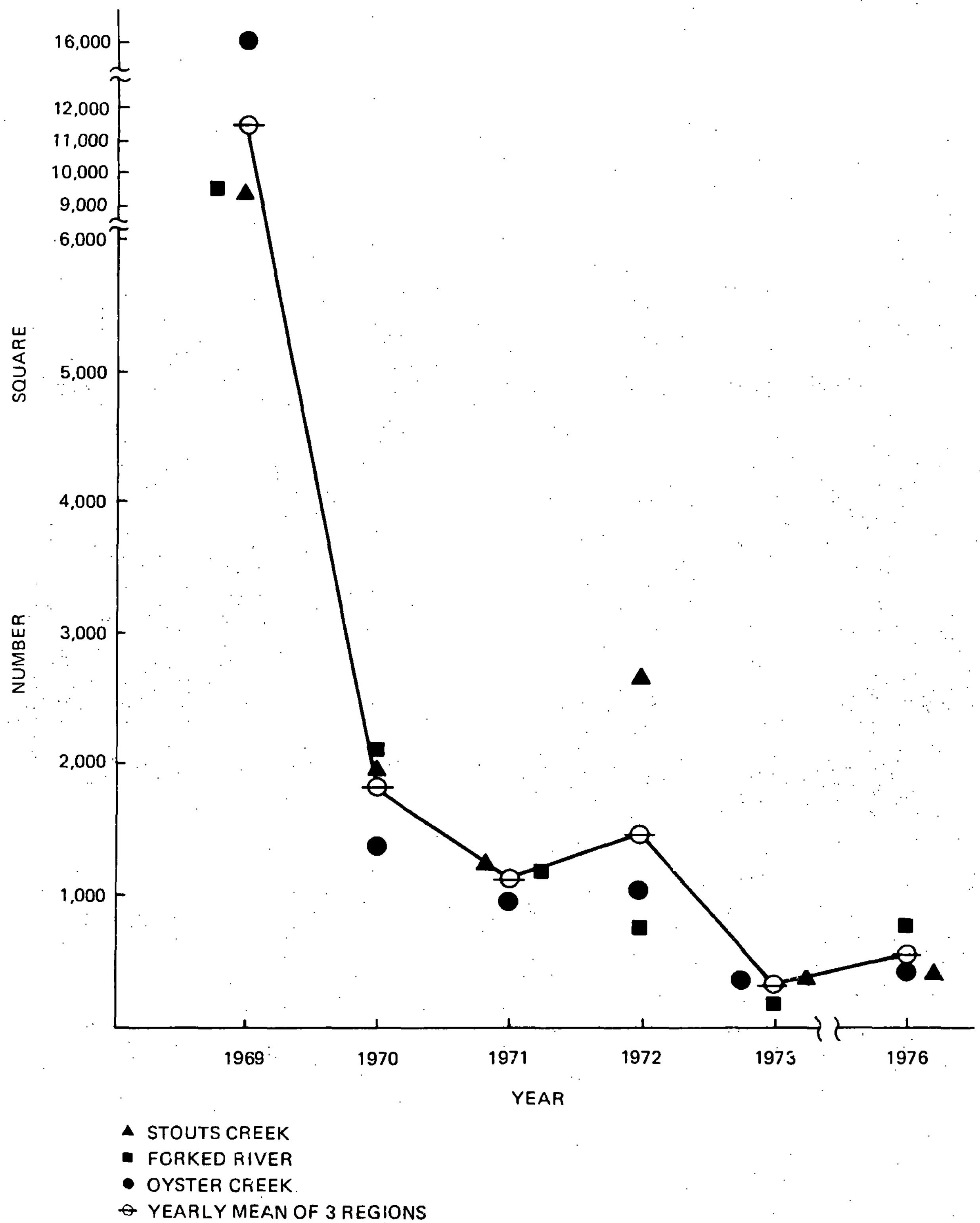

16,000
12,000
11,000
10,000
9,000
6,000
5,000
4,000
3,000
2,000
1,000
NUMBER SQUARE
1969
1970
1971
1972
1973
1976
YEAR
STOUTS CREEK
FORKED RIVER
OYSTER CREEK
YEARLY MEAN OF 3 REGIONS

FIGURE 3.2-10

FIGURE 3.2-11. Diagram of the intake and discharge of the circulating water system and the dilution pumps at the Oyster Creek Nuclear Generating Station.

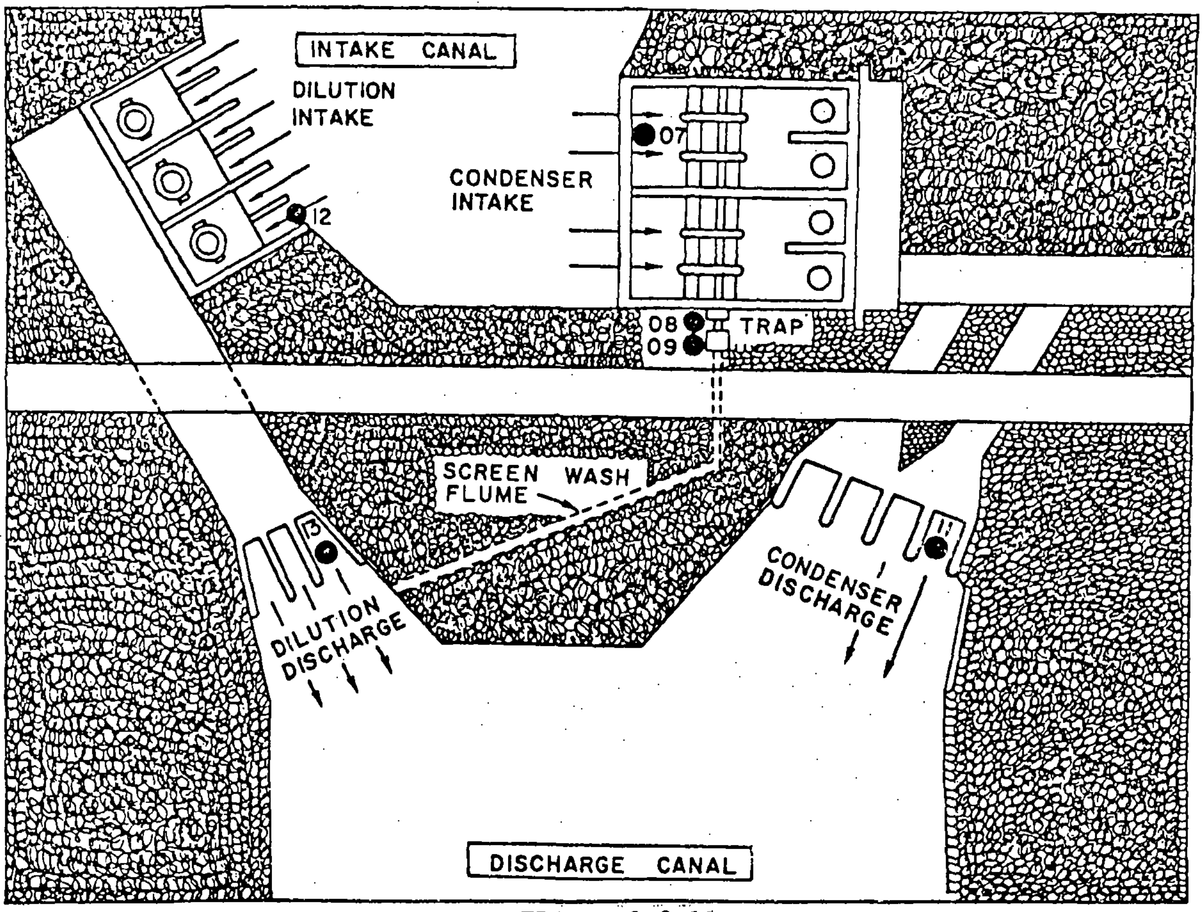

INTAKE CANAL
DILUTION
INTAKE
CONDENSER
INTAKE
07
12
08
09
TRAP
SCREEN WASH
FLUME
13
11
DILUTION
DISCHARGE
CONDENSER
DISCHARGE
DISCHARGE CANAL

FIGURE 3.2-11

FIGURE 3.2-12. Mean annual number of bay anchovy per seine collection from 1966-70 (Marcellus 1972) and 1975-77 at the mouth of Oyster Creek (□), Forked River (•), Sands Point Harbor (★), and Double Creek (○).

[a] Dashed line indicates mean when unusually large catches made in April 1976 because of attraction to heated discharge are included.

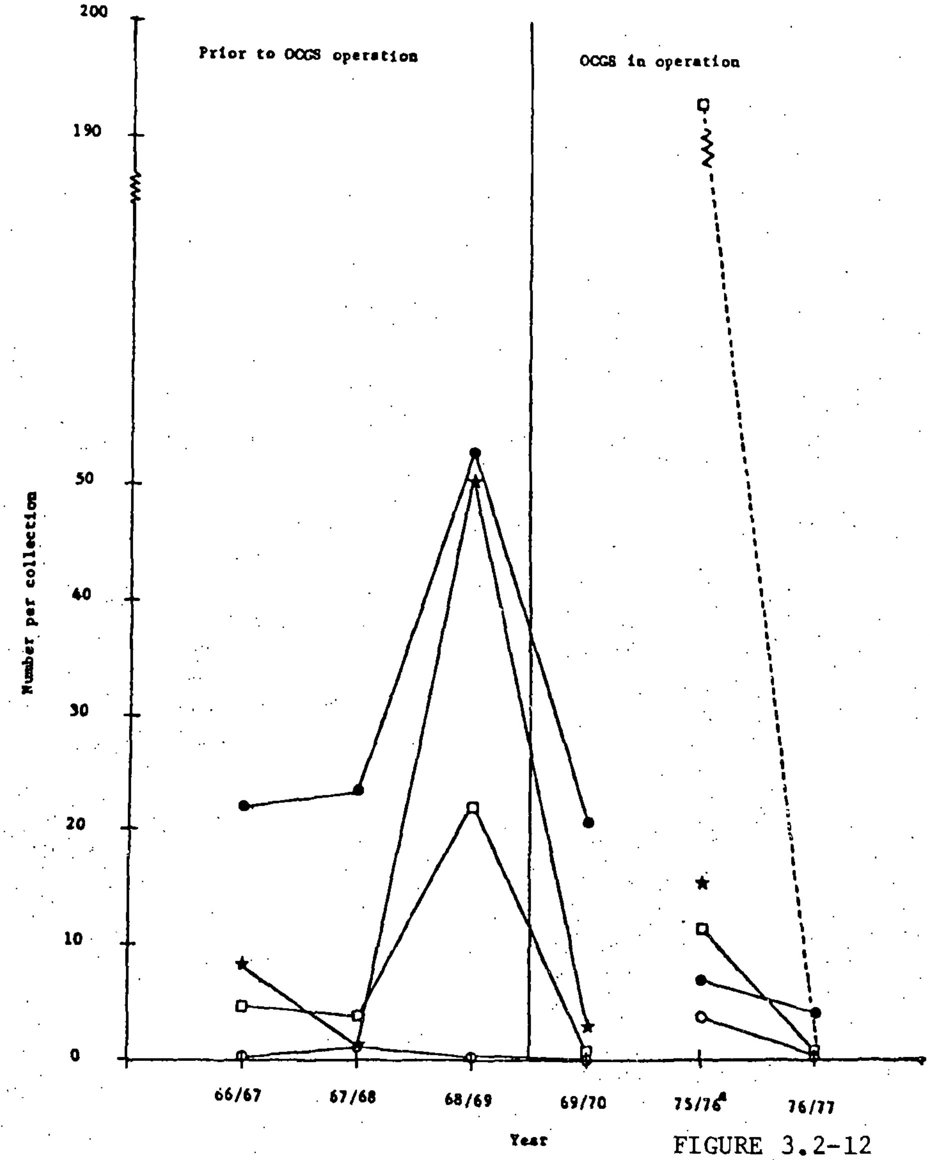
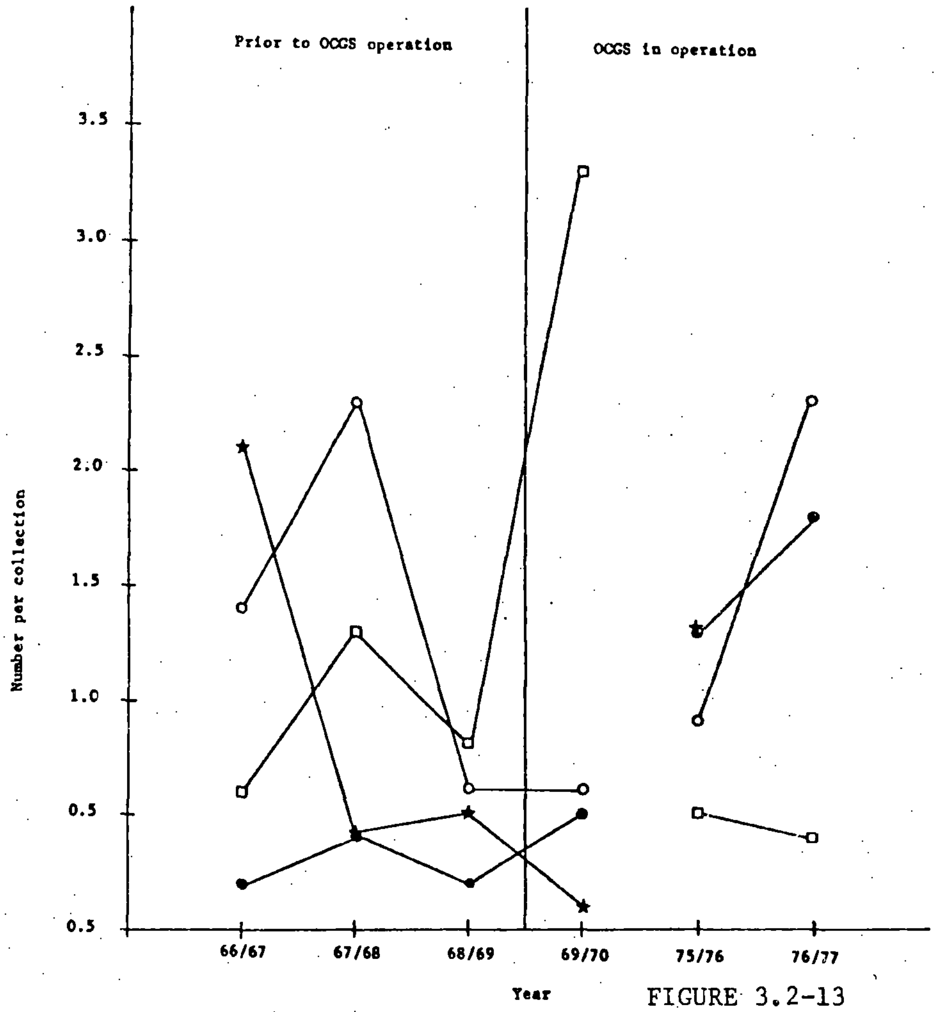

Prior to OCGS operation
OCGS in operation
Number per collection
200
190
50
40
30
20
10
0
66/67
67/68
68/69
69/70
75/76[a]
76/77
Year

FIGURE 3.2-12

FIGURE 3.2-13. Mean annual number of mummichog per seine collection from 1966-70 (Marcellus 1972) and 1975-77 at the mouth of Oyster Creek (□), Forked River (●), Sands Point Harbor (★), and Double Creek (○).



Prior to OCGS operation
OCGS in operation
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.5
Number per collection
66/67
67/68
68/69
69/70
75/76
76/77
Year

FIGURE 3.2-13

FIGURE 3.2-14. Mean annual number of tidewater silverside per seine collection from 1966-70 (Marcellus 1972) and 1975-77 at the mouth of Oyster Creek (□), Forked River (   ), Sands Point Harbor (★), and Double Creek (○).

[a] Marcellus (1972) misidentified tidewater silverside as Atlantic silverside in 1966-67.

[b] Dashed line indicates mean when unusually large catches made in March 1970 because of attraction to heated discharge are included.

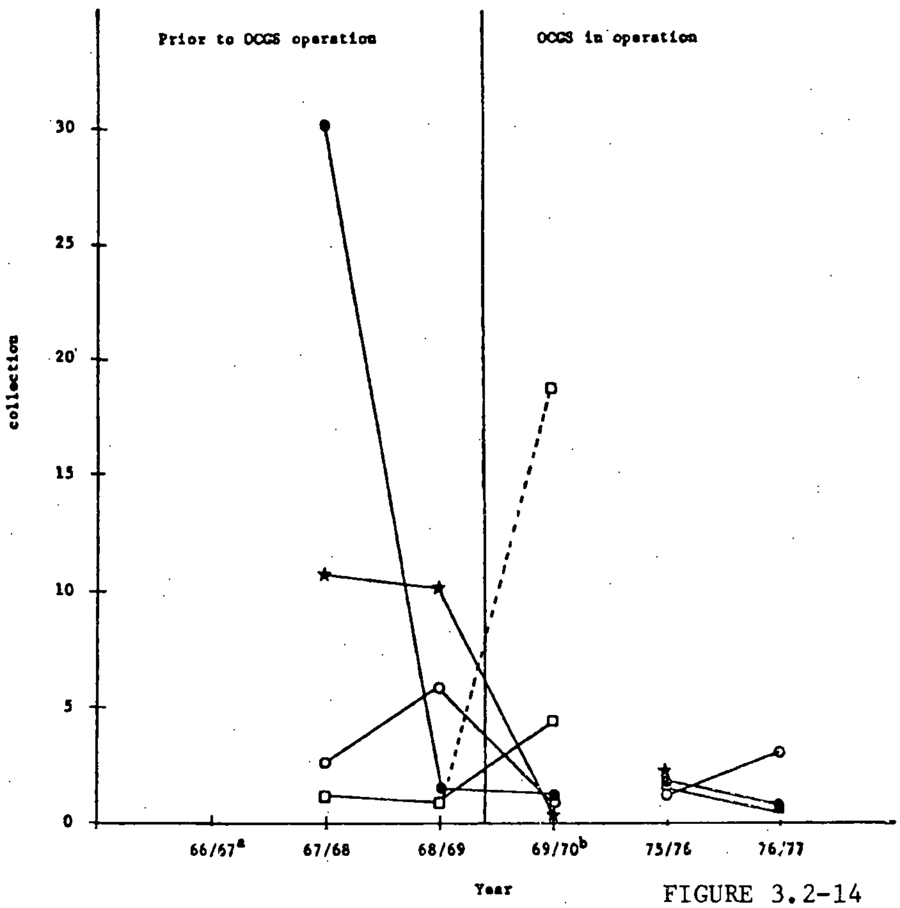
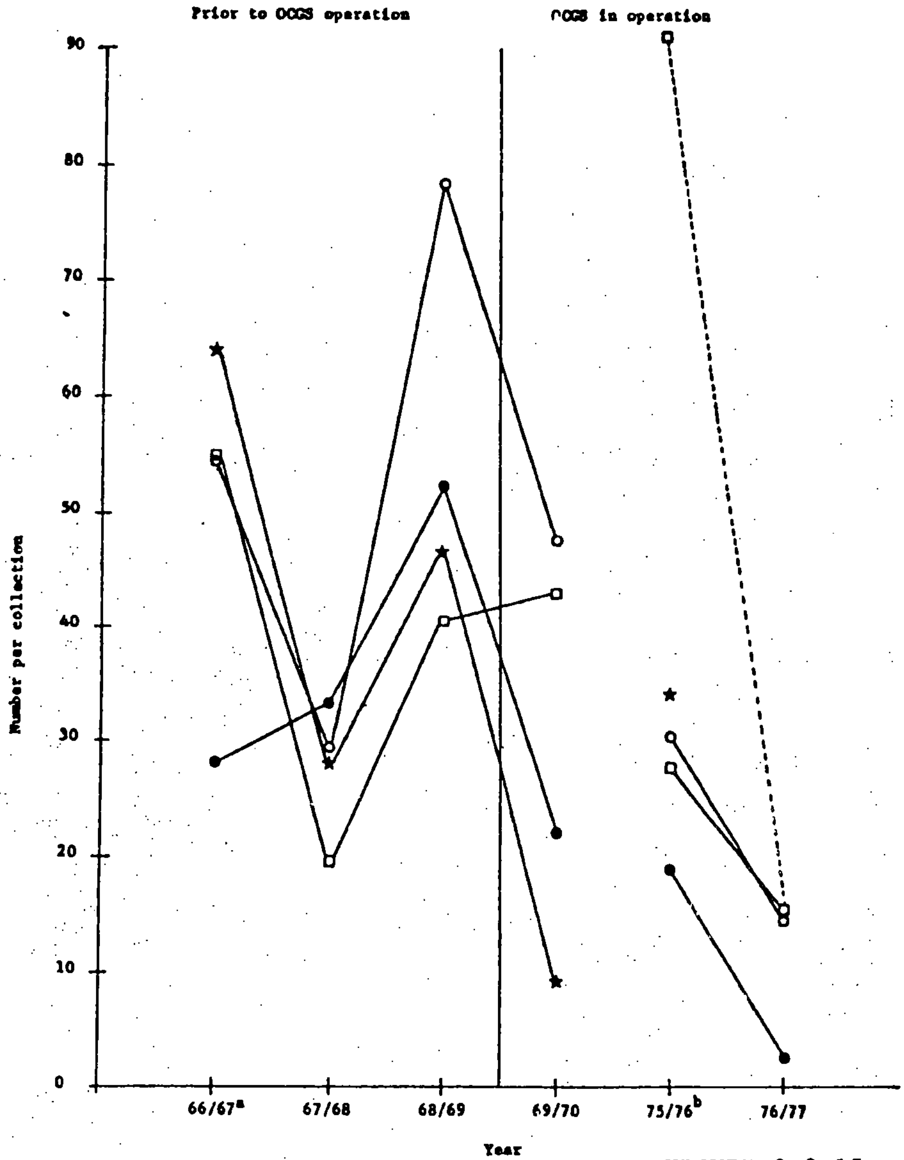

Prior to OCGS operation
OCGS in operation
collection
30
25
20
15
10
5
0
66/67[a]
67/68
68/69
69/70[b]
75/76
76/77
Year

FIGURE 3.2-14

FIGURE 3.2-15. Mean annual number of Atlantic silverside per seine collection from 1966-70 (Marcellus 1972) and 1975-77 at the mouth of Oyster Creek (□), Forked River (   ), Sands Point Harbor (★), and Double Creek (○).

[a] Marcellus (1972) Misidentified tidewater silverside as Atlantic silverside in 1966-67.

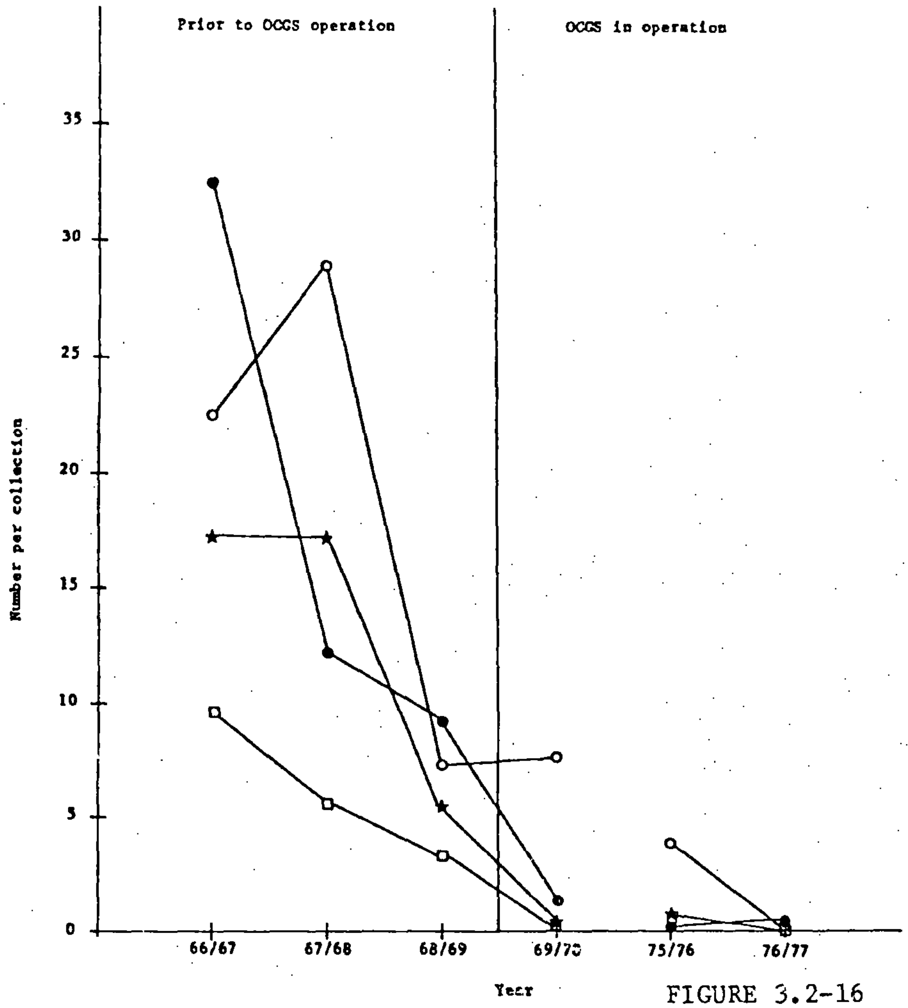
[b] Dashed line indicates mean when unusually large catches made in April 1976 because of attraction to heated discharge are included.



Prior to OCGS operation
OCGS in operation
Number per collection
Year
66/67a
67/68
68/69
69/70
75/76b
76/77
0
10
20
30
40
50
60
70
80
90

FIGURE 3.2-15

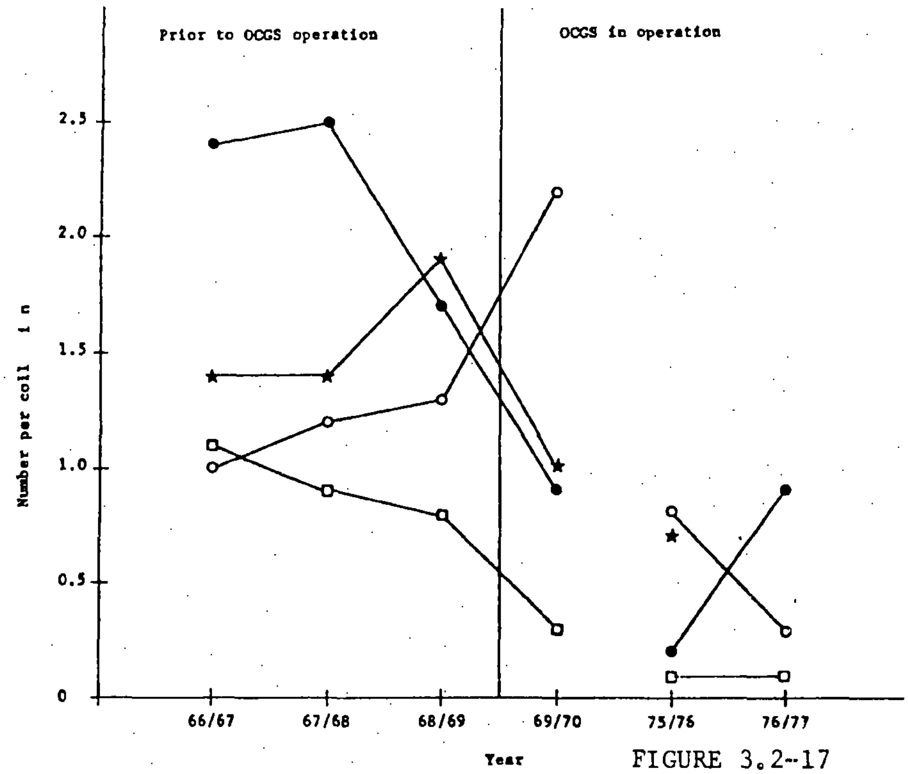
FIGURE 3.2-16. Mean annual number of fourspine stickleback per seine collection from 1966-70 (Marcellus 1972) and 1975-77 at the mouth of Oyster Creek (□), Forked River (●), Sands Point Harbor (★), and Double Creek (○).



Prior to OCGS operation
OCGS in operation
35
30
25
20
15
10
5
0
Number per collection
66/67
67/68
68/69
69/70
75/76
76/77
Year

FIGURE 3.2-16

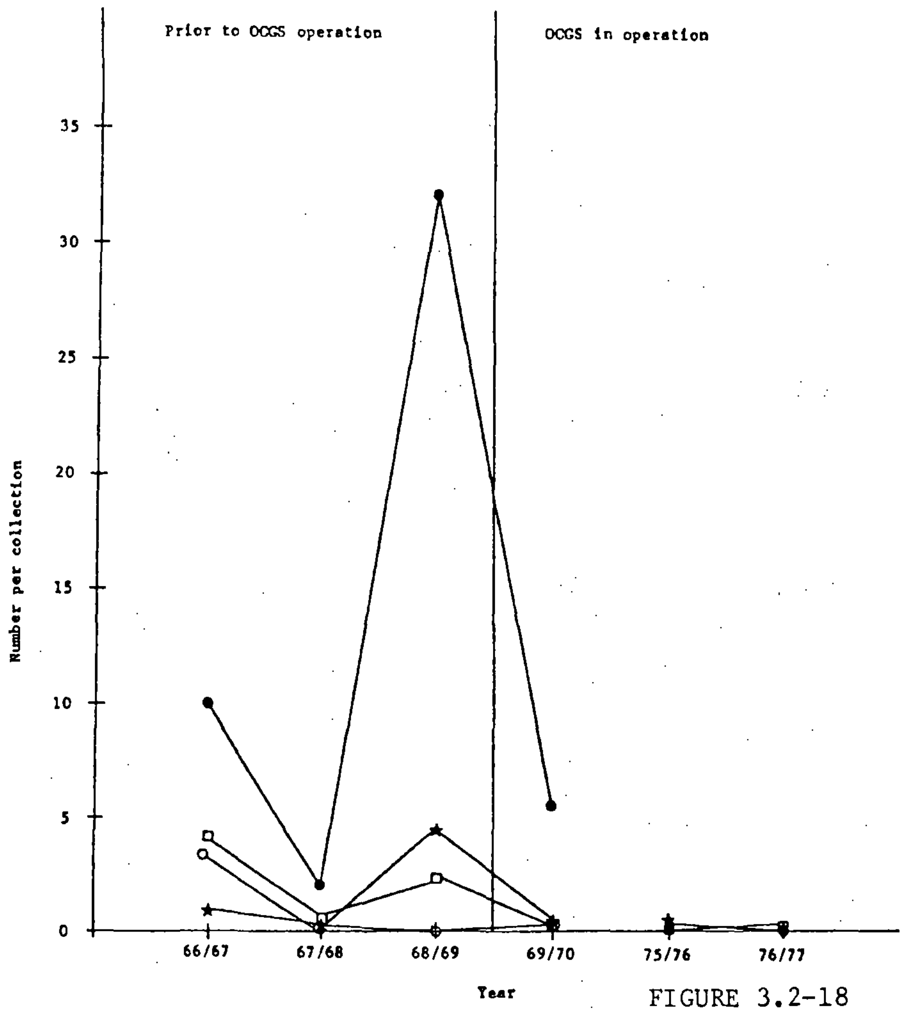
FIGURE 3.2-17. Mean annual number of northern pipefish per seine collection from 1966-70 (Marcellus 1972) and 1975-77 at the mouth of Oyster Creek (□), Forked River (●), Sands Point Harbor (★), and Double Creek (○).



Prior to OCGS operation
OCGS in operation
Number per coil i n
2.5
2.0
1.5
1.0
0.5
0
66/67
67/68
68/69
69/70
75/76
76/77
Year

FIGURE 3.2-17

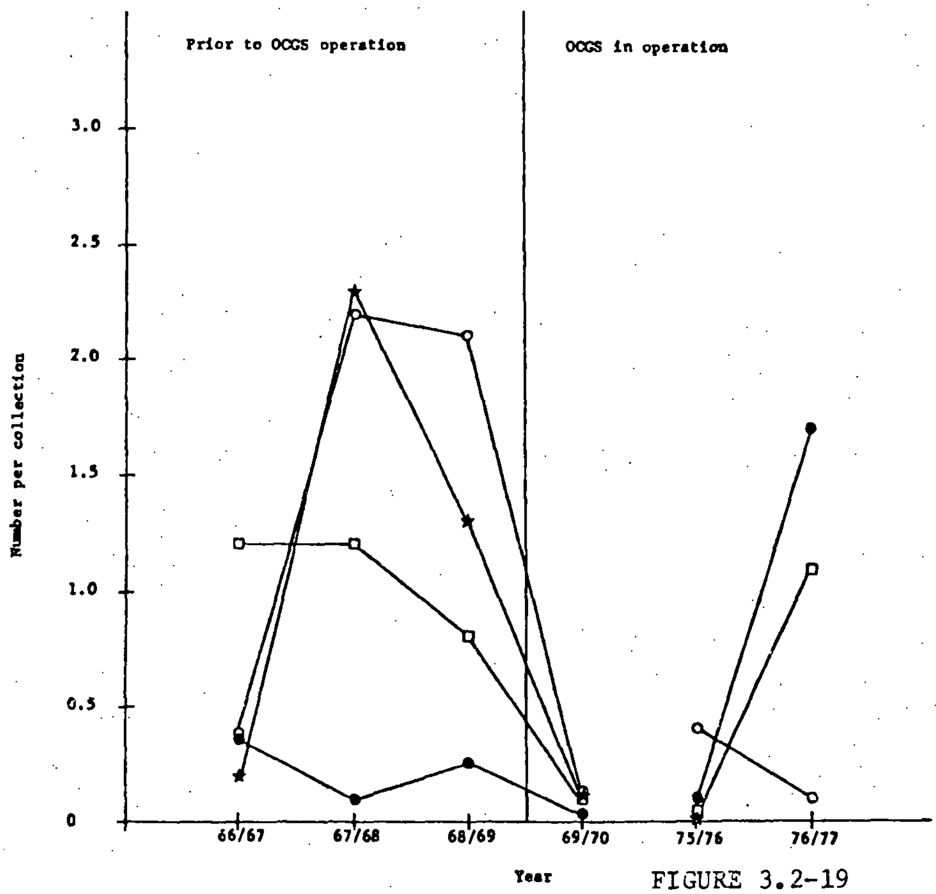
FIGURE 3.2-18. Mean annual number of silver perch per seine collection from 1966-70 (Marcellus 1972) and 1975-77 at the mouth of Oyster Creek (□), Forked River (   ), Sands Point Harbor (★), and Double Creek (○).



Prior to OCGS operation
OCGS in operation
Number per collection
35
30
25
20
15
10
5
0
66/67
67/68
68/69
69/70
75/76
76/77
Year

FIGURE 3.2-18

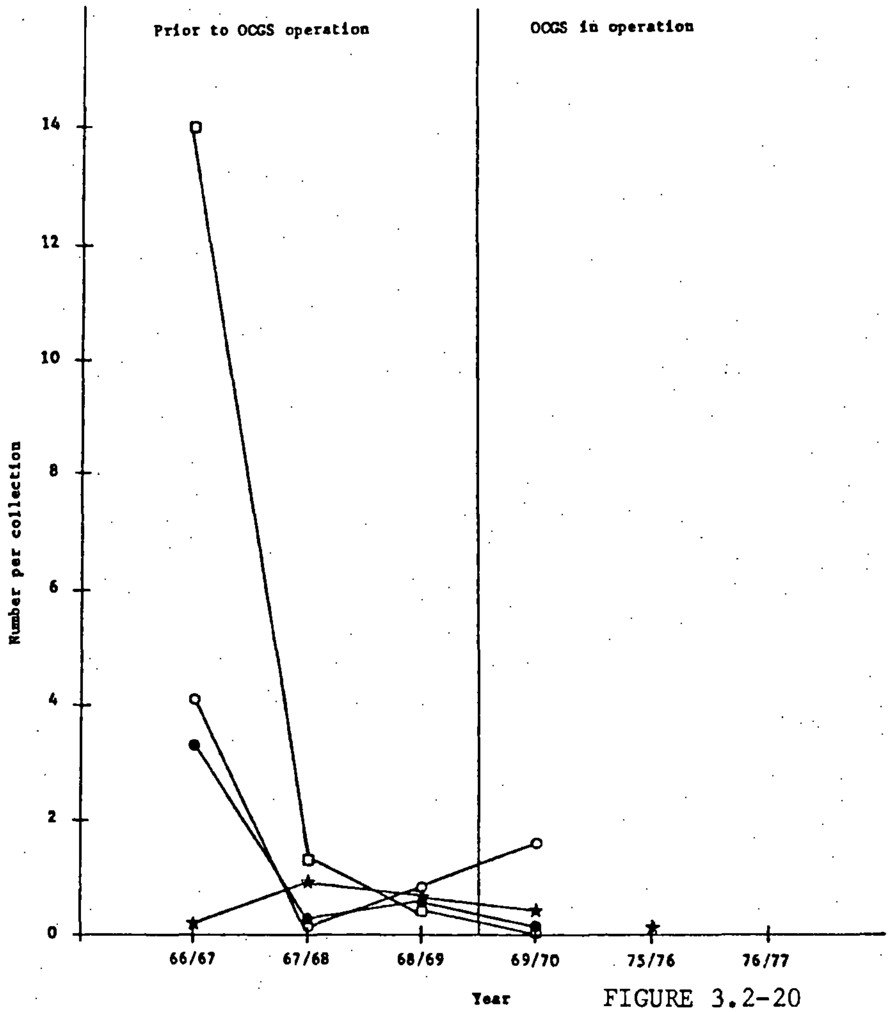
FIGURE 3.2-19. Mean annual number of winter flounder per seine collection from 1966-70 (Marcellus 1972) and 1975-77 at the mouth of Oyster Creek (□), Forked River ( ), Sands Point Harbor (★), and Double Creek (○).



Prior to OCGS operation
OCGS in operation
3.0
2.5
2.0
1.5
1.0
0.5
0
Number per collection
66/67
67/68
68/69
69/70
75/76
76/77
Year

FIGURE 3.2-19

FIGURE 3.2-20. Mean annual number of northern puffer per seine collection from 1966-70 (Marcellus 1972) and 1975-77 at the mouth of Oyster Creek (□), Forked River (●), Sands Point Harbor (★), and Double Creek (○).



Prior to OCGS operation
OCGS in operation
14
12
10
8
6
4
2
0
Number per collection
66/67
67/68
68/69
69/70
75/76
76/77
Year

FIGURE 3.2-20

3.3 Effect of the OCNGS Discharge on Recreational Uses

The addition of heat to the discharge canal has resulted in a substantial sport fishery. Halgren (1973) reported that Oyster Creek had the greatest percentage (34.1) percent of bank fishermen in either the upper or lower section of Barnegat Bay. Sport fishing from the banks or from boats represented 78.1 percent and 8.5 percent, respectively, of the recreational activities in the discharge canal (Halgren, 1973). The fishing season in the canal has been extended later into the year than in other areas of the bay because the heated discharge has attracted fish during fall and winter and blue crab remain active longer into the fall and winter. During December 1971 and November 1972, Oyster Creek ranked second in the number of recreational activities in the lower bay, but in January and February 1972, Oyster Creek ranked first in the number of activities due to the presence of bank fisherman.

The most abundant species caught in the discharge canal in the summer and early fall were blue crab and bluefish. Winter flounder were taken from Oyster Creek during the late winter and early spring. The catch per individual of blue crab was greater in the heated discharge than in similar areas outside of the influence of the OCNGS. It is unlikely, however, that the increased number of crabs and fishes harvested from Oyster Creek would have an impact upon these populations in the bay because only 3.8 percent of the estimated sport fishery catch in the bay for 1972 was taken from the discharge canal (Halgren, 1973).

The results of a creel census conducted from September 1975 to September 1976 indicated that the areas associated with the heated discharge from OCNGS were the most productive of the areas sampled (Tatham et al., 1977). The areas sampled in the bay were limited to the western shore and included the bay from Cedar Creek to the area between the Forked River and Oyster Creek, from this area to Waretown Creek and the northern approach to Barnegat Inlet and Sedge Island.

Of the three areas sampled in Barnegat Bay, the area including Oyster Creek yielded the highest catch per individual (c/i, 5.96); blue crab comprised most of these catches (89.5 percent).

Two other areas, one along Oyster Creek (discharge canal) and the other along the Forked River (intake canal), were surveyed for bank fishermen. Of these two areas, the c/i for Oyster Creek (10.26) was greater than for the Forked River (3.96). Twice as many hours were expended in Oyster Creek as in the Forked River, which yielded 4.5 times more specimens taken from the former. Blue crab (81.8 percent of the total catch) and bluefish (17.0 percent) were the most abundant species taken from the discharge canal (Tatham et al., 1977). Most specimens were caught from May through September, which was expected because the most extensive fishing activity occurred from June through August. Despite the occurrence of a maximum water temperature of 31.5°C, the c/i did not decrease in the discharge canal.

The effect of the OCNGS discharge on recreational uses is to attract fish in late fall and winter and to provide an area where blue crab remain active later. This increases the number of bank fishermen along the discharge canal.

References

Halgren, B.A. [1973]. Phase III - use studies. Pages 175-224 in Studies of the upper Barnegat System. Misc. Rept. No. 10 m (mimeo). NJ Dept. of Envir. Prot., Div. of Fish, Game, and Shellfish. Bur. Fish., Nacote Creek Res. Sta.

Tatham, T.R., D.J. Danila, P. L. Thomas, and Associates. 1977. Ecological studies for the Oyster Creek Generating Station. Progress report for the period September 1975 - August 1976. Vol One. Fin - and shellfish. Ichthyological Assoc., Inc. Ithaca, NY. 338 pp.

3.4 Effect of the OCNGS Discharge on Commercial Uses

Five species of fin and shellfish are commercially harvested in Barnegat Bay: blue crab, American eel, hard clam, winter flounder, and white perch. For blue crab, hard clam and winter flounder commercial landings are discussed in Section 3.1. Landing data for Barnegat Bay and Ocean County between September 1975 and April 1976 are presented in Appendix C1 for all five species. A more complete description of the trends in bay landings for the five species will be filed as an addendum to this report.

Commercial landing data are not sufficiently detailed to determine if commercial fishing occurred in Oyster Creek prior to the operation of OCNGS. Since OCNGS began operation, no commercial landings have been reported from Oyster Creek.

3.5 Aquatic Communities in Oyster Creek, the South Branch of Forked River, and Barnegat Bay Before and After Construction of the OCNGS Intake and Discharge Canals

3.5.1 Fishes and Macroinvertebrates in Oyster Creek and the South Branch of Forked River Before Construction of the OCNGS

In the natural state, both Oyster Creek (Sawyer 1953; AEC, 1974) and the South Branch of Forked River (AEC, 1974) were typical of small, spring-fed, cedar-swamp streams in southern New Jersey. Tidal marsh apparently extended up to the U.S. Route 9 highway bridge in Oyster Creek; the area west of the bridge was wooded swamp. Oyster Creek was fresh water to at least 760 m (2,493 ft) east of the U.S. Route 9 bridge but very low (< 0.5 ppt) salinity was found in the South Branch of Forked River at the U.S. Route 9 bridge (AEC, 1974). The lower portion of each stream was estuarine. Sawyer (1953) reported that the freshwater portion of Oyster Creek was more acidic (pH = 4.2 to 4.6) than the estuarine area (6.3 to 8.0). In Oyster Creek, the aquatic vegetation in fresh water was sparse and at the U.S. Route 9 bridge consisted of Batrachospermum sp. and Vallisneria sp. (Sawyer, 1953). In both streams, extensive areas of eel grass (Zostera marina) and widgeon grass (Ruppia maritima) occurred in the estuarine zone (AEC, 1974).

The pool areas of Oyster Creek (the bottom) was described as shifting and unstable. A bottom sample was taken at the U.S. Route 9 bridge on June 11, 1953 in 1.5 m (4.9 ft) of water; the water was very turbid due to suspended detritus. The bottom was composed of fine sand and silt, and the sample contained a dytiscid larva (n = 1) a caddisfly (Molanna sp.) larva (1), and midge larvae (Sawyer, 1953). At the mouth of Oyster Creek, a bottom sampling net collected Gammarus fasciatus (10), and one blue crab was sighted. The only other crustacea reported from the creek were Macrothrix sp. and Cambarus sp. The mean number of organisms per bottom sample was ten. The stream was classified as poor in food. In a more extensive study of the Oswego River, another acidic pine barrens stream, Fikslin and Montgomery (1971) found 27 species of aquatic insects, two species of isopods, and one amphipod.

Despite the relative unproductivity of Oyster Creek, the New Jersey Division of Fish and Game tried to stock rainbow, brown, and brook trout in this coolwater stream (Table 3.5-1). The brook trout was the most successful. It reportedly survived in Estlows and Finingers (an artificial branch dug to create a freshwater "fishfarm") branches of Oyster Creek but did not reproduce. Occasional periods of low pH often caused mortality of trout in the creek.

Fishes collected in Oyster Creek in 1953 were species typical of acidic coastal streams in New Jersey (Table 3.5-1). The AEC (1974) reported the following fishes as indigenous to Oyster Creek and the South Branch of Forked River prior to OCNGS construction: chain pickerel, redfin pickerel, yellow bullhead, creek chubsucker, pirate perch, mud sunfish, orangespotted sunfish, golden shiner, swamp darter, and American eel. The record of an orange spotted sunfish is apparently in error as this species does not naturally occur in New Jersey (Trautman, 1957). The only native sport fishes which utilize the fresh-water portion of Oyster Creek were the American eel and chain pickerel.

On May 24, 1977, a few collections were made with a 4.6 m seine in the unmodified, fresh-water portion of Oyster Creek and the South Branch of Forked River. No fishes were collected in Oyster Creek just upstream from its confluence with the discharge canal. A sample in the South Branch of Forked River, just west of the U.S. Route 9 bridge, took six fishes and one invertebrate: chain pickerel (n = 1), pirate perch (1), eastern mudminnow (3), mud sunfish (4), bluespotted sunfish (7), swamp darter (18), and a crayfish (4). In a collection made farther upstream, pirate perch (1), mud sunfish (1), swamp darter (3), and a crayfish (2) were taken.

White perch, pickerel, and young Atlantic menhaden reportedly concentrated in the brackish portion of Oyster Creek; however, information regarding use of the stream by anadromous alewife was lacking (letter from A. B. Pyle, New Jersey Division of Fish and Game, to R. Hayford, chief of NJ Bureau of Fisheries; May 1, 1964). Zich (1977) reported that both Oyster Creek and Forked River had spawning runs of herrings. However, these runs were not confirmed by documented field observations. Zich (personal communication) mentioned verbal accounts of spawning runs of the alewife in Oyster Creek and Forked River and of spawning of the blueback herring in low-salinity lagoons. During construction of OCNGS, herring were reportedly abundant in the upper canals during the spring (B. Johansen, Public Service Electric and Gas Co., Newark, NJ; personal communication). Some adult blueback herring and alewife were taken from the South Branch of Forked River during the spring of 1976 and 1977. Some of the alewife were ripe. No spawning herrings were sighted or collected in fresh-water areas of either Oyster Creek or the three branches of Forked River during 1976 and 1977. One young alewife was collected in Oyster Creek.

Little information is available on fishes in Barnegat Bay or the estuarine portion of Oyster Creek and Forked River prior to construction of OCNGS. Estuarine and marine fishes were collected by trawl from 1929 to 1933 in Barnegat Bay, the mouth of Forked River, and Barnegat Inlet (Table 3.5-2). Although these collections were incomplete (Thomas and Milstein, 1974) and any conclusions drawn from them are tentative, a few observations are noteworthy. The general species composition is similar to recent trawl collections (Danila, 1977). The tomcod, however, has apparently disappeared from Barnegat Bay, and the Atlantic croaker was more abundant from 1929 to 1933 than in recent years (Danila, 1977).

Marcellus (1972) collected estuarine fishes in a beach seine survey from 1966 through 1970. Although this study occurred during and after OCNGS construction, he sampled fish populations prior to operation of OCNGS and, therefore, the study reflected the pre-operational species composition of shore-zone fishes. Fishes in the shore-zone consisted mostly of forage fishes and young of species which utilized the estuary as a nursery (Table 3.5-3). The community was dominated numerically by relatively few species: the Atlantic silverside, bay anchovy, fourspine stickleback, and tidewater silverside. Although species assemblages and distributions differed somewhat, the structure of the shore-zone fish community was similar to other estuaries in the northeastern United States (deSylva et al., 1962, Pearcy and Richards, 1962).

3.5.2 Fishes in the Intake and Discharge Canal After Construction and Before Operation of the OCNGS

The South Branch of Forked River and Oyster Creek were dredged and modified extensively as an intake and discharge canal, respectively. Dredging was completed in Oyster Creek by December 1966 and in Forked River by April 1967. The canals were connected in April 1967. These modifications destroyed some of the original freshwater and low-salinity habitat. Both creeks became similar in salinity and temperature to the bay. OCNGS operated intermittently for various test periods until December 1969 when it began commercial operation.

Several studies of fishes were made after construction but prior to operation of OCNGS. A list of 57 fishes taken in a haul seine survey by Wurtz (1969) was reported by the AEC (1974). Forage fishes were most numerous, and most other specimens were probably young or juvenile. Two sport fishes, the northern puffer and winter flounder, were numerous during both 1966 to 67 and 1967 to 68.

An extensive survey of the shore-zone fishes of Barnegat Bay was made by Marcellus (1972) from November 1966 through October 1970. It included three years of postconstruction, pre-operational data and about one year of data with OCNGS in operation. Four of his eight stations were in or adjacent to the intake and discharge canals (Figure 3.5-1). Data from these stations from April 1967 through August 1969 were used to analyze the distribution and abundance of fishes in the intake and discharge canals during the pre-operational period. The mean number per collection (n/coll) of selected species was determined for stations 3 through 8 (Tables 3.5-4 to 3.5-9).

Marcellus's catch was dominated by relatively few species. Eighty-seven percent of his total catch was comprised by the four most numerous species, and the ten most abundant fishes made up 97 percent of the total catch. This dominance of the community by relatively few fishes was similar to other estuaries in the northeastern United States (deSylva et al 1962, Pearcy and Richards 1962). Year-to-year variations were found in the occurrence of species, but in general, these differences were not large. However, catches of individual species were numerically variable from year to year and reflected large fluctuations in the abundance of various year classes.

A one-way analysis of variance (ANOVA) was applied to Marcellus's data to determine if the catches in the upper intake canal (Sta. 4) and upper discharge canal (Sta. 6) were significantly different ($P \lesssim 0.05$) from unmodified stations at the canal mouth (3 to 5) and in the bay (7 to 8). Data were log (X + 1) transformed. Significant differences ($P \lesssim 0.05$) among station means were determined by Duncan's Multiple Range Test (Miller and Freund, 1965). Data for the bay anchovy, mummichog, Atlantic silverside, fourspine stickleback, northern pipefish, silver perch, and winter flounder were analyzed. Although catches of the Atlantic herring, tidewater silverside, and northern puffer were large, these data were not analyzed because these fishes usually occurred sporadically.

Few differences occurred between populations of fishes in the canals and the bay during the pre-operational period. The catch of the most abundant fish, the Atlantic silverside, was not significantly different among stations (Table 3.5-10). Although the largest mean catch of bay anchovy was made at the mouth of Forked River, no differences were found among stations 4 through 7; few specimens were taken at station 8. Catch of the fourspine stickleback and northern pipefish was largest at the mouth of Forked River and smallest at the station in the upper intake and discharge canal. Specific habitat requirements of these fishes probably limited their number in the upper canals. The largest mean catch of silver perch was also made at the mouth of Forked River; other stations had similar mean catches. Fewest winter flounder and mummichog were taken at the two stations in the intake canal. Marcellus believed that most stations had similar species assemblages and that most fishes were widely distributed in the bay.

In conclusion, some of the original fresh-water and low-salinity habitat was destroyed, but fresh-water habitat remained in the unmodified areas of Oyster Creek and the South Branch of Forked River. Estuarine fishes and invertebrates occupied the entire length of the intake and discharge canals and seemed to be similar in species composition and number in both canals and in the bay. The station at the mouth of Forked River was particularly productive, except for winter flounder and mummichog.

3.5.3 Summary

Although the historical data are sparse, the aquatic community in the South Branch of Forked River and Oyster Creek prior to their modification as the OCNGS intake and discharge canals, respectively, was apparently similar to other small, acidic, coastal streams in New Jersey. The lower portion of each stream was estuarine. After modification of these streams, both canals were estuarine. Prior to the addition of heat from OCNGS, the fish community was similar between the two canals and was generally typical of fishes in the bay. The upper portion of the South Branch of Forked River and Oyster Creek remained unmodified, and the fishes there were similar to the fishes that occurred naturally in other fresh-water areas of the stream before modification.

REFERENCES

Atomic Energy Commission. 1974. Final environmental statement related to operation of Oyster Creek Nuclear Generating Station. Jersey Central Power and Light Co. Docket No. 50-219.

Danila, D.J. 1977. Effects of the thermal plume on fishes in western Barnegat Bay in the vicinity of Oyster Creek. Pages 62-86 in Preliminary final report of ecological studies for the Oyster Creek Generating Station, September 1975 - August 1976. Vol. I, Part I. Fin- and Shellfish. Ichthyological Assoc., Inc., Ithaca, NY.

de Sylva, D.P., F.A. Kalber, Jr., and C.N. Shuster, Jr. 1962. Fishes and ecological conditions in the shore-zone of the Delaware River estuary, with notes on other species collected in deeper water. Univ. Del. Mar. Lab., Info. Ser., Pub. No. 5. 164 pp.

Fikslin, T.J., and J.D. Montgomery. 1971. An ecological survey of a stream in the New Jersey Pine Barrens. N.J. Acad. Sci. Bull. 16(1-2): 8-13.

Marcellus, K.L. 1972. Fishes of Barnegat Bay, New Jersey with particular reference to seasonal influences and possible effects of thermal discharges. Ph.D. Thesis. Rutgers University, 190 pp.

Miller, G.J. 1977. Impingement on the traveling screens. Pages 9-23 in Preliminary final report of ecological studies for the Oyster Creek Generating Station, September 1975 - August 1976. Vol. I, Part I. Fin- and Shellfish. Ichthyological Assoc., Inc., Ithaca, NY.

Miller, I., and J.E. Freund. 1965. Probability and statistics for engineers. Prentice-Hall, Inc., Englewood Cliffs, NJ. 432 pp.

Pearcy, W.G., and S.W. Richards. 1962. Distribution and ecology of fishes of the Mystic River estuary, Connecticut. Ecology 43(2): 248-259.

Sawyer, D. [1953]. An analysis of benthic invertebrate populations in some New Jersey coastal streams in New Jersey Fisheries Survey. Report No. Four (unpublished manuscript).

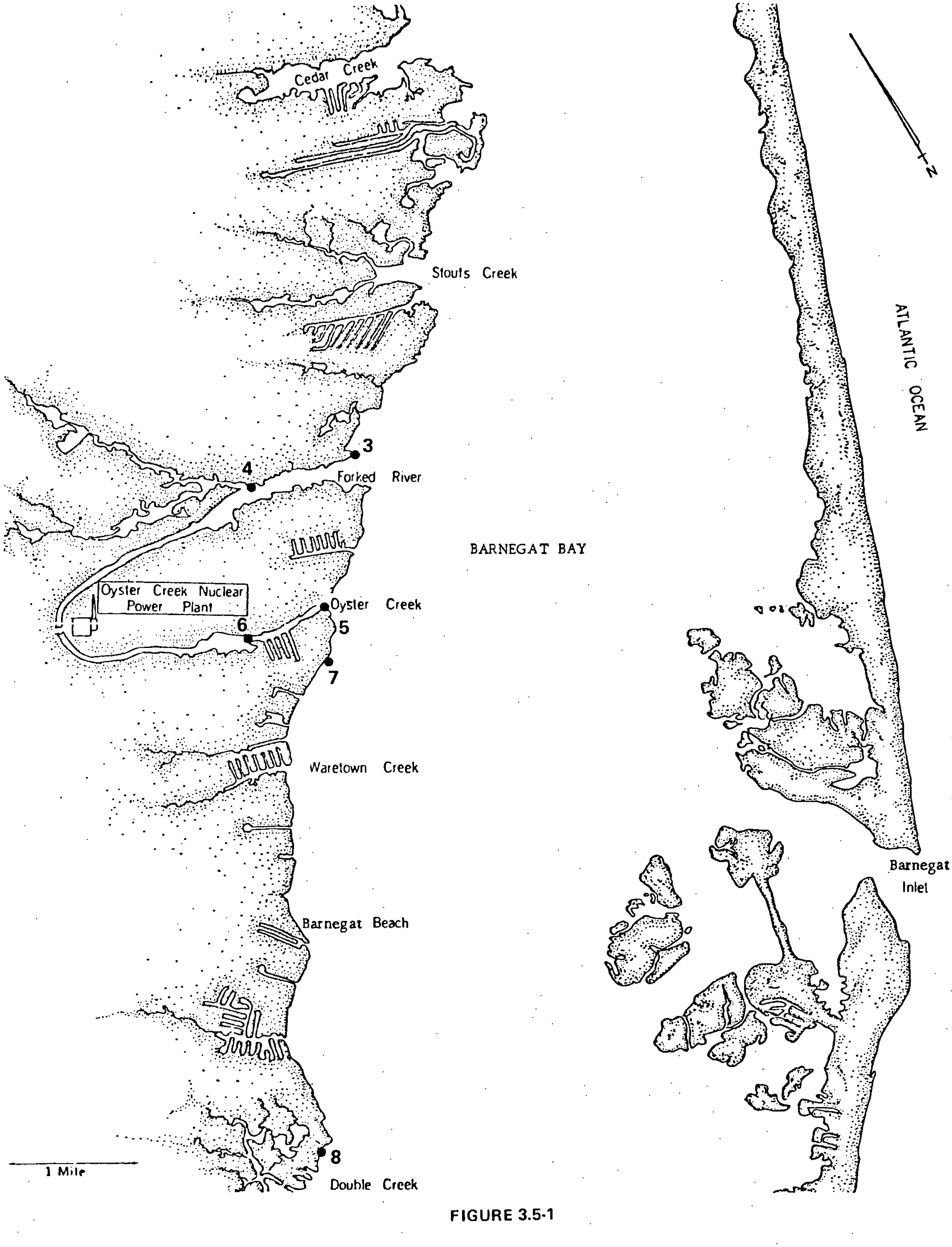
Thomas, D.C., and C.B. Milstein. 1974. A comparison of fishes collected by trawl along the coast of southern New Jersey from 1929 to 1933 with those taken in the vicinity of Little Egg Inlet in 1972 and 1973. Pages 70-75 in Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generation Station, New Jersey. January - December 1973. Vol. I, Fishes. Ichthyological Assoc., Inc., Ithaca, NY. October 1974.

Trautman, M.B. 1957. The fishes of Ohio. Ohio State Univ. Press, Columbus. 683 pp.

Wurtz, C.B. 1969. Barnegat Bay Fish. Report to Jersey Central Power and Light Co. (not seen, cited in A.E.C. 1974).

Zich, H.E. [1977]. The collection of existing information and field investigation of anadromous clupeid spawning in New Jersey. Misc. Report No. 41 (mimeo). N. J. Dept. of Envir. Prot., Div. Fish, Game, and Shellfish. Lar. Fish, Nacote Creek Res. Sta.

FIGURE 3.5-1. Seine stations used by Marcellus (1972).



Cedar Creek
Stouts Creek
3
4
Forked River
BARNEGAT BAY
Oyster Creek Nuclear Power Plant
Oyster Creek
5
6
7
Waretown Creek
Barnegat Beach
8
Double Creek
1 Mile
ATLANTIC OCEAN
Barnegat Inlet
N

FIGURE 3.5-1

Chapter 4

CHAPTER 4: ENVIRONMENTAL EFFECT/IMPACT OF COOLING WATER INTAKE STRUCTURES

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CHAPTER 4: ENVIRONMENTAL EFFECT/IMPACT OF COOLING WATER INTAKE STRUCTURES

The withdrawal of water from coastal estuaries for industrial uses can impact the aquatic community by retaining larger aquatic organisms on the protective screens which precede the circulating-water pumps (impingement) and by the passage of smaller aquatic organisms through the cooling-water system (entrainment). Section 316(b) of the Federal Water Pollution Control Act (33 U.S.C. Section 1326(b)) provides for the protection of the aquatic community by authorizing the establishment of requirements for the location, design, capacity, and construction of cooling water intake structures as part of standards set under Sections 301 and 306 for permitted point sources. The limitations may be established by the permit-issuing authority, under Section 402, or by an agency authorized to issue certifications, under Section 401.

The precise scope of regulation authorized by Section 316(b) is unresolved as of the date of this demonstration. The principal point of contention remaining is whether the statutory authorization to regulate the "capacity" of cooling water intake structures extends so far as to permit the imposition of intake flow limitations which indirectly require the installation of recirculating, or closed-cycle, cooling systems. Opinions of EPA's General Counsel have affirmed EPA's position that it does, but the issue has not yet been addressed by the courts. JCP&L takes the position in this proceeding that Section 316(b) permits only the imposition of requirements to minimize the effect of intake "structures", not cooling system design. The requirements of cooling water flow are determined by cooling system design, which EPA possesses the authority to regulate only under Sections 301, 306 and 316(a).

There are, however, several principals concerning decisions under Section 316(b) upon which there is substantial agreement. The first has to do with the burden of proof to be borne in any proceeding to establish intake structure requirements. Under Section 316(a), the burden is on the permittee to establish by a preponderance of the evidence that a less stringent thermal limitation will be sufficient to satisfy the statutorily mandated requirement of "protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife." Section 316(b), however, provides precisely the reverse -- it is the authority wishing to impose a requirement for intake structures that bears the burden of proving a need for the requirement. (In re Central Hudson Gas & Electric Corp., et al., Decision of the General Counsel No. 63 (July 29, 1977)).

Second, the considerations significant to a determination of intake structure requirements are not limited to the biological impacts of an intake structure on the aquatic community. Section 316(b) requires that intake structure requirements be established so as to "minimize adverse environmental effects" through application of "best technology available." Implicit in the concept of "minimize" and "best" is recognition that a reduction in environmental effects must be balanced against the cost and practicality of obtaining it. Incremental benefits of intake requirements must bear a rational relationship to the costs to be incurred. This is especially important with existing plants, where costs of retrofit may be high, plant capacity may be lost, and, depending on the plant's age and projected useful life, the benefits relatively short-term (In re Central Hudson Gas & Electric Corp., et al., Decision of the General Counsel No. 63; In re Public Service Co. of N.H., Decision of the Administrator Case No. 1 76-7 (June 10, 1977)).

This chapter evaluates the effect of the OCNGS intake structure, and the projected effect of the FRNGS structure, on the biota of the Barnegat Bay area. Section 5.2 reviews some of the alternatives available for modification of the intake structure. Other options to modify, expand or replace the intake structure are under investigation by JCP&L, or will be studied in the event that the impact of the present structure is found unacceptable and already studied alternatives are held to be insufficient remedies. Chapter 6 contains preliminary data assessing the relative cost effectiveness of cooling structure alternatives. While JCP&L does not believe that closed-cycle cooling is within the scope of alternatives which may be required, directly or indirectly, under Section 316(b), the cost effectiveness of such systems also is analyzed in Chapter 6 relative to possible modifications to limit thermal discharges.

As in the case with the Section 316(a) demonstration, the studies assessing the impact of station impingement and entrainment focused on any effects caused to the fish and shellfish populations located in central Barnegat Bay, the area from Good Luck Point to Gulf Point. Also like the Section 316(a) demonstration, assessments of effectrs on bay populations take into account the fact that the area of study is but a part of Barneget Bay and is water connected with other coastal waters and the Atlantic Ocean such that losses experienced by migratory species in the study area may be offset by recruitment from the larger coastal populations.

The common and corresponding scientific names of fishes discussed in this Chapter are given in Table 4.1-1 and 4.1-2.

4.1 Decision Criteria and Overall Rationale

4.1.1 Decision Criteria

Barnegat Bay is a typical mid-Atlantic estuary. Resident fish and shellfish populations (i.e., organisms that utilize the bay during most of the year and during most of their life cycle) use the bay as both a spawning and nursery area. Seasonally migratory fishes utilize the bay primarily as a nursery area, because most of their reproduction occurs in the ocean or in fresh water tributaries of the bay.

The concepts of "minimizing" and "adverse environmental effects" are not defined in Section 316(b), or any other section of the Act. However, considering the potential effects of cooling water intake structures, several criteria may be inferred to guide analysis of data and decisions under Section 316(b). First, mortalities from entrainment and impingement should not be so great as to adversely effect the aquatic populations of the receiving waters. An adverse effect may be defined as a significant reduction -- one greater than naturally occurring variations -- in abundance of important resident species or bay communities. If an adverse effect is found, the significance of the effect must be assessed and evaluated in comparison with the cost of those alternatives available to mitigate it.

If an adverse effect on an aquatic population is not found, the effect of the intake structure on individual organisms should be considered. Virtually any improvement in intake structure design or operation -- up to and including, in EPA's view, closed-cycle cooling systems -- would result in a reduction in individual impacts. While Section 316(b) clearly does not require every modification possible to reduce individual impacts, it may require those which are practical and cost effective. Considering the relatively less significant adverse effect involved, the standards of cost effectiveness which would justify modifications to minimize individual effects would be substantially more stringent than for population effects.

4.1.2. Rationale

The data reviewed below show that the effects of impingement and entrainment at the OCNGS intake have not been so great as to adversely affect the composition, abundance, and seasonal succession of aquatic communities in Barnegat Bay. Based upon comparisons with data from earlier years in Barnegat Bay, and from other estuaries along the Atlantic coast, it is concluded that such changes as have occurred in the bay are within the range of natural variations of estuarine populations.

Variations in populations have been observed throughout the study. Several species in Barnegat Bay have experienced some reduction in abundance since OCNGS began operation, and there is no question that some elements of the bay populations have been directly affected. For example, the lower abundance of planktonic organisms in Oyster Creek than in the Forked River is, most likely, due to entrainment mortalities. It may be that some adverse effects are so subtle that they cannot be observed with the period and intensity of study so far made; however, the available data indicate that the degree and type of changes observed in populations are well within the range of naturally occurring variations observed in similar populations at approximately the same time.

With respect to individual organisms, a sizeable number of mortalities of several species have been observed in the past as a consequence of impingement. Remedial action is being taken to minimize this effect. A modified "Ristroph" type of fish handling system is being installed on one of the OCNGS intake screens. Should it prove operationally feasible and environmentally cost effective, as expected, the remaining intake screens will be modified. Based on experiences with similar systems at other generating stations, the Ristroph system should reduce the rate of impingement mortality of impinged organisms to less than ten percent for most species.

Several methods have been used to analyze the effects of impingement and entrainment mortalities on the bay populations. Population studies of certain species have been conducted in Barnegat Bay to provide a means of evaluating the significace of impingement and/or entrainment mortality on these species. Entrainment mortalities of planktonic organisms commonly are expressed as a percentage of the bay's twelve-hour standing crop, since sampling was performed at OCNGS and in the bay over the same twelve-hour period. Both the entrainment and population data are treated as integrations of the observed abundance over time. The estimated impingement losses of nektonic organisms during the month that the survey was conducted was compared to the estimated populations in the bay, and these losses were expressed as a percent of the bay population.

Direct population surveys are not possible, however, for all species. In these cases, the relative level of populations from year to year can be approximated by comparing commercial fish landings from Barnegat Bay, preoperational catch per unit effort statistics, and data from nearby estuaries and embayments. Data obtained from studies made in Little Egg Harbor and Great Bay have been particularly useful. Each is an estuary generally comparable to Barnegat Bay, but without any significant industrial stress such as might adversely affect their populations. Other useful references include the Indian River estuary and Chesapeake Bay. Data from the recreational fishery in New Jersey and throughout the mid-Atlantic region were used to gain perspective on some impingement losses.

In analyzing the effect of entrainment mortalities on bay populations, computation of changes at the adult population level from larval losses is quite difficult. Very little is known about the natural survivorship of sub-adult to adult stages. An indirect method of analysis based upon a comparison of meroplanktonic and adult population densities between comparable estuaries does provide an assessment of population effects. If the composition, seasonal succession, and either absolute or relative abundance of plankton in Barnegat Bay are approximately the same as those for a comparable relatively unstressed estuary having a balanced, indigenous aquatic population, it may be concluded that the entrainment mortalities consequent to OCNGS operation have not adversely affected the populations of Barnegat Bay.

Although the effects of the OCNGS and the FRNGS intake structure were discussed as the discrete effects of impingement and entrainment, it is often difficult to separate the overall effect of the intake structure on populations of organisms in the bay into a component that is attributable to impingement and one attributable to entrainment. For fishes seasonally present and fishes that have little or no reproduction in the Bay (Atlantic menhaden, striped bass, bluefish, weakfish, spot, northern kingfish, striped searobin, smallmouth flounder, and summer flounder), the major effect of OCNGS and FRNGS is due to impingement, and the effect of the two stations on these species is discussed in Section 4.2. The eggs and larvae of the alewife and blueback herring which spawn in the freshwater portion of some tributary streams, are not entrained at OCNGS, and the major effect on these species is through impingement (Section 4.2). Similarly, impingement has the greatest effect on the horseshoe crab because the eggs are laid in sand and the larvae are not common in the plankton (Meglitsch 1967).

Impingement mortalities do not adversely affect bay populations. Mortalities to individual species should be substantially reduced by the Ristroph modifications to the OCNGS intake structure, which are now under study.

For zooplankton and macroinvertebrates, the greatest effect of the OCNGS, and potentially greatest effect of FRNGS, is through entrainment of one or more life stages of these species through the cooling-water system. Although many adult sand shrimp (3.8 million) and grass shrimp (0.37 million) were impinged at the OCNGS, many more (168 million and 78.4 million, respectively) were passed through the cooling-water system. The significance of entrainment on zooplankton and macroinvertebrate populations in the bay is discussed in Section 4.3. These data demonstrate that the estimated losses at the OCNGS and the projected losses at the FRNGS should not noticeably affect these populations. No cost-effective modifications are available to minimize individual species mortalities.

For some resident fishes (e.g., Atlantic silverside, threespine stickleback, northern pipefish, and winter flounder) intake effects are multiple. Juveniles and adults are impinged on the intake screens, and larvae and small juveniles are entrained through the cooling-water system. The relative significance of these effects is species specific. For the northern pipefish and winter flounder, the greater effect may be through entrainment because less than 1 percent of the estimated number in the central portion of the Bay are calculated to have been lost through impingement at the existing traveling screens, and this loss should be reduced with Ristroph screens.

In 1977, the estimated percentage of larvae and juveniles of the northern pipefish that would have been entrained at the two stations ranged from 1.3 percent to 24.2 percent of those in the central portion of the bay. The breadth of the range is a consequence of the patchy distribution of these individuals in the bay. Percentages would, of course, be highest when a high concentration of larvae is found near the mouth of the Forked River. But this would be relatively infrequent; based on sampling of larvae in this area, the entrainment would have been 5 percent or less of the population on four of five days.

Although the catch of the northern pipefish has declined at three sampling stations in the western Bay since 1966-69, the decline may be attributed to a decrease in vegetation near these points rather than to a decrease in abundance of the northern pipefish throughout the bay. The trawl catch in Barnegat Bay during 1975-77 was similar to or greater than that in a similar New Jersey estuary from 1972 through 1974. From these data it may be concluded that the combined effects of impingement and entrainment should not adversely effect the bay population. Ristroph screens should substantially reduce impingement mortalities. No other modifications can be cost justified.

Although the winter flounder population in Barnegat Bay has been at a low level in recent years, this decline in abundance probably is related to environmental factors rather than entrainment losses. Similar reductions in populations have been observed over the same period in other New Jersey estuaries. Jeffries and Johnson (1974) showed a strong correlation between the decline of the winter flounder population in Narragansett Bay from 1968 through 1972 and the relatively mild winters during these years. With the exception of 1976-77 and 1977-78, southern New Jersey also experienced mild winters in recent years, and this climatic phenomenon may explain the population reductions.

This explanation is further supported by the dramatic increase in the number of young produced immediately after the severe winter of 1977. Because relatively few young were produced in 1976 when 0.5 percent of the larvae that hatched in the bay were entrained at the OCNGS, and because substantially more young were produced in 1977 when 10.4 percent of the larvae in the bay were entrained, the number lost at OCNGS did not appear to be the dominant factor in the number of young subsequently produced. Therefore, it does not appear that the entrainment losses at the OCNGS have harmed the local winter flounder population. The projected incremental losses resulting from the FRNGS operations (an additional 0.9 percent in 1977) should not alter existing conditions.

The threespine stickleback is seasonally present in the bay. Very few specimens have been collected, but its distribution should be similar to the northern pipefish, which is found principally in areas having substantial vegetation. Thus, most juveniles, and adults of the threespine stickelback are found in the vegetated eastern portions of the bay and are not susceptible to either impingement or entrainment. Losses of these few individuals at the OCNGS and the FRNGS will not adversely affect the population in the bay.

As the most numerous fish in the bay, many adult bay anchovy were impinged, and many eggs, larvae, and juveniles were entrained. The population throughout most of the bay is large and the estimated percentage of organisms which would have been impinged at both OCNGS and FRNGS is rather low (2 percent and 11 percent) for the two months in which population surveys were conducted.

Entrainment rates also are low. In 1976, about 5.1 percent of the bay anchovy eggs spawned in Barnegat Bay would have been entrained in OCNGS and FRNGS. The number of larvae entrained during a 12-hour period in 1977 would have ranged from 1.1 percent to 16.6 percent, and was below 8 percent on three of four days. But these estimates are relatively conservative. Although the estimate of percentage of eggs entrained during a spawning season was considered to be accurate, the estimates of larvae, juveniles, and adults affected by the stations were understated because limitations of sampling made population estimates low.

It is unlikely that the impingment and entrainment losses will adversely affect the seasonal population of the bay anchovy in the bay, and it will have no effect on the larger population along the mid-Atlantic coast. The catch of young (age 0+) and adults at two of three stations in the bay has not decreased substantially since the OCNGS began operation (Section 3.2.4), and the densities of eggs and larvae in the bay were not different from those in nearby New Jersey estuaries. In light of its continued dominance of the fish community, and of the similar abundance of all life history stages to densities either in the bay from 1966-69 or in other New Jersey estuaries, it must be concluded that the cooling-water system effects of the OCNGS, and the small incremental losses anticipated for the FRNGS, have not and will not adversely affect the bay anchovy population.

Many Atlantic silverside were lost through impingement and entrainment, but the recent (1975-76) catch of this species in seine collections in the bay was not less than the lowest catches reported prior to 1969 (Section 3.2.4). There are no data available to indicate what changes in population occurred between 1969 and 1975, but a decline in population to 1975-76 could reasonably have been predicted from population reductions observed in other New Jersey estuaries at approximately the same time. For example, the population in nearby Great Bay decreased from 1972 (242/seine collection) through 1974 (82). From these data it reasonably may be inferred that the present central bay population is within the range of natural variation, that the observed reductions are attributable to natural conditions, and, therefore, that the OCNGS has not had an adverse population effect.

Many goby larvae were entrained at the OCNGS. Very few adults were impinged, however, because they remain among bivalve shells and along banks, their preferred habitat, and are not common in the water column. Populations are localized, and the reproduction of this species is a result of numerous localized populations throughout the bay. Since larvae are found near these localized populations, few larvae from areas other than the immediate vicinity of Forked River would be entrained. Since the population in the intake canal has been sustained despite the entrainment losses, it must be concluded that the OCNGS has not had an adverse affect even on the local population. Even if there is an effect on the local population of the intake canal, however, this is essentially a new addition to the bay population (until construction of the intake canal, this area of Forked River was not habitable by gobies) and a significant reduction of the Forked River population would not adversely affect the natural, indigenous population of the bay.

The few northern puffer impinged or entrained at the OCNGS reflected the low population level of this fish in New Jersey in recent years. This was documented in Barnegat Bay before OCNGS began operation, in other New Jersey estuaries, and in the Delaware Bay sport fishery. Because of the low population level, it was not possible to evaluate the effect of the two generating stations by estimating the population of adults and larvae in the bay. But even when this species becomes abundant again, impingement losses should not be great since immediate survival of impinged fish was high (90 percent). Because it spawns in estuarine and ocean waters (Lippson & Moran 1974) significant entrainment is unlikely, furthermore, other fishes in the bay which employ a similar reproductive strategy, such as Atlantic silversides and winter flounder, have not experienced a decrease in bay populations which are attributable to OCNGS entrainment losses. Impingement losses would not adversely affect the bay population and, to the extent that they do occur, may be offset by recruitment from the larger coastal population.

While the study results indicate that substantial numbers of blue crab have suffered mortality as a result of the OCNGS operation, comparisons of the abundance of the bay population to historical data and a comparision of the population structure to that of populations from other estuaries indicate that these losses have had an adverse effect. Although survival is high among impinged blue crabs, an estimated 0.6 percent to 3.8 percent of the blue crab in the central portion of the bay would be lost during a month as a result of both OCNGS and FRNGS operations. Few (<0.5 percent) of the megalopae in the bay were entrained. However, the number of zoeae which would pass through the OCNGS and the FRNGS in a 12-hour period would range from 2.9 percent to 22.7 percent of the population in the central bay.

Despite the size of these numbers, they must be assessed in view of any observed population changes. And, overall, no evidence exists that the OCNGS operation has reduced the standing crop or substantially affected the population in the Bay. Although commercial landings are a somewhat biased statistic and do not always reflect the actual population level, the reported commercial landings in the bay have not decreased since the OCNGS began operation. Indeed, the largest reported commercial landings were from 1973 through 1976, while OCNGS was in operation. Additionally, the age structure of the blue crab population is similar to that of the population in Great Bay, New Jersey. Although relatively small changes in abundance would be difficult to discern because little preoperational data are available, reductions in abundance and changes in the age structure of the population on the order of those produced by the large natural mortality of the blue crab during the winter of 1976-77 have not occurred.

The addition of Ristroph screens to the OCNGS intake should reduce substantially the individual mortalities of blue crab resulting from impingement.

Meroplanktonic stages (eggs and trochophore, straight hinge, and umbo stage larvae) of the northern quahog, Mercenaria mercenaria, are susceptible to entrainment effects of the OCNGS and FRNGS. Because the species spawns predominantly in the summer months, most eggs and larvae of the clam are entrained during this season. In 1976, 1.14×10^{11} straight-hinge and umbo-stage larvae of the northern quahog were entrained, and in 1977, 1.86×10^{9} were entrained. The number of eggs and trochophore larvae entrained could not be determined because of the inability to identify these stages to the species level.

Based on heat shock experiments conducted in the laboratory by Kennedy et al., (1974), most cleavage-stage eggs and about 50 percent of the trochophore larvae of M. mercenaria entrained during the summer of 1976 probably died. Mortality of straight-hinge and umbo larvae was probably less than 10 percent, and with this high percentage of survival, at least 1.03×10^{11} straight-hinge and umbo larvae were alive after passage through OCNGS.

The large numbers of straight hinge and umbo larvae passing through the OCNGS should not preclude successful recruitment of this species in the bay. Data from Kennish (1977) show that a population of M. mercenaria set at the mouth of Oyster Creek in the early 1970's when the OCNGS was in operation. This suggests that larvae surviving passage through the condenser and dilution system of the OCNGS have successfully set at the mouth of the Oyster Creek in the past. It is unlikely that poor recruitment of this species in the bay during the 1970's is caused by operation of the OCNGS. Operation of the FRNGS also should not preclude successful recruitment of the hard clam in the estuary.

Because M. mercenaria is a representative important species for the Section 316(a) demonstration (Section 3.1.6) and because it is the most commercially important bivalve in the bay, additional population studies on this species will be conducted in the summer of 1978.

Although some changes in the species composition and relative abundance of fishes have occurred in the bay since 1969, these changes do not appear to be related to the operation of the OCNGS. Similar increases (i.e., spot) and decreases (i.e., Atlantic silverside, northern kingfish, winter flounder, northern puffer) have occurred in other mid-Atlantic estuaries. Considering the geographical extent of these changes, it must be concluded that they are related to environmental factors which influence the abundance of these species along the whole mid-Atlantic coast. The overall structure of the fish community in 1975-77 (Section 3.2.4) was similar to the community in the bay prior to operation of the OCNGS (Marcellus, 1972), and the communities in other mid-Atlantic estuaries (Milstein et al., 1977; deSylva et al., 1962; Richards and Castagna, 1970; Oviatt and Nixon, 1973; McErlean et al., 1973). Because the balanced indigenous community of fishes in the Bay has remained intact since the operation of the OCNGS, it is concluded that the impingement and entrainment losses at the OCNGS have not had an adverse impact on the bay's aquatic community, and the relatively small additional losses at FRNGS should not alter this.

4.2 Impingement

The vertical traveling water screens which precede the circulating-water pumps will affect aquatic organisms by their entrapment, or impingement on the screens. To evaluate this phenomenon at the OCNGS and FRNGS, I.A. has collected extensive impingement data at the OCNGS traveling water screens since September 1975. These studies have documented the abundance and mortality of all fishes and macroinvertebrates impinged during periods of sampling. Analyses of these studies have focused on fishes and invertebrates designated as representative important species by the EPA Regional Administrator (Section 3.1) and on other abundant organisms. The effects of impingement at the OCNGS and the FRNGS were judged according to the decision criteria discussed in Section 4.1.1.

4.2.1 Rationale

No evidence exists that the losses of organisms through impingement on the existing vertical traveling water screens at the OCNGS have had a discernible effect on either the individual fish and macroinvertebrate populations or the fish community in Barnegat Bay. Increases and decreases in the abundance of populations in the bay were attributable to natural fluctuations in abundance rather than to losses at the OCNGS. Variations in populations observed in the Barnegat Bay area were similar to those that occurred in other estuaries outside the influence of OCNGS at approximately the same time.

Apart from population impacts, individual mortalities have been of concern to JCP&L. However, changes to the intake structure and fish return system are expected to reduce losses substantially. The discharge of the traveling screen wash into the discharge canal has been diverted from near the condenser discharge to the dilution pump discharge. This diversion has eliminated the initial heat shock to organisms washed from the screens and allowed organisms a lower temperature pathway from the discharge canal.

The installation of vertical traveling water screens with a fish lift and return system (Ristroph screens) now is under study by JCP&L and, if it is proven to be opertionally feasible, will be installed at OCNGS. The effect of Ristroph screen use should be to reduce mortalities to less than 10 percent by reducing the time an organism is impinged, keeping impinged organisms in water, and gently returning them to ambient temperature water. Immediate survival of estuarine fishes impinged on Ristroph screens at the Surry plant in Virginia generally has been over 90 percent (White and Brehmer 1977). This change would "minimize" adverse environmental effects;

no other changes would be cost effective. Additional impingement mortalities which may result from the operation of FRNGS should not alter the population balance, although impingement losses with the two stations in operation should be slightly larger than percent losses with OCNGS alone.

The most abundant fishes and macroinvertebrates impinged from September 1975 through August 1977, in numerical order, were the blue crab, sand shrimp, bay anchovy, grass shrimp, Atlantic menhaden, spot, Atlantic silverside, smallmouth flounder, striped searobin, and blueback herring. Invertebrates comprised 79 percent and fishes 21 percent of approximately 13 million specimens impinged. Regression analysis of impingement versus OCNGS operation and other environmental data indicated that time of day, cooling-water flow, and water temperature accounted for 56 percent of the variation in the number of impinged organisms of all species. Overall, most (83 percent) specimens were impinged at night. But, for individual species, the rate varied from 96 percent for the smallmouth flounder and striped searobin to 58 percent for the Atlantic silverside.

Impingement of most fishes occurred during seasonal migrations in the bay rather than when fish were most abundant. For example, the Atlantic menhaden was found in the bay from March through December, but in 1976 an estimated 72 percent of the annual impingement was in October and November. Although the bay anchovy was present in the bay from March through November, most were impinged during April and May in 1976.

For 13 of 16 species statistically analyzed, the estimated number impinged during seven comparable months of 1976 and 1977 was significantly different ($P \leqq 0.2$). Some of the larger differences were for the Atlantic menhaden (17,788 in the first year; 94,960 in the second), bay anchovy (1.8 million; 147,202), bluefish (14,086; 3,935), smallmouth flounder (8,022; 57,713), winter flounder (3,908; 18,618), grass shrimp (373,288; 29,885), sand shrimp (3.3 million; 600,278), and blue crab (5.6 million; 230,691). Although some of these differences probably were due to differences in OCNGS operation, most were attributable to natural variations in population abundance.

The estimated immediate losses of impinged fishes were often high for the existing screens, but these losses would be much lower with the Ristroph screens: blueback herring (65 percent immediate loss with existing screens, 9.6 percent projected immediate mortality with Ristroph screens), Atlantic menhaden (88 percent, 5.1 percent), bay anchovy (96 percent, 18 percent), Atlantic silverside (55 percent, 6 percent), bluefish (54 percent, 14.7 percent), weakfish (61 percent, 41 percent), and spot (59 percent, 3.3 percent).

The estimated number of Atlantic menhaden, bluefish, weakfish, and summer flounder lost through impingement on the existing screens were inconsequential in relation to the commercial and recreational catch in New Jersey. Population surveys were made in the central portion of Barnegat Bay to determine what percentages of the standing crop in this area of the bay were lost through impingement at the OCNGS during a month. The percentages ranged from 2 percent to 10 percent for the bay anchovy; from 0.6 percent to 3.6 percent for the blue crab, and less than 1.5 percent for the northern pipefish, winter flounder, and sand shrimp. With Ristroph screens in operation, these percentage losses should be even less.

4.2.2 OCNGS Impingement Effect

4.2.2.1 Species, number, and mortality of impinged organisms

The estimated number and weight of impinged organisms at the OCNGS were determined from September 8, 1975 through September 2, 1977. No samples were taken from December 24, 1975 through March 7, 1976 or from May 14, through July 12, 1977 because OCNGS was not operating and did not circulate water. During the study period, vertical traveling water screens were in use at the OCNGS, as described in Appendix A3.

For many species, substantial differences existed between the estimated number of organisms impinged during the two study periods, September 8, 1975 to September 1, 1976 and September 1, 1976 to September 2, 1977. Although some of the differences (i.e., bay anchovy, bluefish, winter flounder, northern puffer, grass shrimp, sand shrimp, and blue crab) may be partially attributable to the lack of collections during the two OCNGS shutdowns, many represented natural variability in population abundance between years. A comparison of the estimated number impinged during seven comparable months between the two years indicated a significant difference ($P \leq 0.2$) for 13 of 16 species (Table 4.2-1). During four of these comparable months, the velocity in front of the trash racks from September through December 1975 (three circulating water pumps, mean water velocity of 0.06 to 0.12 m/sec, 0.20 to 0.39 ft/sec) was lower than the velocity from September through November 1976 (four pumps, 0.18 to 0.20 m/sec, 0.60 to 0.66 ft/sec). It could not be determined what portion of the higher impingement of Atlantic menhaden, bluefish, weakfish, spot, and smallmouth flounder during these months in 1976 was attributable to the higher intake velocities and water volume and what portion was attributable to real differences in abundance. For seven species (i.e., bay anchovy, Atlantic silverside, northern pipefish, summer flounder, grass shrimp, sand shrimp, and blue crab) these differences in the number impinged during the seven comparable months between the two years were real differences in abundance.

A stepwise multiple regression analysis was applied to the data from the first year to examine the relationship between impingement of RIS (Section 3.1) and various physical factors. The number of specimens impinged per hour (a dependent variable) due to water temperature, salinity, dissolved oxygen, pH, time of day, wind speed, number of screens in operation and water flow (independent variables) was calculated with the generalized regression equation:

$$Y = a + b_1 x_1 + b_2 x_2 + \ldots\ldots + b_n x_n + \hat{e}$$

Y = natural log of the number of specimens impinged per hour

a = constant

b_1, b_2, ... b_n = the regression coefficients

x_1, x_2, ... x_n = the independent variables

$\hat{e}$ = error term

Time of day was recorded so that the period of greatest impingement had the largest value (Period 2 = 1, Period 1 = 2, Period 4 = 3, and Period 3 = 4). For wind speed, the greatest speed had the highest value: calm = 1, light (1 to 9 mph) = 2, moderate (10 to 25 mph) = 3, and heavy (25+ mph) = 4. The natural logarithmic transformation of the dependent variable was used to help reduce skewness, approximate normality, and change any curvilinear relationships to linear (Sokal and Rohlf, 1969).

Results of this analysis indicated that time of day, cooling-water flow, and water temperature accounted for 56 percent of the variation in the impingement of all specimens. Overall, most (83 percent) specimens were impinged at night. For individual species, the night time impingement rate varied from 96 percent for the smallmouth flounder and striped searobin to 58 percent for the Atlantic silverside. The increase of impingement at night was related to a combination of factors such as diel activity patterns and reduced visibility of the intake structure to aquatic organisms at night.

Impingement of most fishes (i.e., Atlantic menhaden, bay anchovy, Atlantic silverside, northern pipefish, bluefish, weakfish, summer flounder, and winter flounder) occurred when these species were seasonally migrating in the bay rather than when they were most abundant. Therefore, most fishes were impinged when the water temperature was seasonally increasing (spring) or decreasing (fall) because changing water temperature was correlated with the movement of specimens either into, out of, or within the bay.

Water flow at the screens was primarily related to the number of circulating-water pumps in operation. Although the mean intake velocity in front of the trash racks was higher with four pumps than with three pumps in operation with all screens open, it was difficult to discern what portion of any difference between years was attributable to increased water flow and intake velocity, and what part to greater abundance of organisms in front of the screens. At the P.H. Robinson Generating Station in Texas, however, Chase (1975) believed the difference in the number of organisms impinged between two adjacent generating units was caused in part by differences in average maximum approach velocity.

The most abundant fishes and macroinvertebrates impinged from September 1975 through August 1977, in numerical order, were the blue crab, sand shrimp, bay anchovy, grass shrimp, Atlantic menhaden, spot, Altantic silverside, smallmouth flounder, striped searobin, and blueback herring (Table 4.2-2). Invertebrates comprised 79 percent (10,245,070 organisms) and fishes 21 percent (2,721,410) of the specimens impinged. The methodology used to calculate the number impinged annually is presented by Tatham et al. (1978a).

The immediate and 48-hour delayed mortality of organisms impinged on the existing vertical traveling screens was determined. Because mortality of some organisms varied seasonally, the number of organisms lost during a month was calculated by multiplying the estimated number impinged by their percent mortality during that month. The number lost during each month was summed to estimate the total number lost during the two years. This total differed slightly from the sum of the two annual estimates (Table 4.2-3) because of the different estimating techniques. Available delayed mortality data were used to calculate the additional mortality of organisms which survived impingement.

Data from White and Brehmer (1977) were used to estimate what the immediate mortality of impinged fishes would have been if Ristroph screens had operated at the OCNGS during this period. However, the immediate mortality of some species and delayed mortality data for all species impinged on Ristroph screens could not be estimated because no data were available.

The number, mortality, and factors affecting the impingement of abundant species and of the RIS of the fishes and macroinvertebrates at the OCNGS are discussed below in phylogenetic order.

4.2.2.1.1 _Alosa_ _aestivalis_ (blueback herring)

An estimated 28,120 blueback herring were impinged during the first year; 27,496 were impinged during the second year (Table 4.2-3). Some 37 percent of the variation of the impingement of the blueback herring was accounted for by increases in the water flow, time of day (day to night) and by decreases in oxygen level and water temperature. Eighty-two percent of the blueback herring were impinged at night. Although the species was impinged throughout the year, most specimens (66 percent) were impinged during December and 94 percent were collected at a temperature of -1 to 12°C (30.2° to 53.6°F). Few were taken from June through November.

A projected total of 36,137 blueback herring (65 percent of those impinged) were lost from immediate (23,104) and delayed (13,033) mortality (Table 4.2-4). If Ristroph screens were in operation at OCNGS, an estimated 9.6 percent of all blueback herring (5,339) would have died immediately after impingement (Table 4.2-5) and immediate mortality would have been reduced by about 77 percent.

4.2.2.1.2 <u>Brevoortia</u> <u>tyrannus</u> (Atlantic menhaden)

An estimated 17,788 Atlantic menhaden were impinged during the first year, and an estimated 94,960 during the second (Table 4.2-3). Higher intake velocities and water flows occurred through the screens from September through December 1976 than during comparable months in 1975, and this species was substantially more abundant in the bay during the second year (1.21/ trawl collection in 1976-77) than in the first year (0.04).

A decrease in pH and an increase in wind speed and time of day (day to night) accounted for 31 percent of the variability in the impingement of the Atlantic menhaden with the multiple regression analysis. Eighty-four percent of the Atlantic menhaden were impinged at night. The Atlantic menhaden was collected throughout the year, but most specimens (72 percent) were impinged in 1976 during its emigration from the bay in October and November; 87 percent of the Atlantic menhaden were taken at a temperature of 0 to 13°C (32 to 55.4°F).

Ninety-eight percent (110,448) of the impinged Atlantic menhaden were lost due to immediate (31,822) and delayed (78,626) mortality (Table 4.2-6). The addition of Ristroph screens should reduce the immediate mortality by 82 percent. If Ristroph screens were in operation, only 5.1 percent (5,750) of the Atlantic menhaden would have been lost immediately after impingement during this study period (Table 4.2-5).

Most specimens examined from collections at the OCNGS screens were age 0+ (18 percent of all specimens, mean length of 101 mm, 4 in.), age 1+ (12 percent, 190, 7.6), age 2+ (39 percent, 212, 8.3), age 3+ (26 percent, 228, 9), or ages 4+ through 6+ (5 percent); 80 percent of the Atlantic menhaden were immature. All young (age 0+) and age 1+ fish, and 96 percent of age

2+, 59 percent of age 3+, and 4 percent of age 4+ individuals were immature. All age 5+ and 6+ fish were mature. Although age 3+ females were significantly larger (239 mm, 9.4 in.) than age 3+ males (231, 9.1 in.), no significant difference in length by sex was noted for young, age 1+, age 2+, and age 4+ specimens. Although females significantly outnumbered males for the year and during December, this ratio was not significantly different than 1:1 from April through August.

4.2.2.1.3 *Anchoa mitchilli* (bay anchovy)

An estimated 1,811,750 bay anchovy were impinged during the first year, but only 147,202 were impinged during the second (Table 4.2-3). This is the reverse of the case of Atlantic menhaden, when more than five times as many were impinged in the second year than in the first. Although this difference may be partially due to the lack of sampling during the 1977 shutdown of the OCNGS from late April to mid-July, the number of bay anchovy which returned to the bay in 1977 apparently was much smaller than the large population which entered the bay during 1976. The catch by trawl (63.3/coll) and seine (40.76) in 1975-76 also was greater than these catches (42.43, 3.67 respectively) in 1976-77. A decrease in water temperature, salinity, and number of screens in operation and an increase in pH, wind speed, time of day (day to night), and water flow accounted for 61 percent of the variation in bay anchovy impingement. About 63 percent of the specimens were taken at night. Few bay anchovy were collected from January through March because this species was not present in the bay. Most (84 percent) were impinged during April and May 1976, and 92 percent of the impinged bay anchovy were collected at a temperature of 9 to 22°C (48.2 to 71.6°F).

An estimated total of 1,873,109 bay anchovy (96 percent of those impinged) were lost due to immediate (1,506,768) and delayed (366,341) mortality (Table 4.2-7). Ristroph screens should reduce immediate mortality by 77 percent, and only an estimated 18 percent of all individual fish (352,575) should have died immediately after impingement if Ristroph screens were used at the OCNGS (Table 4.2-5).

4.2.2.1.4 *Menidia menidia* (Atlantic silverside)

A projected 61,272 Atlantic silverside were impinged during the first year and 35,051 during the second (Table 4.2-3). This decrease in the number impinged during the second year reflected, in part, a decrease in the number of Atlantic silverside in the bay. Both the trawl (4.02/coll) and seine (38.62) catch in 1975-76 were greater than the catch (0.12, 19.0 respectively) in 1976-77. Impingement of the Atlantic silverside increased as water temperature decreased and water flow increased. These two variables in the multiple regression analysis accounted for 38 percent of the variability in the impingement of this fish. Fewer were impinged during the day (42 percent) than at night (58 percent). Forty-eight percent of all Atlantic silverside were impinged during December 1975 and March 1976. Impingement was probably greatest at these times because this fish was moving within the bay. Generally, few were impinged during January and February and from May through October, even though this species was abundant during the latter period. Ninety-five percent of the Atlantic silverside were taken at a water temperature of -1 to 14°C (30.2 to 57.2°F).

An estimated 53,395 Atlantic silverside (55 percent of these impinged) were lost due to immediate (39,073) and delayed (14,322) mortality (Table 3.2-8). Operation with Ristroph screens should result in an immediate mortality of approximately 6 percent. Thus, only an estimated 5,779 Atlantic silverside (an 85 percent reduction in immediate mortality) should have been lost if Ristroph screens had been in operation from September 1975 through August 1977 (Table 4.2-5).

4.2.2.1.5 Gasterosteus aculeatus (threespine stickleback)

Few (414) threespine stickleback were impinged during the two years of study. All were impinged from February through June, and most specimens (65 percent) were impinged in March. About 68 percent were taken at night. Few (1 of the 30 threespine stickleback specifically examined) were dead immediately after collection.

4.2.2.1.6 Syngnathus fuscus (northern pipefish)

Some 36,066 northern pipefish were impinged during the first year and 11,220 during the second year (Table 4.2-3). Although the catch by trawl and seine were similar between the two years, this difference in number impinged between the two years appears to result from a real difference in the abundance of this species because more were impinged during the fall of 1975 (lower intake velocity) than during the fall of 1976 (higher intake velocities, Table 4-9). About 33 percent of the variation in the impingement of this species was accounted for by the variables in the multiple regression analysis. Decreases in water temperature and increases in oxygen level and time of day (day to night) accounted for this amount of variability. Seventy-nine percent of the specimens were impinged at night. Northern pipefish were impinged during every month but February, but most (51 percent) were impinged during December 1975 and during March and April 1976 when this species was moving within the bay. Eighty-four percent of the specimens were impinged at a water temperature of 4 to 17°C (39.2 to 62.6°F).

A total of 11,693 northern pipefish (25 percent of those impinged) were calculated to have been lost through immediate (1,877) and delayed (9,816) mortality (Table 4.2-9).

The mean size of the northern pipefish impinged at OCNGS was generally larger than fish from other areas because the mesh of the traveling screens was larger than the mesh of the seines and trawls. Gravid males comprised 56 percent of all males collected from the Forked River, the bay, and the discharge canal, but only 36 percent of all males impinged at OCNGS. Most gravid males were taken in May and June. The northern pipefish is short-lived, and most individuals impinged were young (age 0+) or age 1+.

4.2.2.1.7 Morone saxatilis (striped bass)

Only three striped bass were impinged during the two years of this study. This was too small a number from which to make any substantial analysis of impingement rates, mortalities, etc. These three fish were impinged during a five-day period in March 1977.

4.2.2.1.8 Pomatomus saltatrix (bluefish)

An estimated 14,086 bluefish were impinged during the first year but only 3,935 during the second (Table 4.2-3). Because specimens (61 percent) were impinged during May and June 1976, the lower number during the second year undoubtedly was attributable to the OCNGS shutdown during May and June of 1977. Most of the individuals impinged were small young (age 0+). These were probably spawned along the Carolina and Virginia coast and entered the bay during May and June. Seventy-eight percent of the impinged bluefish were collected at a water temperature of 17 to 28°C (62.6 to 82.4°F). Thirty-three percent of the variation in impingement was accounted for in the multiple regression analysis by decreases in the number of screens in operation and increases in water flow. About 66 percent of the bluefish were impinged at night.

An estimated total of 9,781 bluefish (54 percent of those impinged) were lost to immediate mortality (Table 4.2-10). No estimate of the delayed mortality was available because few individuals were held after impingement. If Ristroph screens were in operation, only about 14.7 percent of the bluefish (2,649) should have died immediately after impingement. This would have been a 73 percent reduction in immediate mortality (Table 4.2-5).

The size of impinged fish increased each month from May (mean length of 44 mm, 1.7 in.) to December (206 mm, 8.1 in.). In July and August, two size groups of young (age 0+) were collected indicating a contribution of small young from offshore New Jersey waters. All bluefish were immature, and significantly more males than females were collected.

4.2.2.1.9 Cynoscion regalis (weakfish)

An estimated 11,790 weakfish were impinged during the first year and 27,297 during the second year (Table 4.2-3). The higher mean velocity and water flows through the trash racks during the fall of 1976 (Section 4.2.2.1) and the greater abundance of this species during the second year (1975-76 trawl catch of 0.25/coll, 1976-77 catch of 0.78/coll) may be partially responsible for the increased number of weakfish impinged during the second year. Most (47 percent) were taken during October 1976, and few were impinged from December through July. Eighty-three percent were impinged at a water temperature of 11 to 26°C (51.8 to 78.8°F). About 21 percent of the variation in impingement was accounted for in the multiple regression analysis by decreases in salinity and by increases in time of day (day to night), pH, and water flow. Eighty-two percent were impinged at night.

A total of 23,836 weakfish (61 percent of those impinged) were estimated to have died immediately after impingement (Table 4.2-11). Few weakfish were held for delayed mortality studies, and, therefore, no estimate of this mortality was available. If Ristroph screens were in operation, losses from immediate mortality should have been reduced by approximately 33 percent, and a projected 15,947 fish should have died immediately after impingement (Table 4.2-5).

Young (age 0+) of the weakfish comprised 99 percent of those impinged. During 1975, the modal length of fish taken at OCNGS was 60 to 70 mm (2.4 to 2.8 in.) in September, 70 to 80 mm (2.8 to 3.2 in.) in October, and 130 to 160 mm (5.1 to 6.3 in.) in November. All impinged weakfish were immature.

4.2.2.1.10 Leiostomus xanthurus (spot)

An estimated 48,059 spot were impinged during the first year and 61,573 during the second (Table 4.2-3). During 1976, most specimens (91 percent) were impinged from June through December. About 59 percent of the spot were impinged at a water temperature of 4 to 13°C (39.2 to 55.4°F) and 31 percent at 23 to 29°C (73.4 to 84.2°F). Most spot (85 percent) were impinged at night.

An estimated total of 47,789 spot (44 percent of those impinged) died immediately after impingement (Table 4.2-12). The number of spot lost immediately after impingement (3,618) should have been reduced by about 92 percent (Table 4.2-5) if Ristroph screens were in operation at the OCNGS.

4.2.2.1.11 Menticirrhus saxatilis (northern kingfish)

Only 121 northern kingfish were collected from the intake screens during the two years of the study. This was too few specimens to accurately estimate the total number that would have been impinged during the period. This species was impinged from August through December, but most (72 percent) were taken in October 1976 (Table 4.2-3). Only one of the three specimens examined for condition was dead.

4.2.2.1.12 Prionotus evolans (Striped searobin)

An approximately equal number of striped searobin were estimated to have been impinged during the first (32,354) and second (28,371) year (Table 4.2-3). The multiple regression analysis accounted for only 19 percent of the variation in the impingement of this species. This amount of variation was attributed to decreases in salinity and to increases in pH, water flow, and time of day (day to night). Ninety-six percent of the striped searobin were impinged at night. Seventy-one percent were impinged in August and October 1976, and few were impinged from December through July of either year. Eighty-three percent were taken at a water temperature from 11 to 22°C (51.8 to 71.6°F). An estimated 16,096 striped searobin (27 percent of those impinged) were dead immediately after impingement, but no specimens were lost to delayed mortality (Table 4.2-13). No estimate is available for Ristroph screens with this species.

4.2.2.1.13 Etropus microstomus (smallmouth flounder)

Impingement of the smallmouth flounder was substantially greater during the second year (57,773) than during the first (8,022). Most (77 percent) were impinged in November 1976 (Table 4.2-3), and 99 percent were impinged at a water temperature from -1 to 11°C (30.2 to 51.8°F). Because substantial differences existed between mean intake velocity and water flows during the fall of the two years (Section 4.2.2.1), it was not possible to determine what percentage of the difference between the estimated number impinged during the two years was due to the difference in intake velocity and water flow and what percentage was due to a difference in abundance between the two years. Ninety-six percent were impinged at night. A total of 18,714 smallmouth flounder (28 percent of those impinged) was lost to immediate mortality (Table 4.2-14).

4.2.2.1.14 Paralichthys dentatus (summer flounder)

An estimated 4,266 summer flounder were impinged during the first year and 2,380 during the second year (Table 4.2-3). Very little (3 percent) of the variation in the impingement of the summer flounder was accounted for by the multiple regression analysis.

The summer flounder was impinged from March through December; 41 percent of the individuals were impinged during its emigration from the bay during fall (November 1975 and October 1976). Some 83 percent of those impinged were taken at a water temperature of 8 to 25°C (46.4 to 77°F), and 73 percent were impinged at night.

Only an estimated 543 summer flounder (8 percent of those impinged) experienced immediate mortality (Table 4.2-15). If Ristroph screens were in operation, immediate impingement mortality should be reduced by approximately 66 percent and only an estimated 2.8 percent and only 186 individuals of the summer flounder impinged would have died immediately after impingement (Table 4.2-5).

Five age-classes (ages 0+ to 4+) of the summer flounder were impinged. Most specimens (74.3 percent) were age 2+ (mean length of 270 mm, 10.6 in.); this age-class was dominant during all months except December when young (age 0+) predominated. The ratio of males to females was not significantely different from a 1:1 ratio.

4.2.2.1.15 Pseudopleuronectes americanus (winter flounder)

An estimated 22,526 winter flounder were impinged, and most (18,618) were impinged during the second year (Table 4.2-3). Sixty-three percent of the winter flounder were impinged from November 1976 through January 1977. A portion of this difference between years is attributable to the OCNGS shutdown during January and February 1976, but the winter flounder also was more abundant during the second (trawl catch of 4.6/coll) than the first year (0.35).

Increases in water temperature and decreases in salinity and the number of screens in operation accounted for 28 percent of the variation in impingement of the winter flounder through the multiple regression analysis. Some 87 percent of the fish were impinged at a water temperature of -1 to 8°C (30.2 to 46.4°F), and most (92 percent) were impinged at night. An estimated 5,070 winter flounder (23 percent of those impinged) were lost due to immediate (2,909) and delayed (2,161) mortality (Table 4.2-16).

Most adult winter flounder were impinged from November through January, although some were also impinged from March through May. Most individuals impinged from June through August were young (age 0+) and immature. The mean size of impinged males (225 mm, 8.9 in.) was significantly smaller than that of females (265 mm, 10.4 in.).

4.2.2.1.16 *Sphoeroides maculatus* (northern puffer)

An estimated 3,313 northern puffer were impinged during the first year and 1,516 during the second (Table 4.2-3). Since most (50 percent) were impinged in May 1976, the shutdown of the OCNGS from mid-May through mid-July 1977 probably accounted for the fewer individuals impinged during the second year. Some 67 percent were taken at a water temperature of 15 to 22°C (59 to 71.6°F), and 64 percent were impinged at night. Only 7 percent (345 northern puffer) of those impinged died immediately after impingement (Table 4.2-17).

More males than females were collected during all months except August when 91 percent of the specimens were young, and the sex was not determined. Most specimens with mature gonads were collected during May and June, and mature males outnumbered mature females during both May (3:1) and June (7:1). Most of the specimens were age 1+ and 2+.

4.2.2.1.17 *Limulus polyphemus* (horseshoe crab)

Although the horseshoe crab was not numerically abundant in collections from the traveling water screens, they comprised 3 percent of the estimated biomass of invertebrates impinged in 1975-76. During this period, most individuals (75 percent) were impinged on the trash racks which precede the vertical traveling screens and were removed from these structures when they were mechanically cleaned. Survival of individuals impinged on traveling screens was high; none of the 39 individuals examined was dead immediately after collection. Similarly, most individuals removed from the trash racks were also live immediately after removal. The return of these individuals to the discharge canal by OCNGS personnel immediately after their removal from the trash racks probably insured that most of these individuals survived.

4.2.2.1.18 *Palaemonetes vulgaris* (grass shrimp)

More grass shrimp were estimated to have been impinged during the first year (373,288) than during the second year (29,885). Because most (36 percent) were impinged in June 1976, the difference is accounted for, in part, by the fact that OCNGS was shut down during May and June 1977. The grass shrimp may have been substantially more abundant during the first year because during the seven comparable months, it was 6.7 times more abundant during the first year (Table 4.2-1). The multiple regression analysis indicated that 28 percent of the variability in impingement was attributable to decreases in water temperature and to increases in time of day

(day to night) and water flow. Ninety-four percent of the shrimp were impinged at night. Grass shrimp were taken throughout the year; 85 percent were impinged at a water temperature of -1 to 22°C (30.2 to 71.6°F). An estimated 22,633 grass shrimp (6 percent of those impinged) died immediately after impingement (Table 4.2-18).

4.2.2.1.19 Crangon septemspinosa (sand shrimp)

An estimated 3,342,143 sand shrimp were impinged during the first year but only 600,278 during the second year (Table 4.2-3). As with the grass shrimp, the OCNGS shutdown in 1977 may account for part of this difference in abundance. However, it was 3.3 times more abundant during comparable months between the two years (Table 4.2-1). With the multiple regression analysis, increases in water flow, time of day (day to night), and salinity, and decreases in water temperature and pH accounted for 31 percent of the variability in the impingement of sand shrimp.

Most sand shrimp (95 percent) were taken at night. Sand shrimp were collected throughout the year; but 69 percent of those impinged were collected in December 1975 and in May and June 1976. Few were impinged in August and September. Ninety-six percent of the sand shrimp were impinged at a water temperature of -1 to 20°C (30.2 to 68°F). A total of 840,053 sand shrimp (21 percent of those impinged) experienced either immediate (391,770) or delayed (448,283) mortality (Table 4.2-19).

The mean length of impinged sand shrimp was significantly greater than that of specimens from the discharge canal and the bay but not of specimens from the Forked River. Some 66 percent of the impinged sand shrimp were ovigerous (egg-bearing) as compared to 50 percent of those collected in the Forked River, 18 percent in Oyster Creek, and 6 percent in the bay. The difference between the percentage of ovigerous specimens and the mean length of sand shrimp impinged at the OCNGS and those from the other areas may be partially attributable to the larger mesh of the traveling screens. Most (40 percent) ovigerous sand shrimp were impinged in April, and the fewest during July and August.

4.2.2.1.20 Callinectes sapidus (blue crab)

More blue crab were impinged during the first year (5,627,253) than during the second (230,691). This large difference was due in part to substantial mortality of blue crab from the severe weather during the winter of 1976-77. The estimated population in the bay in 1976 was about five times greater than in 1977. A portion of this difference in the number impinged may also be attributable to the shutdown of the

OCNGS from May 14 to July 12, 1977 (Table 4.2-3). In 1976, 54 percent of all crabs were impinged during June and July. Few were impinged from December through February in either year.

Multiple regression analysis accounted for 68 percent of the variation in the impingement of the blue crab as a function of changes in time of day (day to night),or either increases of oxygen level, and the number of screens in operation or decreases in water temperature, pH, wind speed, and intake water flow. Eighty-two percent of the blue crab were impinged at night, and 99 percent were impinged at temperatures of 9 to 29°C (48.2 to 84.2°F). A total of 600,087 blue crab (10 percent of those impinged) experienced either immediate (403,573) or delayed (196,514) mortality (Table 4.2-20).

Some 91 percent of impinged blue crab were immature. The mean length of both mature and immature blue crab impinged at the OCNGS was somewhat larger than that of specimens collected from the Forked River, Oyster Creek, and the bay. For the year, the ratio of immature males to females was not significantly different from 1:1. But significant differences between the number of immature males and females occurred during all months except October, May, and June. For the year, significantly more mature females than males were impinged. Mature crabs were most abundant in October and May, and gravid females were impinged primarily in June.

4.2.2.2 Assessment of impingement losses

Surveys to estimate the number of the bay anchovy, northern pipefish, winter flounder, sand shrimp, and blue crab in the central portion of Barnegat Bay from Goodluck Point to Gulf Point were conducted during 1976 and 1977 (Table 4.2-21). Surveys could be conducted only for abundant species that could be collected by semi-quantitative gear because pelagic fishes (e.g., Atlantic menhaden, bluefish) could not be sampled quantitatively and other RIS (threespine stickleback, striped bass, northern kingfish, and northern puffer) were relatively uncommon in the bay. A stratified random sampling model was employed, and the population size with confidence limits was estimated (Mackett 1973). Several of the 1976 estimates (Tatham et al., 1977a) were recalculated because of an invalid assumption on gear efficiency and treatment of the data in the original calculation. The large variability of some of these estimates was characteristic of the estimated mean and confidence limits of aggregated distributions (i.e., schools of fishes). The size of most populations was underestimated because of the relative inefficiency of the gear (Loesch et al., 1976), inability to sample the entire water column, relative accessibility of the specimens to capture, and the apparent inability to capture of specimens during periods of movement.

The estimated number of organisms in the central bay was compared to the estimated number of organisms lost through impingement at the OCNGS during the month that the survey was conducted (Table 4.2-21). This comparison was made with the estimated number of organisms lost with the existing traveling water screens and the projected loss immediately after impingement on Ristroph screens. These comparisons were undoubtedly a high (conservative) estimate of the effect of the OCNGS because the populations in the bay were underestimated.

Because a meaningful population survey could not be conducted for many fishes, the number or biomass of fishes lost at the OCNGS was compared to commercial fishery landings or other data which put the impingement losses in perspective. The comparison with commercial landings is a relative index of the magnitude of losses and not a quantitative estimate of the effect of the OCNGS on fishes and blue crab. Although the catch records for some species (e.g., weakfish; Joseph, 1972) may reflect population trends, the commercial catch data are not estimates of absolute abundance of a species because catches may not be accurately reported; fishes caught in one area may be landed in another, and fishing effort is selective and dependent on the current economic value of the fishes. In addition, commercial catches usually select individuals that were older than those lost at the OCNGS. Since the sport catch of the species may be similar to or in some cases may exceed the commercial catch (McHugh, 1977), a comparison of estimated impingement loss to commercial catches was an overestimate of the percentage of a species cropped by the OCNGS to the total harvested by man.

Past data from Barnegat Bay (Marcellus, 1972) and data collected in similar New Jersey estuaries in recent years were used to evaluate changes in the fish community and various populations of fishes in Barnegat Bay since the OCNGS began operation in 1969. Large year-to-year and long-term cyclic fluctuations in abundance of populations, however, confounded statistical analysis of changes in the abundance of fishes in the bay. Natural year-to-year variation in the abundance of many populations was as large as 50 percent to 100 percent for Barnegat Bay from 1966-70 (Marcellus, 1972) and for Great Bay and adjacent bays from 1972 through 1975. The catch of a short-lived species such as the spot may vary as much as 100 percent from year to year (Joseph, 1972); in selected zones in the lower Delaware River the catch of spot in trawl samples rose from 0.1/coll in 1970 to 7/coll in 1971 to 26/coll in 1972 (Thomas, unpublished manuscript). The abundance of the Atlantic silverside in seine collections near Little Egg Inlet, New Jersey, declined from 1972 (242/coll) to 1974 (82/coll). Long-term cyclic changes, such as the reduction in the population of the weakfish in the mid-Atlantic area from 1945 to 1967 (Joseph, 1972), may be due to climatic changes, overfishing, or other causes which acted over a large portion of a specie's range.

Local changes in the population abundance must be evaluated in light of population changes over a much broader area and often only very large changes that exceed the natural variability can be detected. Although these changes are true differences in abundance, they may not be significiant in the statistical sense.

Estuarine fish populations are also characterized by large natural changes in species composition. Near Little Egg Inlet, the Atlantic silverside comprised 49 percent of all fish taken in 1972, but it accounted for only 24 percent of all specimens in 1973 and 9 percent in 1974. Similarly, the catch of spot in the bays and ocean near Little Egg Inlet varied widely from 1972 (ranked ninth by numerical abundance) to 1973 (third) and 1974 (22nd).

4.2.2.2.1 Atlantic menhaden

The estimated number of the Atlantic menhaden lost through impingement on the existing traveling water screens, (110,448) in the two years of the study is quite small in comparison to observable indicia of population abundance. For example, it is equivalent to only approximately 2.2 collections of a purse seine by a single commercial fishing boat off the coast of New York (Reintjes, 1969). The relative biomass lost at the OCNGS (6 metric tons, 13,230 lbs.) is even smaller, comprising only 30 percent of the biomass of a single purse seine off the coast of New York because many of the fishes lost through impingement were young, and therefore were smaller than the commercially-harvested fish. The biomass lost would be very small (< 0.01 percent) in relation to the average annual commercial landings (47,788 metric tons, 1.05×10^8 lbs) in New Jersey from 1971 through 1975 (McHugh, 1977). Mortality of Atlantic menhaden during a single incidence of natural mortality of juveniles and adults in Chesapeake Bay has been as high as 1.3 million fish (Maryland State Fisheries Administration, 1974, 1975). Considering the number of Atlantic menhaden commercially landed in New Jersey and the number that died from incidents of natural mortality, the relatively few individuals killed by the OCNGS operations clearly have not adversely affected the protection or propagation of this species.

With Ristroph screens, the estimated loss immediately after impingement by OCNGS should be insignificant (5,750 specimens, 0.3 metric tons, 662 lbs). This immediate loss is equivalent to the number of fish taken in 0.1 sets of a commercial purse seine off the coast of New York (Reintjes, 1969).

4.2.2.2.2 Bay anchovy

In May 1976 a population survey for the bay anchovy was conducted in a relatively small area of the bay because this fish is a schooling species, and its distribution was expected to be extremely aggregated. However, analysis of this first survey indicated that this precaution was unnecessary. A second survey was conducted in the central bay from Goodluck Point to Gulf Point in October 1976. The estimated number in the bay during mid-May was 5,770,401 $\pm$ 2,310,352, and the population during October 1976 was estimated to be 2,616,646 $\pm$ 908,668 (Table 4.221).

An estimated 2 percent to 10 percent of the population of the bay anchovy in Barnegat Bay was lost through impingement at OCNGS. Trawl collections, however, greatly underestimate bay anchovy populations because many individuals are distributed in the water column above the trawl. No evidence exists that the population of this species in Barnegat Bay has decreased substantially because of the operation of the OCNGS. As in most mid-Atlantic estuaries, the bay anchovy was one of the most abundant fishes in the bay, and the catch of young and adults at two of three stations in the bay has not substantially decreased since the OCNGS began operation (Section 3.2.4). Even though most of the bay anchovy lost in May 1976 were mature, the mean monthly density of eggs (7-82/m^3) and larvae (0.1-11.9/m^3) in Barnegat Bay during June and July 1976 was approximately equal to the densities of eggs (16.9-115.2/m^3) and larvae (0.3-6.9/m^3) from nearby Great Bay and Little Egg Harbor from June and July 1972-1975.

If Ristroph screens had been in operation, the percentage of the bay population that would have been killed immediately after impingement should have ranged from 0.4 percent to 1.7 percent of the estimated bay population. Such losses would be insignificant, and should not adversely affect the population in the bay.

4.2.2.2.3 Threespine stickleback

Because of the relatively low population level of the threespine stickleback in recent years, few of this species have been impinged at OCNGS, and it was not possible to determine what percent of the population they comprised. From gross observations, survival of individuals was high.

4.2.2.2.4 Northern pipefish

Most of the northern pipefish were found in areas of aquatic vegetation, particularly in the extensive eelgrass beds in the eastern portion of the bay (Table 4.2-21). A population survey conducted on this species in June 1976 showed that the northern pipefish was more abundant in the shallow, eastern bay (513,735 ± 150,165) than in the deeper, western part of the bay (60,732 ± 58,039). From late July to early August 1977, more (1,757,622 ± 474,487) northern pipefish were again taken in the eastern bay than the western part of the bay (280,428 ± 445,360). A second survey was conducted about six weeks later in the summer, and recruitment of young into the population had occurred by that time.

The population survey in 1976 indicated that the number of fish impinged during June was less than 1 percent of the population in the eastern bay (513,735 ± 150,165) and only 4 percent of those from the western bay (60,732 ± 58,039). The 1977 survey indicated that less than 1 percent of the estimated population from either the eastern (1,757,622 ± 474,487) or western (280,428 ± 445,360) bay was impinged. Since an estimated 75 percent of impinged fish survived, the number killed at the OCNGS screens was less than 1 percent of the number of the bay. The concentration of the northern pipefish in the eelgrass beds in eastern bay readily explains the low percentage of the population impinged. Such low mortalities do not threaten to adversely affect the species population in the bay.

4.2.2.2.5 Striped bass

The three striped bass impinged were equivalent to the daily sport catch of six anglers fishing from a charter boat in Great Bay. This number is very small in relation to the 2,688 striped bass caught in the upper Barneget Bay sport fishery in 1972 (Halgren, 1973) and the estimated New Jersey sport catch (142,600) during 1976 (Figley, 1977). The few individuals lost at the OCNGS were inconsequential to the population of the striped bass either off New Jersey of the larger stock along the mid-Atlantic coast.

4.2.2.2.6 Spot

The many spot impinged at the OCNGS reflected its recent abundance in Barnegat Bay and other mid-Atlantic estuaries. This abundance is the result of a recent increase in this population which also was noted in Great Bay and Delaware Bay (Miller 1978). Because most specimens of the spot taken in the bay were young, these recent population increases demonstrate that the mortalities have not, and do not, threaten to adversely affect either the population in the bay on the mid-Atlantic Coast.

Large natural variations of this species are well recognized, and the catch from one year to the next may increase or decrease by 100 percent (Joseph, 1972). Barnegat Bay is near the northern limits of the range for the spot, and the number of this species lost at the OCNGS will not threaten the propagation or protection of this fish along the Atlantic coast.

4.2.2.2.7 Northern kingfish

The relatively few northern kingfish impinged at the OCNGS is the result of reduced population of this fish along the entire New Jersey coast in recent years. Large fluctuations in the population of various other drums (e.g., Atlantic croaker, silver perch) have been documented in Great Bay from 1972 through 1974, and fluctuations in the abundance of the northern kingfish have been noted at Corson's Inlet, New Jersey (Phillips, 1914) and Great South Bay, New York (Bean, 1901).

Although young may use the bay as a feeding area and may be common in the bay when this species is abundant along the coast, it was more abundant in the ocean and surf near Little Egg Inlet than in adjacent bays. Because the abundance of the population in Barnegat Bay is apparently related to factors which affect populations along the entire coast rather than only in the bay, its low abundance decline was unrelated to the operation of the OCNGS.

4.2.2.2.8 Summer flounder

Few summer flounder were lost as a consequence of impingement at the OCNGS. Since the recreational harvest (about 185,000 fish during 1975) in New Jersey is large (Figley, 1977), the loss of about 300 individuals at the OCNGS in the first year was inconsequential. The approximate total of 543 fish lost in the two years was equivalent to the average daily catch of 126 anglers who fished from charter boats in Great Bay. If Ristroph screens were in operation, mortalities should have been reduced to about 186 (average daily catch of 43 anglers). These losses are inconsequential to the population of the summer flounder in New Jersey and would not affect its protection and propagation.

4.2.2.9 Winter flounder

A bay population survey for the winter flounder was made in April 1976, and the estimated population was 194,370 $\pm$ 43,047. In March 1977 the population was estimated as 111,005 $\pm$ 23,174 individuals (Table 4.2-21). The 1977 estimate was lower than the 1976 estimate, in part, because one area where fish were expected to be relatively abundant was not sampled because of sampling difficulties.

From late March through mid-April 1976 and 1977, less than 1 percent of the estimated winter flounder in the central bay were lost through impingement, and the number lost would undoubtedly have been less if Ristroph screens had been in operation during this period. The population level of winter flounder in Barnegat Bay and other southern New Jersey estuaries has been low in recent years, but the greatly increased number of young collected in Barnegat Bay in 1977 suggests that this fluctuation in the population in the bay may have resulted, in part, from an environmental factor rather than operation of the OCNGS. Jeffries and Johnson (1974) demonstrated that the decline of the winter flounder population in Narragansett Bay from 1968 through 1972 was related to the relatively mild winters during these years. With the exception of 1976-77 and 1977-78, southern New Jersey also has experienced mild winters in recent years, and this phenomenon may explain the recent decline in these populations.

In light of the decreases in the populations of winter flounder in southern New Jersey in recent years and the increase in the number of young produced in Barnegat Bay in 1977, it seems unlikely that the recent decline of this population in the bay up to 1977 was related to impingement on the OCNGS screens. Because the percentage of population losses at OCNGS was so low (<1 percent of the bay population) and the recent fluctuations were apparently related to environmental factors (e.g., water temperature), it must be concluded that impingement losses will not significantly affect the protection and propagation of this population in the bay.

4.2.2.2.10 Northern puffer

The few individuals of the northern puffer impinged at the OCNGS reflect the low levels of these populations in New Jersey estuaries in recent years. Marcellus (1972) documented the decline in Barnegat Bay from 1966-69 just prior to the operation of the OCNGS. A decline in the population of the northern puffer was also noted in other New Jersey bays (Hamer, 1972; Vennel, undated) and in the Delaware Bay sport fishery (Miller, 1978). With this low population level of the northern puffer, it was not possible to estimate the population in the bay.

On the other hand, the immediate survival of this species on the existing traveling water screens was high (90 percent). And this rate should become ever lower (possible less than one percent) if the OCNGS is equipped with Ristroph screens. Mortality of this low a magnitude will not adversely affect the bay's northern puffer population.

4.2.2.2.11 Other fishes

Both bluefish and weakfish are migratory fishes which are derived from large populations in the mid-Atlantic region. In light of the quantity of bluefish (22,533 metric tons, 496 x 10^7 lbs, in 1970) and weakfish (6,368 metric tons, 1.4 x 10^7 lbs) harvested from the mid-Atlantic recreational fisher (McHugh, 1977), the biomass of bluefish (0.11 metric tons, 242.6 lbs) and weakfish (0.45 metric tons, 992.3 lbs) lost through impingement at the OCNGS was unconsequential. An estimated 416,000 bluefish and 144,000 weakfish also were taken by the recreational fishery in New Jersey during 1975 (Figley, 1977). In light of the large number of individuals removed by commercial and sport fishermen in the mid-Atlantic region, the few immature young lost at the OCNGS will not affect the populations of these two species.

Although many Atlantic silverside, blueback herring, striped searobin, and smallmouth flounder were lost through impingement on the existing traveling water screens at the OCNGS, the number of these species in the bay were not estimated because they were not considered "representative, important species", and little other relevant data on their abundance exist. Mortality of these species should be reduced with Ristroph screens in operation. Based on data from the Surry generating station (White and Brehmer 1977), the immediate mortality of the blueback herring should be reduced by about 77 percent.

The absence of any adverse effect may be inferred from the fact that the recent (1975-76) catch of the Atlantic silverside in seine collections in the bay was as great as the catch prior to 1969 (Section 3.2.4.3). The population was maintained in Barnegat Bay despite the fact that a steady decline in the population of this species was observed in nearby Great Bay from 1972 (242/seine coll) through 1974 (82). Thus, no adverse effect has been seen.

Without preoperational data on the other three species, the effect of impingement losses cannot be evaluated completely. Collections in other New Jersey estuaries and the ocean off Little Egg Inlet indicate, however, that both the smallmouth flounder and striped searobin are more abundant in the ocean than in the bays, and that the local estuaries are not an important nursery or reproductive area for these species. It is, therefore, very unlikely that impingement of these species at OCNGS will adversely affect these populations.

4.2.2.2.12 Sand shrimp

A population survey of sand shrimp in the shore zone of the western bay was taken in April 1977 (Table 4.2-21), and estimates were made of the number of sand shrimp from the shoreline to 10 m

(32.8 ft) from shore. More sand shrimp (68,000 ± 16,000) were in the shore zone from Double Creek to Waretown than from Waretown to Cedar Creek (44,000 ± 35,000)

Only larger-sized sand shrimp were impinged at the OCNGS. Based on their length, it was concluded that about 10 percent (11,200) of the sand shrimp in the shore zone of the western bay (i.e., all sand shrimp greater than 40 mm, (1.6 in.) in length, and 10 percent of those 20 to 40 mm, (0.8 to 1.6 in.) in length could be impinged on the 9.5 mm (0.4 in.) mesh of the traveling water screens. The population of the sand shrimp in the bay from Goodluck Point to Gulf Point was undoubtedly much larger than the estimated population in the relatively small area, 0.2 percent of the bottom area from Goodluck Point to Gulf Point) sampled.

The population in the deeper areas of the bay was roughly estimated from the density of the sand shrimp in trawl collections at the mouth of the Forked River during April 1977. If these densities in the trawl collections were representative of the density of this form in deeper areas in the bay, then an estimated 11,177,600 sand shrimp were in the remaining portion of the bay, of which 10 percent (1,117,760) were large enough to be impinged on the traveling screens.

During April 1977, an estimated 17,397 sand shrimp were lost after impingement at the OCNGS. This represented only about 1.5 percent of the estimated number in the central bay from Goodluck Point to Gulf Point. Therefore, it was judged that the operation of the OCNGS has not harmed the sand shrimp population in the bay.

4.2.2.2.13 Blue crab

More blue crab were estimated to have been in the eastern bay (3,671,889 ± 570,200) than the western bay (260,667 ± 70,078) during a bay population survey taken in July 1976 (Table 4.2-21). From late July to early August 1977, the population in the eastern bay (603,530 ± 234,299) was again greater than that in the western bay (102,385 ± 42,643), and the overall population in the bay in 1977 was substantially less than in 1976. The decrease in the population in 1977 resulted in part from high mortality of young blue crab during the severe winter of 1976-77.

The estimated population, particularly in the western bay, was considered a substantial underestimate during both years. This underestimate may be due in part to gear avoidance because swimming crabs may have avoided the trawl in the deeper areas of the bay. In the western bay, many immature crabs may have been in the shore zone, tide pools, and tidal creeks, and therefore may not have been sampled by the 4.9-m (16 ft) trawl. In the eastern bay, the 2.7-m (9 ft) trawl usually fished from surface to bottom in shallow water, and gear avoidance may have been reduced.

Based on the 1976 survey, the number of blue crab lost through impingement at the OCNGS in July was about 3.5 percent of the estimated population in the bay. In August 1977, however, only 0.6 percent of the population in the bay was lost at OCNGS. Both of these percentages are probably high because of the low population estimate for the western bay.

Commercial landings are not truly reflective of species population dynamics and are a highly biased statistic, but over several years provide a reasonably reliable index of population trends. It is notable then that the reported commercial landings in the bay have not decreased since the OCNGS began operation, and that the largest reported commercial landings were from 1973 through 1976. Additionally, the age structure of the blue crab population was similar to that of the population in Great Bay. Although relatively small changes in abundance would be difficult to discern because little pre-operational data are available, major reductions in abundance and changes in the age structure of the population, on the order of those produced by the large mortality of the blue crab during the winter of 1976-77, have not occurred. Because observed changes in the population have been within the limits of natural variation and the present structure of the bay population is similar to that found in a similar estuary which did not receive heated discharges, it must be concluded that impingement at OCNGS has not adversely affected the bay population.

4.2.2.3 Conclusion

No evidence exists that the losses of organisms through impingement on the existing traveling water screens at the OCNGS have had discernible effects on the individual fish populations, the fish community, or the population of the sand shrimp and blue crab in Barnegat Bay. Although some changes in the species composition and relative abundance of fishes have occurred in the bay since 1969, these changes apparently are unrelated to the operation of the OCNGS.

The magnitude and effects of the losses observed were often less than natural mortalities for some species (e.g., blue crab, Atlantic menhaden). Similar increases (i.e., spot) and decreases (i.e., Atlantic silverside, northern kingfish, winter flounder, northern puffer) have occurred in other New Jersey and mid-Atlantic estuaries, and, therefore, are probably related to factors which influence the abundance of these species along the mid-Atlantic coast and not just Barnegat Bay. The overall structure of the fish community in 1975-77 (Section 3.2.4) was similar to the community of the bay prior to operation of the OCNGS (Marcellus, 1972), the communities in other

New Jersey estuaries (Milstein et al., 1977), and the communities in other mid-Atlantic estuaries (deSylva et al., 1962; Richards and Castagna, 1970; Oviatt and Nixon, 1973; McErlean et al., 1973). Although little preoperational data exist, little unexplained variation in the abundance of the local fish populations has occurred (Section 3.2.4.3).

Section 316(b) requires that the adverse environmental effects of cooling-water intake systems be minimized. Since no adverse population effects have resulted from impingement at the OCNGS intake, attention should be directed toward whether OCNGS is employing those measures which are cost effective to limit mortalities of individual organisms that are impinged. The mortalities of individuals impinged at OCNGS historically have been relatively large and JCP&L has conducted studies on several technologies which potentially minimize impingement effects (Section 5.2). While alternative systems may be possible, the Ristroph screen has the best potential to be feasible and cost effective in Barnegat Bay. The environmental and operational characteristics of Ristroph screens are being investigated in an on-going study. Should the OCNGS test of these screens achieve the low mortality rates found at the Surry Station, this screen will be installed at the OCNGS intake structure to minimize impingement.

4.2.3 Predicted effect of FRNGS

The species of fish and macroinvertebrates impinged at the FRNGS should be similar to that reported for the OCNGS (Section 4.2.2.1).

Since the FRNGS intake will have only two Ristroph screens and will circulate approximately 40,000 gallons per minute, the number of organisms impinged at the FRNGS will be substantially less than that impinged at the OCNGS (six screens; 460,000 gpm). The number of abundant and representive important species which will be impinged and suffer mortality as a consequence of impingement at the FRNGS can be projected from the OCNGS data gathered from September 1975 through August 1977. Assuming a direct correlation between intake flow and rate of impingement, projected losses are calculated by multiplying the number lost at the OCNGS during this period by the ratio of the water withdrawn by the FRNGS to that at the OCNGS. Table 4.2-22 provides representative estimates of FRNGS for eight important species. For two reasons, these are likely to understate the impingement which actually will be observed at FRNGS. First, the FRNGS intake is to be located in an area of substantial flow past the screens, which would tend to move organisms by the screens much more quickly and provide a greater opportunity for escape to those found near the intake. Second, the FRNGS will have a much lower intake velocity (design intake velocity of 0.2 m/sec; OCNGS intake velocity of 0.5 to 0.7). Finally, the probability of immediate survival with Ristroph screens would be 1.5 to 13.2 times greater than that with the existing vertical traveling water screens at the OCNGS (Table 4.2-5).

With Ristroph screens in operation at the FRNGS the losses at both the OCNGS and FRNGS should be slightly greater than the losses experienced at the OCNGS from September 1975 through August 1977 (Table 4.2-22). Because the losses at the OCNGS from 1975-77 did not have a demonstrated effect on the balanced indigenous populations (Section 4.2.2) it must be concluded that the slightly greater impingement losses to be experienced with both stations in operation should not have an adverse effect on the fish and invertebrate communities in the bay. And because the use of Ristroph screens should minimize the losses of individual organisms, the requirements of 316(b) are satisfied with respect to the effects of impingement.

4.3 Entrainment

The passage of water through the cooling-water system of electric generating stations often harms small aquatic organisms entrained with it. The five-minute passage of water through the cooling-water system of the OCNGS may cause mortality of organisms from exposure to thermal, mechanical, hydraulic, or biocidal stresses. Although less water is withdrawn from the bay by closed-cycle cooling-water systems, such as the FRNGS, mortality of organisms is usually 100 percent.

The degree of stress and mortality experienced by organisms entrained through the OCNGS cooling system was studyed by IA from September 1975 through August 1977. Although all species of organisms entrained were studied to some extent, particular emphasis was placed on the zoo- and ichthyoplankton of abundant and representative important species of fish and shellfish. This portion of the report evaluates the entrainment effect of the OCNGS and the incremental effect of the FRNGS on the biota in Barnegat Bay. The criteria by which the effects of entrainment are evaluated are discussed in Section 4.1.2.

4.3.1 Rationale

Although little data exist on zoo- and ichthyoplankton communities in the bay prior to 1969, entrainment of plankton at the OCNGS does not appear to have affected either the invertebrate and fish communities or the various populations in the bay to a point where changes can be detected.

Although losses of zooplankton occurred as a consequence of entrainment through the OCNGS, the species composition, distribution, and seasonal succession of the zooplankton in Barnegat Bay have been found to be similar to those in other estuaries in the northeastern United States. Although most zooplankton populations are resident in the bay, the winter flounder, bay anchovy, and northern pipefish were the only RIS of fish that had substantial local reproduction in 1975-77. During this period, the fish community in the bay has not experienced any variation in species composition or abundance that may be attributable to entrainment losses at the OCNGS. The additional losses of most zoo- and ichthyoplankton at the FRNGS will be relatively small and should represent only an additional 0.1 percent to 3.4 percent of these forms in the bay during a 12-hour period. It must be concluded, therefore, that the entrainment of organisms by the operation of the OCNGS has not adversely affected the aquatic community of the bay. The incremental losses consequent to operation of FRNGS will not change that result.

A total of 5.16×10^{13} microzooplankton (zooplankton <500 microns in length) were entrained through the OCNGS during the ten months that the OCNGS circulated water in the first year, and 4.03×10^{13} were entrained during the eight months sampled in the second year. Statistically significant ($P \leqq 0.2$) differences in abundance for six comparable months between the two years occurred for 15 of 18 forms statistically analyzed. Only the estimated number of rotifers, polychaete larvae, and total bivalve larvae were not significantly different. Most (78 percent) of the microzooplankton were holoplankton (organisms that are planktonic for their entire life cycle). Copepods accounted for 89 percent of the holoplankton with Acartia clausi, A. tonsa, and Oithona colcarva (brevicornis) the predominant species. Meroplankton (organisms that spend only a portion of their life cycle or daily activity in the water column) accounted for 22 percent of the entrained microzooplankton; larvae of barnacles (33 percent of all meroplankton), polychaetes (27 percent), bivalves (12 percent), and gastropods (13 percent) were most numerous.

An estimated total of 4.25×10^{11} macrozooplankton (zooplankton >500 microns in length) were entrained during the 287 days that the OCNGS circulated water during the first year and 9.98×10^{10} during the second (304 days). For 19 of 25 forms statistically analyzed, the difference in the total number entrained during seven comparable months was significant ($P \leqq 0.2$) between the two years. For the two years, 12 forms had an annual mean density greater than $1.0/m^3$ for at least one year. The density of Neomysis americana and the hydromedusae Rathkea octopunctata and Sarsia spp. exceeded $10/m^3$. A comparison of the mean density between day and night collections showed that mysids; amphipods; cumaceans; zoeae, juveniles, and adults of the sand shrimp and grass shrimp; epitokes of Nereis spp.; zoeae of mud crabs; and megalopae of the blue crab were more abundant at night.

From December through April, larvae of the winter flounder and sand lance were the dominant larvae entrained. The estimated number entrained during seven comparable months for the two years was significantly different ($P \leqq 0.2$) for both larvae with sand larvae more abundant in 1975-76 and winter flounder larvae in 1976-77. From May through September, eggs of the bay anchovy and larvae of the bay anchovy, gobies, silversides, and northern pipefish were the predominant ichthyoplankton. Although the number of larvae and juveniles of the bay anchovy that were entrained in seven comparable months was significantly different ($P \leqq 0.2$) for the two years, the number of bay anchovy eggs, and larvae of the northern pipefish and gobies were not. For the bay anchovy, most eggs were entrained from May through July; the greatest densities of larvae occurred in June and July. Goby larvae were most abundant in July 1976.

The condition of microzooplankton entrained through the OCNGS cooling-water system could not be determined because detritus and phytoplankton in the collections made observation of individuals impossible. Clearly, however, losses do occur and, based on studies from other generating stations, losses are due primarily to thermal effects. Losses from entrainment also can be identified, although not quantified, indirectly. The decrease in the density of barnacle larvae, polychaete larvae, copepod nauplii, _Acartia_ _tonsa_, _Acartia_ spp., and unidentified bivalve larvae from the OCNGS discharge to the mouth of Oyster Creek in 1976 probably was due in part to entrainment mortalities.

The mere occurrence of entrainment losses does not, of course, mean that there is an impact on the population of the bay. Other studies have demonstrated that losses of holoplankton in a discharge canal did not necessarily reduce populations in an estuary (Davies and Jensen, 1974). In this study, no evidence of changes in the general structure of the microzooplankton community in Barnegat Bay was found, and the species composition, distribution, and seasonal succession of the microzooplankton were similar to that described from other estuaries and embayments in the northeastern United States. Incremental losses at the FRNGS are not expected to change this.

The mortality of entrained macrozooplankton at the OCNGS appeared to be caused mostly by temperature and was generally low at discharge temperatures below 30°C (86°F). Only large, soft-bodied ctenophores suffered obvious mechanical damage. For macrozooplankton, the number of a form entrained during a 12-hour period was compared to the estimated number of that form in the bay. For most comparisons (70 percent), the number entrained was less than 5 percent of the estimated number in the bay and for about half of the comparisons it was less than 2 percent. Zoeae of _Hippolyte_ spp., _Upogebia_ _affinis_, _Panopeus_ _herbstii_, _Neopanope_ _texana_, _Pagurus_ spp., _Libinia_ spp., the sand shrimp, blue crab, and adults and juveniles of the mysid _Mysidopsis_ _bigelowi_ had more than 5 percent of the number in the bay entrained during a 12-hour period on some days and less than 5 percent on others.

These losses have not caused any observable variations in the bay population. The seasonal variation, species composition, and relative abundance of this community in the bay, however, was similar to those in Great Bay.

The operation of FRNGS should not change existing conditions. Based on 1977 survey data, the additional percentage of macrozooplankton that would be entrained at the FRNGS during a 12-hour period ranged from 0.1 percent to 3.4 percent of the forms in the central bay. Megalopae of the blue crab would experience greater losses at the FRNGS than at the OCNGS because most zoeae survive entrainment at the OCNGS. However, these losses at the FRNGS will be a small percentage (< 0.1 percent) of those in the bay and should be inconsequential.

Although larvae of the winter flounder and sand lance, and juveniles of the bay anchovy collected at the OCNGS discharge had significantly ($P \leqq .05$) greater immediate mortality than those collected at the OCNGS cooling-water intake, high collection mortality precluded a reliable determination of the percent mortality attributable to entrainment. Most abundant ichthyoplankton decreased in density from the Forked River to the mouth of Oyster Creek, but these losses had no apparant effect on the ichthyoplankton or fish populations in the bay. The seasonal occurrence, abundance, and species composition of the ichthyoplankton in Barnegat Bay were generally similar to those reported in estuaries from Long Island to Chesapeake Bay. Although the entrainment loss of eggs or larvae of a particular species over a 12-hour period occasionally was greater than 10 percent of the estimated population in the central portion of Barnegat Bay, it generally was less than 4 percent. Recent changes in the species composition and relative abundance of fishes in Barnegat Bay appear due to natural population fluctuations and not to entrainment losses at the OCNGS, because similar changes were noted for estuaries beyond the influence of the OCNGS.

The number of eggs and larvae lost in the FRNGS cooling tower should be about 8.7 percent of those entrained at the OCNGS, and these incremental losses range from 0.1 percent to 1.9 percent of the number in the central bay. These incremental losses are not likely to have any effect on bay populations.

4.3.2 OCNGS entrainment effect

4.3.2.1 Species and number of organisms

Zoo- and ichthyoplankton collections were taken at the intake and discharge of the OCNGS cooling-water system to estimate the species composition, abundance, and mortality of organisms passed through the circulating water system (four pumps; 115,000 gpm per pump). From September 1975 through August 1976, collections were taken during all months except January and February because the OCNGS was shut down from December 26, 1975, through March 3, 1976. From September 1976 through August 1977, macrozoo- and ichthyoplankton collections were taken during all months except June although the OCNGS did not circulate water from May 14 through July 12. Microzooplankton (planktonic invertebrates < 500 microns in length) collections were not taken from December 1976 through

February 1977 because important species of microzooplankton were not abundant during this period in 1975-76. When the OCNGS did not circulate water, collections at the dilution pump discharge were used to estimate the density of organisms in the intake canal.

The estimated number of a form entrained during each of the two years studied was calculated only for the days that the OCNGS circulated water during 1975-76 (287 days) and 1976-77 (304 days). The estimated number of a form entrained at the OCNGS from September 1975 through August 1976 and reported in Tables 4.3-3 to 4.3-5 differed from those reported by Tatham et al. (1977b) because of different estimating techniques. The numbers reported for the second year and in this report more accurately represent the number entrained at the OCNGS because the estimating technique gave equal weight to each month. The computational differences between the two methods are discussed by Tatham et al. (1978b).

The difference ($P \leqq 0.2$) in the number of most (39 of 53) zoo- and ichthyplankton species entrained for six (microzooplankton) or seven (macrozoo- and ichthyoplankton) comparable months between the two years was significant. The variation was least for ichthyoplankton; the abundance of only four of nine forms was significantly different. While some of these differences may reflect actual increases and decreases in abundance between the two years, they are within the range of natural variation of plankton populations (Heinle, 1977).

During the five-minute passage through the OCNGS cooling-water system, zoo- and ichthyoplankton are subject to mechanical, hydraulic, thermal, and biocide stresses. Although the maximum increase in temperature (delta T) of the water passed through the OCNGS (four pumps in operation) is 12.7°C (22.9°F), the monthly average delta T in 1975-77 is less than 10°C (18°F) Table 4.3-2, 4.3-2) and this delta T is discussed as the operational mode. With three circulating water pumps in operation during full power output, the delta T may be as high as 18.3°C (33°F). After discharge, forms were exposed to the discharge temperature for an additional 15 minutes until the heated water mixed with ambient temperature water from the dilution pumps (Section 3.2.2.1). The immediate mortality of forms entrained at the OCNGS was estimated from collections that were taken at the OCNGS discharge and were held at the discharge temperature for approximately 15 minutes.

4.3.2.1.1 Microzooplankton

A total of 5.16×10^{13} microzooplankton (including unidentified forms) were entrained through the OCNGS during the 10 months that the OCNGS circulated water in the first year, and 4.03×10^{13} were entrained during the eight months sampled in the second year (Table 4.3-3). With the exception of rotifers, polychaete larvae, and total bivalve larvae, the estimated number of specimens entrained through the OCNGS during six comparable months between the two years was significantly different ($P \leq 0.2$) for 15 of 18 forms (Table 4.3-6). Some differences may reflect real variations in abundance between the two years, but they are within the range of natural variation for plankton populations (Heinle, 1977). A significant difference ($P \leq 0.2$) in the densities of copepod nauplii and the larvae of gastropods, bivalves, and barnacles was found between day and night collections, but the reason for these differences is not known.

Most (78 percent) of the microzooplankton were holoplankton (organisms that are planktonic for their entire life cycle). An estimated 4.17×10^{13} and 3.36×10^{13} holoplankton were entrained during the first and second year, respectively (Table 4.3-3). Copepods (all developmental stages) accounted for 89 percent of all holoplankton. Nauplii were the most numerous life stage (41 percent of all microzookplankton, 59 percent of all copepods) in both years and an approximately equal number of nauplii was entrained during the first (2.21×10^{13}) and second (1.98×10^{13}) years. They were common $28,509/m^3$ (Table 4.3-7). A significantly greater number of copepod nauplii were found during the day than at night.

Acartia clausi, _A. tonsa_, and _Acartia_ spp. comprised 49 percent of all adult copepods and copepodites. After nauplii, _Acartia_ spp. (mostly copepodites) was the most numerous form. A total of 6.11×10^{12} _Acartia_ (adults and copepodites of all species) were entrained in the first year and 4.42×10^{12} the second. _A. clausi_, a boreal-temperate form, was collected between October and June with the greatest densities from March through May. _A. tonsa_, a temperate-tropical species, replaced _A. clausi_ in June and was generally common until October.

Oithona colcarva (_brevicornis_) and _Oithona_ spp. accounted for 35 percent of all adult copepods and copepodites. They are common to abundant from July through October and were present throughout the year. _Oithona_ was more numerous during the second year (average density of $10,770/m^3$; 6.75×10^{12} entrained) than the first ($2,994/m^3$; 1.51×10^{12}).

Rotifers comprised 11 percent of all holoplankton. The average density was $7,943/m^3$ (4.81×10^{12} entrained) during the first year and $3,840/m^3$ (1.21×10^{12}) during the second. They occurred in every month but were abundant in fall and spring.

Meroplankton (organisms that spend only a portion of their life cycle or daily activity in the water column) accounted for 22 percent of the entrained microzooplankton (Table 4.3-3). An estimated 6.98×10^{12} and 6.69×10^{12} meroplanktonic forms were entrained in the first and second year, respectively. Larvae of barnacles (33 percent of all meroplankton), polychaetes (27 percent), bivalves (12 percent), and gastropods (13 percent) were most numerous.

Barnacle larvae averaged 8,204/m^3 in the first year (7.31 x 10^{12} entrained) and 1,784/m^3 in the second year (1.48 x 10^{12}). They were collected in every month but were common to abundant from April through June (Table 4.3-7). Young and Frame (1976) identified the barnacles (Balanus improvisus, B. eberneus, B. balanoides, and B. crenatus on test panels in the OCNGS intake and discharge canals. A significantly greater density of barnacle larvae was found during the day than at night.

The average annual density of all polychaete larvae was similar during the first (4,154/m^3) and second (4,019/m^3) year, and the estimated 4.34 x. 10^{12} larvae entrained during the first year also was similar to the 3.99 x 10^{12} entrained during the second. Larvae were common throughout the year except from December through March when only a few were present. The greatest concentrations (> 10,000/m^3) occurred in April and May when larvae of Polydora spp. were abundant. Polydora spp. comprised most of the polychaete larvae taken in April (83 percent).

A total of 1.40 x 10^{12} bivalve larvae were entrained in the first year (average density of 1,902/m^3) and 9.46 x 10^{11} in the second year (1,650/m^3). Fewer larvae were entrained during the second year because the OCNGS did not circulate water from mid-May through mid-July when bivalve larvae were common. Most bivalve larvae were unidentified because the taxonomy of this group is extremely difficult. Although bivalve larvae were collected in all months, most were taken in April and May during the first year, and most were collected during the second year from September through November and in August. The difference between the seasonal occurrence of maximum density during the two years may have resulted in part from variable spawning seasons of bivalves annual variation in spawning seasons of bivalves; are also common (Chanley and Andrews, 1971). Bivalve larvae were significantly more numerous in day collections than in night collections.

More straight-hinge and umbo-stage larvae of the northern quahog, Mercenaria mercenaria, were entrained in the first year (1.14 x 10^{11}) than the second (1.86 x 10^9). During the second year, however, the OCNGS did not operate from May 14 through July 12 because of refueling, and many larvae probably were present during this period. They comprised 8 percent of all bivalve larvae (20 percent of all identified bivalve larvae) during the first year but less than 1 percent (2 percent) during the second year. Larvae of the dwarf surf clam, *Mulinia lateralis*, were collected in small numbers from April through October. They averaged 331/m^3 (42 percent of all identified larvae) in the first year and 203/m^3 (97 percent) in the second.

Gastropod larvae (13 percent of all meroplankton) were collected in every month and were common from April through September. The average density in the first year (1,080/m^3) was less than that during the second (2,781/m^3). A significantly greater density of larvae was found at night than during the day.

4.3.2.1.2 Macrozooplankton

A total of 185 forms was entrained at the OCNGS from September 1975 through August 1977, but the number entrained during each year was estimated only for common (annual mean density 1/m^3) and RIS forms. Some 4.25 x 10^{11} specimens were entrained during the first year and 9.98 x 10^{10} during the second (Table 4.3-4). For 19 of 25 forms statistically analyzed, the difference in the total number entrained during seven comparable months were significant ($P \leq 0.2$) between the two years. Some of these may be real differences in abundance between the two years, but other differences may be due to the large range of variability found when sampling similar plankton populations (Heinle 1977). Only the number of *Oxyurostylis smithi*, *Ampelisca* spp., gravid *Mysidopsis bigelowi*, mud crab zoeae, grass shrimp, and sand shrimp were not significantly different between the 2 years (Table 4.3-8).

During the first year, 15 forms comprised 1 percent or more than the entrained individuals, while only eight forms accounted for 1 percent or more during the second year (Table 4.3-9). For the two years, 12 forms had an annual mean density greater than 1.0/m^3 for at least one year; the density of *Neomysis americana* and the hydromedusae *Rathkea octopunctata* and *Sarsia* spp. exceeded 10/m^3 (Table 4.3-10). For 10 of these 12 forms, the difference in density between years was less than a factor of 10. But the difference between years was much larger for *R. octopunctata* (840 times) and *Sarsia* spp. (21). Despite year-to-year variation in abundance, the common forms generally had similar patterns of seasonal occurrence during the two years.

More individuals of the ctenophore *Mnemiopsis leidyi* were entrained during the first year (9.79 x 10^8) than during the second (3.41 x 10^7). During the first year the mean density of *M. leidyi* was 0.170/m^3, but during the second year the density declined to 0.002/m^3. This difference between years was the result of natural variation in abundance. The number of *Beroe ovata* entrained during the two years (2.87 x 10^7, 2.00 x 10^7; Table 4.3-4) was about equal.

N. americana was collected year-round. It was generally least abundant in January ($< 9/m^3$) and most abundant ($> 55/m^3$) in March. The annual entrainment estimate of *N. americana* was 1.19×10^{10} during the first year and 2.29×10^{10} during the second (Table 4.3-4). *Mysidopsis bigelowi* was common from July through November and was most abundant ($7/m^3$) in August. During other months, it was generally absent or present in small numbers. The annual entrainment estimate of *M. bigelowi* was 6.36×10^8 during the first year and 1.38×10^9 during the second.

Zoeae of the mud crabs *Neopanope texana* and *Panopeus herbstii* were collected from April through September. Maximum abundance of *N. texana* ($37/m^3$) and *P. herbstii* ($26/m^3$) occurred in June and July, respectively. The annual entrainment estimate of mud crab zoeae was 1.67×10^{10} during the first year and 5.51×10^9 during the second. The estimate was lower during the second year because the OCNGS was shut down during part of the reproductive period.

Zoeae of the sand shrimp were collected in all months. They were common from March into July and were most abundant in May ($16/m^3$) and June ($15/m^3$). The annual entrainment estimate was 9.98×10^9 during the first year and 1.61×10^9 during the second. The smaller estimate during the second year was due in part to a decrease in adults which was observed in entrainment and impingement collections during the second year.

Adults and juveniles of the sand shrimp were most abundant (monthly mean density $> 0.4/m^3$) from December through March and in August during the first year. During the second year, however, the mean density exceeded $0.4/m^3$ only in February. Since the form was more abundant during the first year ($0.25/m^3$) than during the second year (0.13), the annual entrainment estimate was greater during the first year (1.04×10^8) than the second (6.37×10^7).

Arrowworms, primarily *Sagitta elegans*, were collected from September into April, and they were most abundant in February 1976 ($25/m^3$). The annual mean density for the first year ($3.59/m^3$) (Table 4.3-10) was about seven times larger than that of the second year ($0.5/m^3$). More were entrained during the first year (6.75×10^8) than the second (3.81×10^8), and the difference between the two annual entrainment estimates would have been even greater if the OCNGS had operated during January and February 1976.

The amphipods *Ampelisca* spp. (30 percent of entrained amphipods during the first year), *Jassa falcata* (26 percent) and *Microdeutopus gryllotalpa* (16 percent) were collected year-round. *J. falcata* was common from June 1976 through July 1977 and had no obvious pattern of seasonal occurrence.

An estimated 2.68 x 10^9 *J. falcata* were entrained during the first year and 6.73 x 10^9 during the second. *Ampelisca* spp. were common from March through July and least abundant from November through February. An estimated 2.11 x 10^9 were entrained during the first year and 1.70 x 10^8 during the second. *M. gryllotalpa* was common from April through July and was least abundant in January. The number entrained during the first and second year was estimated to have been 1.23 x 10^9 and 1.01 x 10^9, respectively. The difference between the two years occurred, in part, because the OCNGS was shut down, and no individuals were entrained from May 14 through July 12, 1977. The annual mean densities for the first and second year were 1.22/m^3 and 0.74/m^3, respectively.

Corophium spp. accounted for 8 percent of all entrained amphipods. From September through November 1977, 57 percent of all identified *Corophium* spp. were *C. acherusicum*, 28 percent were *C. tuberculatum*, 14 percent were *C. bonelli*, and one percent were *C. insidiosum*. The annual entrainment estimate for *Corophium* spp. was 7.92 x 10^8 during the first year and and 1.72 x 10^8 during the second. The estimate was lower in the second year because no individuals were entrained from mid-May through mid-July 1977 when the OCNGS was shut down.

The cumacean, *Leucon americanus*, was collected year-round, was most abundant from April through October, and was least abundant in January. This form was substantially more abundant during the first year (Table 4.3-10), and therefore, more were entrained during the first year (estimated 1.07 x 10^9) than during the second (2.41 x 10^8).

Sarsia spp. were collected from January into May and were most abundant from February through April. The difference in abundance between the first year (annual mean density of 0.6/m^3) and the second (13.7/m^3) was large, and more were entrained during the second year (1.52 x 10^{10}) than during the first (4.11 x 10^8). *Rathkea octopunctata* was collected in most months but was common only from January through April. More were entrained during the second year (4.20 x 10^{10}) than the first (2.30 x 10^7). Both of these hydromedusae were extremely abundant during the second year (Table (4.3-10) and illustrated the large difference in density that can occur between years.

Megalopae of the blue crab were collected from mid-August through October. Most were collected in September during both the first (84 percent of entrained megalopae) and second (54 percent) year. The annual entrainment estimate for this form was 5.18 x 10^7 for the first year and 1.89 x 10^8 for the second, and these megalopae were more abundant the second year (0.15/m^3) than the first (0.09/m^3).

A three-way (month x station x day-night) ANOVA was computed for common and important species of macrozooplankton, but significant interactions precluded analysis of day-night differences. A comparison of the mean density between day and night collections showed obviously greater night time abundance for mysids; amphipods; cumaceans; zoeae, juveniles, and adults of the sand shrimps and grass shrimp; epitokes of _Nereis_ spp.; zoeae of mud crabs; and megalopae of the blue crab. The greater density of most forms at night probably resulted from diel vertical migration. Zoeae may have been more abundant at night because the hatching of crab and shrimp eggs appeared to increase at night. The density of arrowworms and the ctenophores _Mnemiopsis leidyi_ and _Beroe ovata_ did not show any obvious difference between day and night collections.

4.3.2.1.3 Ichthyoplankton

A total of 28 species of ichthyoplankton was entrained at the OCNGS from September 1975 through August 1977 (Table 4.3-11) The American eel (2.4 percent of entrained larvae and juveniles during the first year), bay anchovy (48.4 percent), northern pipefish (2.0 percent), sand lance (13.1 percent), gobies (22.8 percent), and winter flounder (8.9 percent) were common during the first year. Eggs of the bay anchovy (96.1 percent of entrained eggs) and cunner (1.4 percent) were the dominant eggs (Table 4.3-11). During the second year, larvae and juveniles of the bay anchovy (54.9 percent), northern pipefish (1.4 percent), sand lance (3.4 percent), gobies (8.4 percent), and winter flounder (29.2 percent) were abundant while eggs of the bay anchovy (89.7 percent), tautog (3.0 percent), and cunner (4.8 percent) were the most common eggs (Table 4.3-11).

Entrainment estimates between seven comparable months for the two years were significantly different ($P \leq 0.2$) for larvae and juveniles of the bay anchovy, sand lance, and winter flounder. The number of eggs of the bay anchovy, and of larvae and juveniles of the northern pipefish and gobies entrained were not significantly different between the two years (Table 4.3-12).

Eggs of the bay anchovy were entrained from April through October but most were collected from May into July. The highest density ($98.4/m^3$) was in July 1976 (Table 4.3-13). An estimated 2.43×10^{10} eggs were entrained during the first year but only 4.32×10^8 were entrained during the second year (Table 4.3-5). The substantial difference was due to the shut down of the OCNGS from May 14 through July 12, 1977, and the smaller population of the bay anchovy during the second year (Section 4.2.3.2.3).

Larvae and juveniles of the bay anchovy occurred from May through December. The greatest density ($18.8/m^3$) occurred in July 1977. Although the OCNGS did not circulate water from mid-May through mid-July, and eggs were more abundant during the first year (annual density of $18.7/m^3$) than during the second ($4.4/m^3$), the estimated number entrained during the first year (1.61×10^9) was only slightly greater than that during the second (1.02×10^9). This apparently resulted from the greater density, and therefore greater survival rate of larvae during the second year.

Goby (Gobiosoma spp.) larvae were common during the warmer months. They occurred from May through October and reached maximum abundance ($3.0/m^3$) in July 1976. An estimated 7.70×10^8 goby larvae were entrained during the first year and 1.84×10^8 during the second. The greater number entrained during the first year reflected, in part, the shutdown of the OCNGS from May into July 1977.

Sand lance (Ammodytes spp.) and the winter flounder accounted for most of the larvae entrained from January through April. The greatest density (2.0/m) of sand lance was in January 1976, while more winter flounder larvae were entrained during the second year (1.92×10^9) than during the first (1.61×10^8). Fewer sand lance larvae were entrained during the first year (4.04×10^7) than during the second (1.74×10^8), but the OCNGS did not circulate water during January and February 1976.

4.3.2.2 Immediate and delayed effects of entrainment

Macrozoo- and ichthyoplankton collections were taken at the intake and at the discharge of the OCNGS. Microzooplankton collections were not taken at the intake because large amounts of detritus and phytoplankton in collections at the OCNGS discharge obscured individuals, and therefore, their condition was not determined.

The number of organisms killed immediately after entrainment (after the five-minute in-plant transit and 15 minutes in the discharge canal, until mixing substantially reduces the discharge temperature) was calculated for 1975-76 because the OCNGS operated throughout the summer months during that year. During 1977, the OCNGS did not circulate water from May 14 through July 12. The number of organisms killed each month was calculated from the estimated number entrained during the month and the percent mortality of these forms at the normal OCNGS discharge temperatures (actual ambient temperature plus 10°C (18°F) during that month. The percent mortality of a form at each temperature was multiplied by the number of the form entrained at that temperature (estimated number entrained each month x percent of days during the month that were at that discharge temperature) to calculate the number lost during that month.

Relatively small differences exist between the estimated number entrained annually (Section 4.3.2.1) and the sum of the monthly estimates because different methods were used to estimate the two numbers (Tatham 1978b).

From June through August 1976, the average OCNGS discharge temperature (actual ambient temperature plus 10°C, 18°F) exceeded 35°C (95°F) on 58 of 87 days (66 percent), 39°C (102.2°F) on 7 days (8 percent), and never exceeded 40°C (104°F) (Table 4.3-14). If OCNGS had operated with a delta T of 13°C (23.4°F), the average discharge temperature (actual ambient temperature plus 13°C, 23.4°F) would have exceeded 35°C (95°F) on 81 of 87 days (93 percent), 39°C (102.2°F) on 57 days (66 percent), and never exceeded 43°C (109.4°F) (Table 4.3-14).

The effect of entrainment also was examined by determining the difference between the density of forms in either the Forked River (macrozoo- and ichthyoplankton) or the OCNGS discharge (microzooplankton) and at the mouth of Oyster Creek (Section 3.2.2.2). During this summer, the OCNGS operated at less than its full-rated capacity (670 MWe) during the months of June (548 MWe), July (526), August (569), and September (580). Only live individuals were collected at the mouth of Oyster Creek because dead plankton settles to the bottom (Carpenter et al., 1974; Marcy, 1976; Tatham et al., 1977b). Although most losses at the mouth of Oyster Creek were attributable to entrainment losses,some percentage may also be attributable to secondary entrainment losses. Reproduction of forms in the canal, however, may introduce eggs and larvae which thereby mask losses from primary and secondary entrainment. Some apparent differences in abundance also may be caused by the large natural variations in plankton populations (Heinle, 1977). This is particularly true for forms that are present in low densities.

4.3.2.2.1 Microzooplankton

The condition of microzooplankton entrained through the OCNGS cooling-water system could not be determined because detritus and phytoplankton in the collections made observation of individuals impossible. Therefore, data on the mortality of various species were estimated from laboratory studies and entrainment data reported for these species at other locations.

Although intermittent application of chlorine has been suggested as the primary cause of mortality of *Acartia tonsa* at the Chalk Point power plant (Heinle, 1969), Carpenter et al. (1974) found no relationship between entrainment mortality of copepods and concentrations of free residual chlorine as high as 0.24 mg/l at the Millstone Point Power Plant. Mattice and Zittel's (1976) review of the literature indicated that the concentration of free available chlorine at the end of the OCNGS condenser tubes (< 0.5 ppm, contact time about 1 min) was slightly below the concentration and contact time which caused mortality of A. tonsa and barnacle nauplii. These concentrations, however, should be experienced only by forms passing through the condenser tubes during periods of chlorination. Since one of the six condenser sections is chlorinated at a time and since the concentration of the chlorine deceases rapidly as the chlorinated water mixes with the unchlorinated water from the other condenser sections, the resultant concentration of chlorine in the OCNGS discharge (maximum of 0.11 mg/l) was below the lethal values reported by Mattrice and Zittel (1976). Chlorination occurs during only half the day (720 min), and only 8.3 percent of the total amount of water circulated at the OCNGS will be exposed to the higher concentrations during chlorination of the condenser tubes.

Mortality of microzooplankton from mechanical stress is apparently site-specific. Mechanical and hydraulic stresses caused substantial mortality of copepods entrained through the Millstone Point Power Plant on Long Island Sound (Carpenter et el., 1974). Although few individuals were dead immediately after passage, some 50 percent were dead after 3.5 days and 70 percent were dead after 5 days. At Northport, New York, however, copepods, polychaete larvae, and barnacle larvae entrained through a power plant experienced little mechanical damage immediately after entrainment. Suchanek and Grossman, (1971) and Icanberry and Adams (1974) found little mechanical damage of trochophore larvae entrained through four power plants in California. Mechanical damage of zooplankton entrained at the OCNGS is apparently minimal because Sandine (1973) reported that some copepods entrained at the OCNGS had less than 20 percent mortality after about two hours. With the exception of soft-bodied forms (e.g., ctenophores), most macrozooplankton pass through the OCNGS without obvious physical damage.

Most studies reported that entrainment losses of zooplankton were due primarily to thermal effects, and the amount of thermal stress experienced by entrained organisms varies with ambient water temperature, delta T, and exposure time (Davies and Jensen, 1974). Little mortality of entrained copepods occurred below a discharge temperature of 34°C (93.2°F) (Suchanek and Grossman, 1971; Lackey, 1974; Icanberry and Adams, 1974). At a laboratory acclimation temperature of 25°C (77°F), a 15-minute exposure of A. tonsa to 35°C (95°F) produced 10 percent mortality (Heinle, 1069). Reeve and Cosper (1970) found that as A. tonsa was acclimated to progressively higher temperatures, it tolerated a temperature as high as 36°C (96.8°F). At a temperature of 26°C (78.8°F), a 10°C (18°F) increase for 15 minutes produced about 10 percent mortality, and after a six-hour exposure 25 percent mortality. The upper thermal limit for A. tonsa was 37°C (98.6°F); survival at this temperature after three hours was poor regardless of acclimation temperature (Reeve and Cosper 1970).

Sandine (1973) found that at the OCNGS the cold-water copepod A. clausi experienced 60 percent mortality in June when exposed to a discharge temperature of 30° to 31°C (86 to 87.8°F) for 1.5 to 2.0 hours. Most A. clausi, however, were entrained from March through May (average bay temperature of 6.1 to 17.8°C, 11.0 to 32.0°F; Burns and Roe, 1974) and should not experience a discharge temperature greater than 28°C (82.4°F). With the maximum delta T (13°C, 23.4°F), the discharge temperature may reach 31°F (87.8°F) in May. A. tonsa and Oithona colcarva suffered less than 20 percent mortality at OCNGS discharge temperatures up to 35°C (95°F) (Sandine, 1973); however, at a discharge temperature of 40.4°C (104.7°F), 80 percent mortality occurred. Some portion of the 57 percent decrease in density of A. tonsa at the mouth of Oyster Creek (Section 3.2.2.4.1) may have been attributable to entrainment mortality because the OCNGS discharge temperature exceeded 35°C (95°F) on 57 of 87 days (66 percent) during the summer of 1976 (Table 4.3-4). If the OCNGS had operated with a maximum delta T, the discharge temperature would have exceeded 35°C (95°F) on 81 of 87 days (93 percent).

Larvae of the northern quahog would be entrained primarily during summer. Although northern quahog larvae were collected in entrainment collections, they occurred in too few collections to determine accurately their pattern of seasonal occurence, and these data were obtained from a study of the northern quahog in a nearby estuary. Carriker (1961) noted that the northern quahog in Little Egg Harbor spawned at a water temperature from 22 to 30°C (71.6 to 86°F) with maximum spawning from 24 to 26°C (75.2 to 78.8°F). At comparable temperatures in Barnegat Bay and an average delta T (10°C, 18°F), larvae would be subject to a temperature from 32 to 40°C (89.6°F to 104°F) during the five-minute passage through the OCNGS cooling-water system and 15-minutes residence in the undiluted discharge water. If most larvae occurred at a bay temperature of 24 to 26°C (75.2 to 78.8°F), they would experience a discharge temperature of 34 to 36°C (93.2 to 96.8°F). At a maximum delta T of 13°C (23.4°F), larvae would be exposed to a temperature of 35 to 43°C (95 to 109.4°F) throughout the spawning season and during maximum abundance (bay temperature of 24 to 26°C, 75.2 to 78.8°F) would experience a temperature of 37 to 39°C (98.6 to 109.4°F).

Based on heat-shock experiments in the laboratory, Kennedy et al. (1974) estimated that cleavage-stage eggs of the northern quahog would experience 10 percent mortality after a 20 minute exposure to 30°C (86°F), 50 percent mortality at 33°C (91.4°F), and 90 percent at 35°C (95°F) and above. During the summer of 1976 (Table 4.3-14), the OCNGS discharge temperature exceeded 35°C (95°F) on 57 days (66 percent); and most entrained cleavage-state eggs probably died. If the OCNGS had operated at a maximum delta T, the temperature would have exceeded 35°C (95°F) on most (93 percent) days.

The more temperature-tolerant trochophore larvae of the northern quahog had 10 percent mortality at 35°C (95°F), 50 percent at 36°C (96.8°F), and 90 percent at 37°C (98.6°F) after a 20-minute exposure (Kennedy et al., 1974). In 1976, some entrained trochophores probably died because the OCNGS discharge temperature exceeded 36.7°C (98°F) on 40 of 87 days (46 percent) and 37.8°C (100°F) on 18 days (21 percent). If the OCNGS had operated at a delta T of 13°C (23.4°F), 36°C (96.8°F) would have been exceeded for 78 days (90 percent) and 37.4°C (99.3°F) for 67 days (77 percent), and most trochophores would have died.

Since Kennedy et al. (1974) did not give data for the time that straight-hinge larvae would be exposed to the OCNGS discharge temperature (20 minutes), data for a 30 minutes exposure were used. For a 30 minute exposure during the period of maximum abundance (bay temperature of 24 to 26°C, 75.2 to 78.8°F), straight-hinge larvae should experience less than 10 percent mortality because the temperature was less than 40.7°C, 105.3°F). Similarly from June through August 1976, mortality should not have exceeded 40°C (104°F) on any day. If the OCNGS had operated at maximum capacity, 40°C (104°F) would have been exceeded on 46 of 87 days (53 percent) but 43°C (109.4°F) would have never been exceeded. At 43.1°C, (109.6°F), straight-hinge larvae would experience 29 percent mortality after a 30-minute exposure. Therefore, it was unlikely that more than 10 percent of the straight-hinge larvae entrained during the summer of 1976 died from thermal shock.

Polychaete and barnacle larvae should be relatively unaffected by the temperature increase experienced during entainment. At the P.H. Robinson and Cedar Bayou power plants in Texas, barnacle (probably B. eburneus) nauplii had more than 80 percent survival at 38°C (100.4°F) and more than 50 percent survival about 40°C (104°F) (Schlicht, 1976). Polychaete larvae were unaffected by entrainment at almost all discharge temperatures up to 38°C (100.4°F) at the Northport Power Plant on Long Island Sound (Suchaneck and Grossman, 1971). Since the average OCNGS discharge temperature exceeded 38°C (100.4°F) for 18 of 87 days (21 percent) and never exceeded 40°C (104°F) from June through August, the 72 percent decrease in the density of barnacle larvae and 42 percent decrease in polychaete larvae at the mouth of the Oyster Creek (Section 3.2.2.4.1) may not be entirely attributable to thermal stress from OCNGS entrainment. Sampling variability may also contribute to these differences. If OCNGS had a delta T of 13°C (23.4°F), the discharge temperature would have exceeded 38.6°C (101.5°F) on 57 of 87 days (66 percent) and 40°C (104°F) on 40 days (46 percent).

4.3.2.2.2 Macrozooplankton

The condition of macrozooplankton taken at the intake and discharge of the OCNGS cooling-water system was determined within 15 minutes of collection (Table 4.3-15). Although some small forms (e.g., zoeae of crabs and shrimp) were abundant, their condition could not be determined quantitatively because of their small size, the limited time available to examine a sample, and the large amounts of detritus which often obscured them. The condition of cumaceans, some amphipods, and arrowworms was difficult to determine because even live individuals often remained motionless when touched with a probe.

Most of the mortality of entrained macrozooplankton appeared to be caused by temperature. Biocidal and mechanical effects appeared minimal because mortality of most forms was generally low at OCNGS discharge temperatures below 30°C (86°F).

Only large, soft-bodied ctenophores suffered obvious mechanical damage. Many of the ctenophores *Mnemiopsis leidyi* and *Beroe* spp. examined from OCNGS discharge collections were fragmented although small (< 20 mm) individuals, especially *Beroe* spp., were collected without obvious damage. This fragmentation probably resulted from mechanical stresses of impact on the traveling screens and passage through the OCNGS cooling-water system. Bongers et al. (1975) also found damage and fragmentation of ctenophores entrained at a steam electic generating station on the Potomac River.

The condition of arrowworms was not determined quantitatively, but qualitatively more individuals with bent bodies were observed in OCNGS discharge collections. This damage may be attributable to increased net damage because the current velocity was greater in the OCNGS discharge than in the OCNGS intake.

Zoeae of the mud crabs (*Neopanope texana*, *Panopeus herbstii*, and *Rhithropanopeus harrisii* have been reared successfully at 30 ± 2°C (86 ± 3.6°F) by Chamberlain (1961). *R. harrisii* zoeae had better survival over the cyclic temperature range of 30 to 35°C (86 to 95°F) than at a constant temperature of either 30 or 35°C (86 to 95°F) (Costlow and Bookhout 1971). Qualitative observations indicated that few mud crab zoeae were affected by passage through the OCNGS at a discharge temperature below 35°C (95°F). *R. harrisii* zoeae exposed to a temperature of 37°C (98.6°F) or below for 180 minutes survived, but at a temperature of 38°C (100.4°F) or above they died (Chase, 1977). Although little or no mortality would be expected for mub crab zoeae entrained during May, mortality may occur from June through August when the discharge temperature exceeds 37.5°C (99.5°F). From June through August 1976, the OCNGS discharge temperature exceeded 37.8°C (100°F) on 18 of 87 days (21 percent), and 24 percent (2.85×10^9) of the estimated 1.21×10^{10} mud crab zoeae entrained during the year were exposed to these temperatures (Table 4.3-15). Loss of these organisms may partially explain the 44 percent decrease in the density of mud crab zoeae in collections at the mouth of the discharge canal (Table 4.3-16). If the delta T at the OCNGS had been 13°C (23.4°F), the OCNGS discharge temperature would have exceeded 37.4°C (99.3°F) on 67 of the 87 days (77 percent).

Qualitative observations of sand shrimp zoeae indicated abnormal swimming behavior at OCNGS discharge temperatures above 30°C (86°F). This form did not survive a 24-hour exposure to a temperature that varied from 25 to 30°C (77 to 86°F) (Regnault and Costlow 1970). The OCNGS discharge temperature exceeded 30°C (86°F) on every day from June through August 1976. An estimated 4.06×10^9 (48 percent) of the estimated 8.48×10^9 sand shrimp zoeae entrained during the first year were exposed to a discharge temperature above 30°C (86°F) (Table 4.3-15) and probably died. Collections at the mouth of Oyster Creek canal showed a 47 percent decrease in the density of sand shrimp zoeae over densities in the Forked River during March and from October through March; this density decrease was 59 percent from April through September (Table 4.3-16).

Adult and juvenile sand shrimp had 75 percent mortality at OCNGS discharge temperatures above 35°C (95°F), 42 percent from 32.5 to 35°C (90.5 to 95°F), and 53 percent from 30 to 32.5°C (86 to 90.5°F) respectively. The apparent discrepancy of higher mortality at 30 to 32.5°C (86 to 90.5°F) than at 32.5 to 35°C (86 to 95°F) is small and probably reflects variability of the estimates rather than a real difference. The mortality of forms exposed to a temperature from 30 to 35°C (86 to 95°F) was assumed to be 53 percent. At temperatures from 27.5 to 30°C (81.5 to 95°F), the average mortality was 23 percent, and below 27.5°C (81.5°F) mortality averages less than 10 percent. Sand shrimp were most abundant from December through May and during July and August. During summer, the OCNGS discharge temperature exceeded 30°C (86°F) on all days (Table 43-14). About 38 percent (3.35×10^7) of the estimated 8.89×10^7 sand shrimp entrained during the first year were exposed to a temperature of 30°C (86°F) and probably died. An insufficient number of this form was collected to determine a change in density at the mouth of Oyster Creek.

Adult and juvenile N. americana entrained at an OCNGS discharge temperature above 35°C (95°F), from 32.5 to 35°C (90.5 to 95°F), and from 30 to 32.5°C (86 to 90.5°F) had a mortality of 94 percent, 82 percent, and 36 percent, respectively. Below 30°C (86°F), mortality rarely exceeded 10 percent. Maximum abundance of N. americana was generally from February through April when the discharge temperature at the OCNGS discharge was below 25°C (77°F). However, this mysid was also abundant in June and August when the OCNGS discharge temperature usually (93 percent of the days) exceeded 32°C (89.6°F) (Table 4.3-14). An estimated 5.74 to 10^9 (54 percent) of the estimated 1.06×10^{10} N. americana entrained during the first year died. Collections at the mouth of Oyster Creek showed a 65 percent decrease in density of N. americana for March 1976 and from October 1976 through March 1977. From April through September, this decrease averaged 92 percent.

Zoeae of the grass shrimp (Palaemonetes spp.) have been reared successfully at 30.6 ± 0.5°C (87.1 ± 0.9°F) (Sandifer, 1972), and qualitative observations indicated that the form was relatively unaffected by an OCNGS discharge temperature below 35°C (95°F). Chase (1977) found that grass shrimp zoeae survived a 180-minute exposure to a temperature as high as 37°C (98.6°F) but at 38°C (100.4°F), none survived. During summer 1976, the OCNGS discharge temperature exceeded 37.8°C for 18 of 87 days (21 percent) and an estimated 27 percent (2.11×10^8) of the 7.95×10^8 grass shrimp zoeae entrained during the first year were exposed to a discharge temperature above 37.5°C (99.5°F) (Table 4.3-15). Collections at the mouth of Oyster Creek from April through September, however, showed a 67 percent increase in grass shrimp zoeae possibly due to reproduction in Oyster Creek (Table 4.3-16).

Few adult and juvenile grass shrimp were collected. Their mortality averaged 89 percent at discharge temperatures above 35°C (95°F) and 0 to 33 percent at temperatures below 35°C (95°F). Most grass shrimp were entrained during July and August, and an estimated 1.91×10^7 (42 percent) of the estimated 4.53×10^7 grass shrimp entrained during the first year should have died assuming mortality of 33 percent (OCNGS discharge temperature of 30 to 32.5°C, 86 to 90.5°F) and 89% (above 35°C, 95°F). The average OCNGS discharge temperature during summer 1976 exceeded 35.6°C (96.1°F) on 57 of the 87 days (66 percent); with a maximum delta T of 13°C (23.4°F), this temperature would have been exceeded on 81 days (93 percent). Too few adult and juvenile grass shrimp were collected to determine a change in density at the mouth of Oyster Creek.

Amphipods had less than 10 percent mortality when exposed to an OCNGS discharge temperature below 35°C (95°F) from April through July 1976. In August, 37 percent of the amphipods collected from 30 to 35°C (86 to 95°F), the mean mortality was 36 percent in June and July, and 65 percent in August. An estimated 1.86×10^9 (25 percent) of the estimated 7.46×10^9 amphipods entrained during the first year probably died. Collections at the mouth of Oyster Creek showed a 14 percent increase in the density of unidentified amphipods during March 1976 and from October through March, but an 80 percent decrease from April through September.

Epitokes of *Nereis* spp. occurred from April through September. During April and May, mortality was 65 percent at a temperature from 27.5 to 30°C (81.5 to 86°F), but below 27.5°C (81.5°F) mortality did not exceed 20 percent. An estimated 2.08×10^6 *Nereis* spp. epitokes died in April and May. From June through September, mortality did not exceed 25 percent at OCNGS discharge temperatures from 27.5 to 37.5°C, (81.5 to 99.5°F), and an estimated 5.02×10^6 epitokes died during these months. For the first year, an estimated 7.10×10^6 (24 percent) of the 3.05×10^7 *Nereis* spp. epitokes were killed. A 70 percent decrease in the density of epitokes of *Nereis* spp. occurred in collections at the mouth of Oyster Creek.

Of the 32 blue crab megalopae collected at a temperature above 30°C (86°F), four were dead. Chase (1977) found no mortality of megalopae entrained at the P.H. Robinson Generating Station in Texas at a discharge temperature of 37°C (98.6°F) and held for up to one hour, or of megalopae exposed to temperatures as high as 38°C (100.4°F) for 180 minutes. Little mortality should result from entrainment at the OCNGS because most (>90 percent) blue crab megalopae occurred in September (average bay temperature of 22.2°C, 40°F, average OCNGS discharge temperature of 32.2°C, 90°F) and October (15.5°C, 60°F; 25.5°C, 77.9°F) when the OCNGS discharge temperature was usually below 33°C (91.4°F).

4.3.2.2.3 Ichthyoplankton

Unlike zooplankton, entrained ichthyoplankton may be affected more by mechanical damage than by either temperature of biocides. Marcy (1976) found that 80 percent of the mortality of ichthyoplankton entrained at the Connecticut Yankee Power Plant was attributable to mechanical damage. At a power plant at Northport, New York, Austin et al. (1973) reported 27 percent to 57 percent of the mortality of juveniles of four marine fishes was caused by mechanical damage. Of all the stresses associated with entrainment, chlorination probably has the least effect on entrained ichthyloplankton (March, 1974).

Although larvae of the winter flounder and sand lance, and juveniles of the bay anchovy collected at the OCNGS discharge had significantly greater immediate mortality than those collected at the OCNGS cooling-water intake, high collection mortality precluded reliable determination of the percent mortality attributable to entrainment. Mortality of larvae of the bay anchovy and gobies, and of juveniles of the northern pipefish also was high in discharge samples but not significantly so. Because mortality of most species could not be quantified adequately, 100 percent mortality was assumed for purposes of evaluating OCNGS impact and the number lost was equal to the number entrained (Table 4.3-5).

Estimated mortality of winter flounder larvae in collections from the OCNGS discharge, as determined with the Bongo sampler, varied with the size of the larvae. Mortality of larvae smaller than 5 mm (0.2 in.) was essentially 100 percent, but larger larvae had 63 percent mortality. This estimate of the immediate mortality of entrained winter flounder larvae may still be high because preliminary results with a sampler designed to reduce net mortality indicated that entrainment mortality may be only 33 percent.

A seasonal estimate of the number of entrained winter flounder larvae in each size-class was determined with a method slightly modified from Houde (1977), as discussed by Tatham et al. (1978b). This seasonal estimate of the total number of larvae entrained was 27 percent to 46 percent (Tables 4.3-17, 4.3-18) lower than the annual entrainment estimate because of the method of calculation. Seasonal estimates were a more accurate determination of the total number entrained because they were calculated with data only from months in which the larvae occurred; annual estimates used a weighted average for the entire year.

Since the exact mortality of winter flounder larvae was uncertain, the projected number lost was calculated with both estimates of entrainment mortality. Based on the higher estimate of mortality (63 percent for larger larvae, 100 percent for larvae below 5 mm, 0.2 in.), an estimated 1.17×10^9 of the 1.40×10^9 winter flounder larvae entrained were lost immediately after entrainment through the OCNGS during 1977. If the lower estimate of 33 percent mortality for all larvae were used, an estimated 4.67×10^8 larvae died immediately after entrainment (Table 4.3-18). For 1976, the estimated mortality was between 8.33×10^7 (percent mortality of larger larvae) and 2.9×10^7 (33 percent mortality of all larvae) for the estimated 8.7×10^7 larvae entrained (Table 4.3-17).

4.3.2.3 Population studies in Barnegat Bay

The daily population of abundant macrozoo- and ichthyoplankton in Barnegat Bay from Goodluck Point to Gulf Point ($118.8 \times 10^6/m^3$) was estimated from daylight collections in the bay. Microzooplankton collections were not taken because the species of interest (i.e., blue crab zoeae, northern quahog larvae) either were collected by other gear or their occurrence in the plankton was too brief to detect and implement a sampling program. Collections were taken by randomly sampling from 87, 0.4 x 0.4-km quadrates. Usually, 50 of the 87 quadrates were randomly chosen and sampled on a day. For forms which were primarily found in the plankton after sunset, a more limited area of the bay from Cedar Beach to Gulf Point ($107.5 \times 10^6/m^3$) was sampled at night.

The volume of each quadrate sampled was estimated from the mean surface area of a representative number of quadrates and the estimated depth in each quadrate. Density of organisms in the sample was multiplied by the volume of that quadrate. The mean number of organisms and the mean volume of the quadrates sampled were computed. This mean number per quadrate was extrapolated to the total number in the bay.

4.3.2.3.1 Macrozooplankton

During 1977, seven surveys to estimate the population of abundant and important macrozooplankton in the bay were conducted during daylight hours from March 11 through July 21. Two surveys were conducted at night during September 1977 to estimate the number of blue crab megalopae in the bay. The number of 19 forms in the bay was calculated for dates on which these forms were abundant (Table 4.3-19).

4.3.2.3.2 Ichthyoplankton

During 1977, six surveys to estimate the population of abundant and important ichthyoplankton were conducted during daylight hours from March 11 through July 21. The number of five forms in the bay was calculated for days when these forms were abundant (Table 4.3-20).

An estimate of the total number of winter flounder larvae and of bay anchovy eggs produced during the entire reproductive season was extrapolated from the daily population estimates using a method slightly modified from Houde (1977). The modifications of Houde's methods are detailed in Tatham et al. (1978b). The seasonal estimate of the number of winter flounder larvae in various size-classes during 1976 and 1977 was calculated, and the total number of larvae hatched in the bay during these years was estimated from the exponential regression of seasonal abundance of each size-class on the estimated age of that size-class (Tables 4.3-17, 4.3-18). This estimate of the larvae hatched was necessary because the small, newly-hatched larvae were not adequately sampled by the collection gear.

4.3.2.4 Analysis of entrainment effect

Some portion of the decrease in the density of many forms in collections from either Forked River or the OCNGS discharge to the mouth of Oyster Creek undoubtedly resulted from losses at OCNGS (Section 3.2.2.3). Although these decreases resulted from both primary and secondary entrainment losses, losses from primary entrainment probably exceeded those from secondary entrainment because organisms passed through the OCNGS cooling-water system were exposed to a higher temperature than those secondarily entrained.

4.3.2.4.1 Microzooplankton

The decrease in the density of barnacle larvae, polychaete larvae, copepod nauplii, Acartia tonsa, Acartia spp., and unidentified bivalve larvae from the OCNGS discharge to the mouth of Oyster Creek in 1976 probably was due in part to entrainment losses at the OCNGS. These losses, however, did not appear to have reduced the populations in the bay. Under similar conditions in the Indian River, Delaware estuary, Davies and Jensen (1974) found that a reduction in the holoplankton component of the microzooplankton populations in the discharge canal of a steam electric generating station did not cause a decrease of these forms in the estuary.

Although most cleavage-stage eggs and about half of the trochophore larvae of the northern quahog that were entrained during the summer of 1976 probably died, mortality of straight-hinge and umbo larvae was probably less than 10 percent because the average OCNGS discharge temperature did not exceed 40°C (104°F) (Table 4.3-14). With this high survival, at least 1.03×10^{11} straight-hinge and umbo larvae probably were live after passage through OCNGS and the undiluted thermal discharge, and it is doubtful that the lack of recruitment into this population in recent years has resulted from OCNGS entrainment losses (Section 3.2.2). The population reduction in this species has been observed throughout the bay and not merely in the areas which could be influenced by the OCNGS intake or discharge.

No evidence of changes in the general structure of the microzooplankton community in Barnegat Bay was found. The species composition, distribution, and seaonal succession of the microzooplankton were similar to that described from other estuaries and embayments in the northeastern United States (Deevey, 1952, 1956, 1960; Jeffries, 1964, 1967; Cronin et al., 1962; Sage and Herman, 1972; Swiecicki and Prendergast, 1976).

4.3.2.4.2 Macrozooplankton

To evaluate the magnitude of the OCNGS effect, the number of a form entrained during either a 12-hour period of daylight or a 12-hour period of darkness (for mysids, blue crab megalopae, and Libinia spp. megalopae) was compared to the estimated number of the form in the bay (Table 4.3-19). For most (70 percent) comparisons, the number entrained was less than 5 percent of the estimated number in the bay, and for about half of the comparisons less than 2 percent. Although zoeae of Hippolyte spp., Upogebia affinis, Panopeus herbstii, Neopanope texana, Pagurus spp., Libinia spp., the sand shrimp, and blue crab, and adults and juveniles of the mysid Mysidopsis bigelowi had more than 5 percent of the number in the bay entrained during a 12-hour period, they also had days when less than 5 percent of the population was entrained. This variability in the percentage entrained was attributed in part to the variable distribution of these forms in the bay and at times to a relatively large concentration of gravid females in the intake canal. The large percentage of Uca spp. and Rhithropanopeus harrisii zoeae entrained at the OCNGS may be attributable, in part, to large adult populations in the less saline areas of the north and central branches of the Forked River.

Although losses of macrozooplankton occurred from entrainment of forms at the OCNGS, the seasonal variation, species composition, and relative abundance of this community in the bay was similar to those from Great Bay, a New Jersey estuary that is relatively free from environmental stress (Swiecicki and Prendergast, 1976).

4.3.2.4.3 Ichthyoplankton

Although most abundant ichthyoplankton showed a decrease in density from the Forked River to the mouth of Oyster Creek, these losses had no apparent effect on the ichthyoplankton in the bay. The seasonal occurrence, abundance, and species composition of the ichthyoplankton in Barnegat Bay generally were similar to those reported in estuaries from Long Island to Chesapeake Bay (Croker, 1965; Dovel, 1967; Scotton 1970; 1970; Croker, 1965; Perlmutter, 1939; Richards, 1959; Wheatland, 1956). Although various studies (Wheatland, 1956; Richards, 1959; Perlmutter, 1939; Scotton, 1970, Croker, 1965) found that eggs and larvae of the Atlantic menhaden were relatively common, few were entrained at the OCNGS. This may reflect both the general decline of the Atlantic menhaden population in the mid-Atlantic area (Nicholson 1975), and its tendency to spawn in offshore waters (Nicholson 1972).

Although most zooplankton populations are resident in the bay, the winter flounder, bay anchovy, and northern pipefish are the only important species of fish that had substantial local reproduction in 1975-77. Spawning of the Atlantic menhaden, bluefish, weakfish, northern kingfish, and summer flounder occur primarily in ocean water, and few larvae were entrained at the OCNGS. The relatively small exchange of water between Barnegat Bay and the ocean may also account for the few larvae of marine spawners in the bay. The population of the threespine stickleback in southern New Jersey estuaries has been low in recent years; no eggs and few larvae were entrained at the OCNGS. Since this species spawns and young occur in vegetation, it is unlikely that a substantial number of eggs and young will be entrained. Few eggs or larvae of the northern puffer were entrained because the population of this species has been at low levels throughout New Jersey in recent years (Section 4.2.2.1.16). Their decrease in abundance occurred in the late 1960s and early 1970s and was related to natural phenomena. Most New Jersey estuaries are relatively unimportant to the reproduction of the anadromous striped bass (Raney, 1952).

The estimated number of a form in the bay in 1977 was compared to the number of these forms entrained at the OCNGS during a comparable 12-hour period of daylight (Table 4.3-20). If the OCNGS did not circulate water on the date that a survey was conducted, the mean density of a form in collections from the dilution pump discharge was multiplied by the volume of water that would have been passed through the OCNGS (460,000 gpm) to estimate the number of a form which would have been entrained at the OCNGS. The estimated number of bay anchovy eggs that were spawned and winter flounder larvae that were hatched in the bay during the year were compared to the total number of these forms entrained through the OCNGS during the year.

Winter flounder

In 1977, the estimated number of winter flounder larvae in the bay was 1.53×10^9 on March 11 and 1.30×10^9 on March 28. With four circulating-water pumps in operation, the percentage of the population entrained per 12-hour period for these two dates were 1.1 percent and 1.0 percent, respectively (Table 4.3-20). Over the entire 1977 reproductive season, however, a total of 10.4 percent of the of the 1.35×10^{10} larvae hatched in the bay were entrained (Table 4.3-18), and an estimated 3.5 percent (4.67×10^8) to 8.7 percent (1.17×10^9) were killed immediately after entrainment. This range of percentages occurs because of the uncertainty of the mortality estimates. With four pumps in operation during most of March and April 1976, this percentage was estimated to be from 0.1 percent (2.9×10^7) to 0.4 percent (8.3×10^7) of the 1.88 $\times 10^{10}$ larvae produced during the reproductive season. In 1976, 0.5 percent of the larvae hatched in the bay were entrained (Table 4.3-17).

The effect of a loss of 3.5 percent to 8.7 percent of the larvae in the bay immediately after entrainment is difficult to interpret because the correlation between the number of larvae and young is not well defined. Although the population of winter flounder in the bay in 1976 (194,370 ± 43,047) and 1977 (111,005 ± 23,174) were roughly equivalent and a similar number of larvae hatched during 1976 (1.88 x 10^{10}) and 1977 (1.35 x 10^{10}), the number of young produced in 1975-76 (0.4/trawl collection, 0.2/seine collection) was substantially less than the number produced in 1976-77 (4.8, 0.9). These differences between the two years were attributable to differences in the survival rate of larvae between the two years. Similarly, a greater percentage of the population was entrained at the OCNGS during the year when the greater number of young was produced.

The lack of substantial preoperational data, the substantial decline in the population of the winter flounder in most New Jersey estuaries in recent years, and the variables (e.g., survival rate) in the population dynamics of this species further complicated analysis of entrainment effects. This recent decline in the Barnegat Bay population was probably attributable to an environmental factor (e.g., water temperature) rather than the OCNGS operation because this decrease also occurred in southern New Jersey estuaries that were beyond the influence of the OCNGS (Section 3.2.4.2). In Narragansett Bay, Rhode Island, Jeffries and Johnson (1974) found that 78 percent of the variation in the abundance of the winter flounder population was attributable to climatic trends during the reproductive season. Substantial reproductive success occurred during severe (cold) winters, while the reproductive success was poor during milder winters. The winter of 1976-77, which produced the substantial number of young in Barnegat Bay, was more severe than several previous winters.

No evidence exists that the winter flounder population has declined substantially in Barnegat Bay as the result in entrainment losses at the OCNGS, or that the population has been adversely affected by the operation of the OCNGS cooling-water system. The number of young collected by seine in 1975-76 and 1976-77 was within the range of values reported by Marcellus (1972) prior to the operations of the OCNGS (Section 3.2.4) and declines in the winter flounder population in the bay paralleled changes in the populations in other estuaries in southern New Jersey.

Bay anchovy

The estimated population of bay anchovy eggs in the bay on five dates in 1977 ranged from 4.94 x 10^8 to 5.72 x 10^9. If the OCNGS had circulated water during June and July of 1977, an estimated 0.1 percent to 1.5 percent of these eggs would have probably been entrained at the OCNGS during a 12-hour period

(Table 4.3-20). Since the OCNGS did not operate during June and July 1977, a comparison of the seasonal population (4.35×10^{11}) and seasonal entrainment estimate (1.79×10^{10} eggs of the bay anchovy was done for 1976. Approximately 4.7 percent of the bay anchovy eggs spawned in Barnegat Bay in 1976 were entrained at the OCNGS (Table 4.3-21).

Daily population estimates of larvae of the bay anchovy in the bay during 1977 ranged from 7.47 to 10^6 x 7.73×10^8. If the OCNGS had been circulating water, an estimated 1.1 percent to 15.3 percent of the population would have been entrained per 12-hour period (Table 4.3-20). The large range of the percent entrained per 12-hour period was probably due to the variability of the distribution of larvae in the bay. When larvae were relatively abundant near the mouth of the Forked River, high estimates of the percentage of the population entrained per day were found; however, on three of four days, this percentage was below 8 percent.

It is unlikely that the loss of these eggs and larvae would harm the seasonal population of the bay anchovy in the bay, and it would have no effect on the larger populations along the coast. The catch of young and adults at two of three stations in the bay has not substantially decreased since the OCNGS began operation (Section 3.2.4) and the bay anchovy remains a dominant species in the bay. The density of eggs and larvae of this species were not different from those in nearby New Jersey estuaries (Section 4.2.2.3.2).

Northern pipefish

The number of juvenile northern pipefish in the plankton was relatively constant from May through July. The estimated percentage of juveniles entrained at the OCNGS per 12-hour period ranged from 1.2 percent to 22.3 percent (Table 4.3-20), but was less than 5 percent on four of five days. This large range of percentages was probably due to the variability in the distribution of juveniles in the Bay. When they were relatively abundant near the mouth of the Forked River, the estimated percentage of entrainment was high. Juveniles were not abundant enough for a seasonal analysis.

Declines in the catch of the northern pipefish have occurred at three stations in the bay since 1966-69, but these declines may not reflect a decrease in the abundance of the bay population. Although Marcellus (1972) did not completely describe the amount of vegetaion at these stations, it appears that vegetation was more abundant there from 1966-69 than in 1975-77. A reduction in vegetation would account for at least part of the decline in the catch at these stations, since vegetation is an important factor affecting this species' distribution. The absence of a substantial adverse effect on the population of northern pipefish in bay is evidenced by the similarity of the bay to that of a comparable, unstressed estuary, Little Egg Harbor. The trawl catch of the northern pipefish in Barnegat Bay during 1975-76 (0.5/coll.) and 1976-77 (0.3) was similar to or greater than the trawl catch (adjusted for differences in tow time) in Little Egg Harbor from 1972 through 1974 (0.15 to 0.25).

Goby

The daily population of goby larvae (2.28×10^5 to 1.76×10^6) in the bay was relatively small in relation to the number entrained at the OCNGS and, therefore, the estimates of the percentage entrained per 12-hour period were high (23.7 percent to $<$ 100 percent of the estimated bay population, Table 4.3-20). These high percentages probably were due to the relatively large number of gobies residing near the OCNGS. The construction of the intake and discharge canal may have substantially increased the habitat for adults in these areas and resulted in a large number of gobies near the OCNGS. Because goby eggs are adhesive, high densities of larvae tend to occur near the localized habitat of the adults. The large population of gobies in the intake and discharge canals probably produced a large number of larvae near the OCNGS and therefore, unrealistically high entrainment estimates. If the population of the goby in the area near the OCNGS has been maintained, despite entrainment losses, then it cannot be deemed adversely affected.

The localized nature of the OCNGS impact on the goby population, even were it severe, would not have an adverse impact on bay populations. Indeed, even the loss of the population near OCNGS would not have a significant affect since they represented additions to the natural bay population, consequent to the creation of a new habitat by construction of the intake and discharge canals.

Other fishes

No evidence exists that changes in the species composition and relative abundance of fishes in Barnegat Bay since the OCNGS began operation were related to entrainment losses at the OCNGS. Many fishes which showed increases (i.e., spot) or decreases (i.e., northern kingfish, northern puffer) in abundance since 1969 have little or no reproduction in the bay, and these changes have also occurred in other New Jersey estuaries. Although the abundance of some fishes that reproduce in the bay (i.e., winter flounder, Atlantic silverside) have decreased since the OCNGS began operation, the abundance of these fishes has also decreased in other New Jersey and mid-Atlantic estuaries (Section 3.2.4), and these decreases were probably related to environmental factors which influenced the abundance of these species throughout the mid-Atlantic area. The overall structure of the fish community in 1975-77 (Section 3.2.4) is similar to the community in the bay prior to operation of the OCNGS (Marcellus, 1972), the communities in other New Jersey estuaries (Milstein et al., 1977), and in other mid-Atlantic estuaries (deSylva et al., 1962; Richards and Castagna, 1970; Oviatt and Nixon, 1973; McErlean et al., 1973).

4.3.2.5 Conclusion

Although some losses of microzooplankton entrained through the OCNGS occur, the species composition, distribution, and seasonal succession of the microzooplankton in Barnegat Bay are similar to those in other estuaries in the northeastern United States. The holoplankton component of microzooplankton populations are resilient and losses from a point source do not necessarily reduce populations in estuaries (Davies and Jensen, 1974).

Although most of the entrained cleavage-stage eggs and some trochophore larvae of the northern quahog were probably lost, most straight-hinge and umbo larvae probably survived the temperature increase. Since at least an estimated 1.03×10^{11} straight-hinge and umbo larvae (90 percent of entrained larvae) probably survived entrainment and subsequent exposure to above ambient temperature water in the discharge canal in 1976, it is doubtful that the low recruitment into the population in recent years has resulted from the OCNGS opera tion (Section 3.2.2).

Although some losses of entrained macrozooplankton have occurred, no obvious changes in the community due to the operation of the OCNGS was suggested. Seasonal variation, species composition, and relative abundance of the community in Barnegat Bay were similar to those of the community from Great Bay (Swiecicki and Prendergast, 1976). It does not appear that the OCNGS operation has either affected the structure of the sand shrimp and blue crab population or reduced the standing crop of juvenile and adult blue crab in the bay.

Similarly, the fish community in the bay has not experienced any variation in species composition or abundance of populations that reproduce in the bay that were not also noted for other southern New Jersey and mid-Atlantic estuaries, and therefore, these reductions in Barnegat Bay were attributed to environmental factors that affect those populations throughout the mid-Atlantic area rather than OCNGS entrainment losses.

Although little data exist on zoo- and ichthyoplankton communities in the bay prior to 1969, it does not appear that entrainment of these forms at the OCNGS has affected either the invertebrate and fish communities in the bay or the various component populations to a point where changes were detected. The species composition, relative abundance, and seasonal occurrence of these planktonic forms were not obviously different from those in other estuaries in the northeastern United States in recent years.

4.3.3 Predicted effect of the FRNGS

The species composition, relative abundance, and seasonal occurrence of zoo- and ichthyoplankton entrained at the FRNGS will be similar to those found at the OCNGS (Section 4.3.2.1) because both stations draw water from a common intake canal. Because the density of forms in the water entrained at the FRNGS will be the same as that of forms entrained at OCNGS, the number of important species and other abundant zoo- and ichthyoplankton that may have been entrained at the FRNGS during 1975-76 and 1976-77 was estimated as a percentage of the number of these forms entrained at the OCNGS during this period (Tables 4.3-22 to 4.3-24). This percentage (8.7 percent) was determined from this volume of water entrained at the FRNGS (40,000 gpm) and at the OCNGS with all circulating water pumps in operation (460,000 gpm).

4.3.3.1 Effect of entrainment

All forms entrained at the FRNGS will enter the cooling tower. Mortality of entrained forms was assumed to be 100 percent and the number which would be killed would be the same as the number entrained (Tables 4.3-22 to 4.3-24).

4.3.3.2 Incremental effect of entrainment losses

Significance of the incremental losses of zoo- and ichthyoplankton at the FRNGS to the bay population was evaluated by adding the estimated losses at the FRNGS to the estimated losses at the OCNGS (Table 4.3-25). For macrozoo- and ichthyoplankton, the combined losses at the two generating stations were compared to the estimated number of forms in the bay (Section 4.3.3.4).

4.3.3.2.1 Microzooplankton

In light of the productivity of zooplankton populations (Davies and Jensen, 1974; Jeffries and Johnson, 1976), losses of these forms at the FRNGS would be relatively unimportant to the populations in the bay. Although the estimated 9.92×10^9 straight-hinge and umbo larvae of the northern quahog that would have been entrained at the FRNGS in 1976 were only 8.7 percent of the larvae which passed through the OCNGS, the loss of larvae at the FRNGS may be approximately equal to the number of larvae lost at the OCNGS (Table 4.3-25) because all larvae which would be entrained at the FRNGS die. However, 84.3 percent of the total larvae which would have been entrained at the two stations in 1976 would have been passed live into the upper portion of Oyster Creek.

4.3.4.3.2 Macrozooplankton

The projected losses at the FRNGS were determined from data based on days that the OCNGS operated from September 1975 through August 1976 (Table 4.3-15). For abundant forms, the incremental loss at the FRNGS would have ranged from 16 percent (Neomysis americana) to 37 percent (mud crab zoeae) of the immediate loss at the OCNGS (Table 4.3-25). For megalopae of the blue crab, a form which had little mortality at the OCNGS, the losses at the FRNGS would have exceeded those at the OCNGS.

The increased percentage of the bay population that was entrained at the two generating stations during a 12 hour period would have been relatively small for most forms. In 1977, this increased percentage would have ranged from less than 0.1 percent for forms which had a relatively small percentage of the estimated number in the bay that were entrained, to 3.2 percent for forms with a larger percentage of the population entrained (Table 4.3-25). Most forms, however, which had a relatively large percentage of the estimated number in the bay entrained had an unrealistically high estimate of the number entrained because of the large concentration of gravid females in the intake canal (e.g., sand shrimp, mud crab), large populations of adults in the less saline areas of the north and central branches of the Forked River (e.g., Uca spp. zoeae) or patches of organisms that were only abundant on occasion near the mouth of the Forked River (Section 4.3.2.4.2). The projected loss of blue crab megalopae at the FRNGS on September 19, 1977 (6.2×10^4) and September 28 (2.4×10^4) would have been less than 0.1 percent of the estimated number in the bay on those days (Table 4.3-19). Since the losses at the FRNGS would represent a small (< 6.6 percent) incremental loss in comparison to losses at the OCNGS, and since the OCNGS loss did not cause measurable effects on the bay communities (Section 4.3.3), it is unlikely that the FRNGS losses will cause noticeable effects either on the macrozooplankton and invertebrate community of the bay or on the populations of the various component species.

4.3.4.3.3 Ichthyoplankton

The projected losses at the FRNGS were determined from data based on days that the OCNGS operated from September 1975 through August 1976 (Table 4.3-5). Because it was assumed that most forms were dead immediately after entrainment at the OCNGS, the incremental loss of most forms at the FRNGS would be 8.7 percent. This incremental loss at the FRNGS would have increased the percentage of entrainment losses for a 12 hour period by less than 0.1 percent (bay anchvy eggs) to 1.9 percent (juvenile northern pipefish). Forms which are projected to have a large percentage of the population entrained at the two generating stations, however, either had an unrealistically high estimate of the number entrained at the OCNGS (e.g., gobies) or are abundant only on occasion near the mouth of the Forked River (juvenile northern pipefish, Section 4.3.2.4.2).

Some larvae of the winter flounder survived entrainment through the OCNGS (Section 4.3.2.2.3), and the incremental loss which will be experienced at the FRNGS will be greater than the 8.7 percent of the mortality experienced at the OCNGS. The loss of 1.4 x 10^7 winter flounder larvae projected from 1977 data would constitute an increase of 10.4 percent to 26 percent over the number lost at the OCNGS (Table 4.3-25). The percentage of the number in the bay that would have been lost at the two generating stations in 1977 would have increased by 0.9 percent (from 3.5 percent at only the OCNGS to 4.4 percent at both stations; 33 percent mortality of all larvae) or 0.8 percent (from 8.7 percent to 9.5 percent; 63 percent mortality of larvae larger than 5 mm, 0.2 in.).

4.3.4.4 Conclusion

The additional losses of most zoo- and ichthyloplankton at the FRNGS will be relatively small and would represent only an additional 0.1 percent to 3.2 percent of the number of these forms that were entrained during a 12 hour period. Although the losses of forms which had little or no mortality at the OCNGS (i.e., blue crab megalopae) will be greater at the FRNGS, these losses should represent a small (<0.1 percent) percent of the number in the bay. It must be concluded, therefore, that the incremental losses at the FRNGS will not adversely affect the balanced, indigenous population of the bay.

References

Austin, H.M., J. Dickinson, and C. Hickey. 1973. An ecological study of ichthyloplankton at the Northport power station, Long Island, N. Y. N. Y. Ocean Sci. Lab., Montauk, NY. (not seen, cited in March 1976).

Bean, T.H. 1901. Catalogue of fishes of Long Island. Sixth Ann. Rept. N.Y. Forst, Fish, and Game Comm.: 373-398. (not seen, cited in Schafter 1965).

Bongers, L.H., T.T. Polgar, A.J. Lippson, G.M. Krainak, L.R. Moran, A.F. Holland, and W.A. Richkus. 1975. The impact of the Morgantown Power Plant on the Potomac estuary: an interpretive summary of the 1972-1973 investigations. Prepared for Maryland Dept. of Nat. Res., Power Plant Siting Program by Martin Marietta Corp. MP-15. 144 pp.

Burns and Roe, Inc. 1974. Oyster Creek No. 1 Circulating Water System study (phase 1). Prepared for General Public Utilities Corp. 131 pp.

Carpenter, E.J., B.B. Peck, and S.J. Anderson. 1974. Survival of copepods passing through a nuclear power station on northeastern Long Island Sound, USA. Mar. Biol. 24: 49-55.

Carriker, M.R. 1961. Interrelation of functional morphology, behavior and autecology in early stages of the bivalve Mercenaria mercenaria. J. Elisha Mitchel Sci. Soc. 77(2): 168-241.

Chamberlain, N.A. 1961. Studies on the larval development of Neopanope texana sayi (Smith) and other crabs of the family Xanthidae (Brachyura). Chesapeake Bay Inst., Tech. Rept. 22: 1-35.

Chanley, P. and J.D. Andrews. 1971. Aids for identification of bivalve larvae of Virginia. Malacologia 11(1): 45-119.

Chase, C.L. 1977. Survival of zooplankton entrained into the cooling water system and supplemental cooling towers of a steam-electric generating station located on Galveston Bay, Texas. M. S. Thesis. Texas A & M Univ. 230 pp.

Chase, D.M. 1975. Survival rates of impinged organisms. Pages 97-105 in Effects of adding Unit 4 and cooling towers at the P.H. Robinson Generating Station on terrestrial plants and aquatic animals. Depts. of Soil and Crop Sci. and Wildl. and Fish. Sci., Texas A & M Univ. and Texas Agric. Exper. Exper. Sta. Project 1869.

Costlow, J.D., Jr., and C.G. Bookhout. 1971. The effect of cyclic temperatures on larval development in the mud crab _Rhithropanopeus harrisii_. Pages 201-210 _in_ D.J. Crisp, ed. Fourth European Mar. Biol. Symp. Cambridge Univ. Press, London.

Croker, R.A. 1065. Planktonic fish eggs and larvae of Sandy Hook estuary. Chesapeake Sci. 6(2): 92-95.

Cronin, L.E., J.C. Daiber, and E.M. Hulbert. 1962. Quantitative seasonal aspects of zooplankton in the Delaware estuary. Chesapeake Sci. 3(2): 63-93.

Davies, R.M., and L.D. Jensen. 1974. Entrainment of zooplankton at three mid-Atlantic power plants. Pages 131-155 _in_ L.D. Jensen, ed. Proc. of Second Workshop in Entrainment and Intake Screening. Johns Hopkins Univ., Baltimore, MD.

Deevey, G.B. 1952. Quantity and composition of the zooplankton of Block Island Sound, 1949. Bull. Bing. Oceanogr. Coll. 13(3): 120-164.

____. 1956. Oceanography of Long Island Sound, 1952-1954. V. zooplankton. Bull. Bing. Oceanogr. Coll. 15: 113-155.

____. 1960. The zooplankton of the surface waters of the Delaware Bay region. Bull. Bing. Oceanogr. Coll. 17: 1-54.

de Sylva, D.P., F.A. Kalber, J., and C.N. Shuster, Jr. 1962. Fishes and ecological conditions in the shore zone of the Delaware River estuary, with notes on other species collected in deeper water. Univ. Del. Mar. Lab., Inf. Ser. Publ. No. 5, 164 pp.

Dovel, W. 1967. Fish eggs and larvae of the Magothy River, Maryland. Chesapeake Sci. 8(2): 125-129.

Figley, W. 1977. New Jersey's sport fishery. N. J. Outdoors 4(5): 20-21.

Halgren, B.A. 1973. Phase III - use studies. Pages 175-224 _in_ Studies of the Upper Barnegat System. Misc. Rept. No. 10m (mimeo) N. J. Dept. of Envir. Prot., Div. of Fish, Game, and Shellfish. Burl Fish., Nacote Creek Res. Sta.

Hamer, P.E. 1972. Phase III - Use studies. Pages 115-141 _in_ Studies of the Mullica River-Great Bay estuary. Misc. Rep. No. 6-1 (mimeo) N. J. Dept. of Envir. Prot., Div. of Fish, Game, and Shellfish. Bur. Fish., Nacote Creek Res. Sta.

Heinle, D.R. 1969. Temperature and zooplankton. Chesapeake Sci. 10 (3 and 4): 186-209.

Heinle, D.R. 1977. Phytoplankton and zooplankton collection problems and relevance of entrainment to the ecosystem. Pages 110-117 in L.D. Jensen (ed.). Third National Workshop on entrainment and impingement. Section 316(b)-research and compliance. Ecological Analysts, Inc., Melville, New York.

Hess, K.W., M.P. Sissenwine, and S.B. Saila. 1975. Simulating the impact of the entrainment on winter flounder larvae. Pages 1-29 in S.B. Saila, ed. Fisheries and energy production: a symposium. D.C. Heath and Co., Lexington MA.

Houde, E.D. 1977. Abundance and potential yield of the round herring, Entrumeus teres, and aspects of its early history in the eastern Gulf of Mexico. Fish. Bull. 75(1): 61-89.

Icanberry, J.W., and J.R. Adams. 1974. Zooplankton survival in cooling water systems of four thermal power plants on the California coast - Interim Report. March 1971-January 1972. Pages 13-22 in L.D. Jensen, ed. Proc. Second Workshop on Entrainment and Intake Screening. Johns Hopkins Univ., Baltimore, MD.

Jeffries, H.P. 1964. Comparative studies on estuarine zooplankton. Limnol. Oceanogr. 9: 348-358.

____. 1967. Saturation of estuarine zooplankton by congeneric associates. Pages 500-508 in G. Lauf, ed. Estuaries Am. Assoc. Adv. Sci. Publ. No. 83. Washington, D.C.

____, and W.C. Johnson. 1974. Seasonal variations of bottom fishes in the Narragansett Bay area: Seven-year variations in the abundance of winter flounder (Pseudopleuronectes americanus). J. Fish. Res. Bd. Canada. 31(6): 1057-1066.

____, ____. 1976. Petroleum, temperature and toxicants: examples of suspected responses by plankton and benthos on the Continental Shelf. Univ. Rhode Is. Mar. Reprint 69: 96-108.

Joseph, E.B. 1972. The status of the Sciaenid stocks of the Middle Atlantic coast. Chesapeake Sci. 13(2): 87-100.

Kennedy, V.S., W.H. Roosenberg, M. Castagna, and J.A. Mihursky. 1974. Mercenaria mercenaria (Mollusca: Bivalvia): temperature - time relationship for survival of embryos and larvae. Fish. Bull. 72(4): 1160-1166.

Lackey, J.B. 1974. Entrainment studies at Turkey Point on Biscayne Bay: have thermal effects affected the plankton of Biscayne Bay? Pages 187-191 in L.D. Jensen, ed. Proc. Second Workshop on Entrainment and Intake Screening. Johns Hopkins Univ., Baltimore, MD.

Loesch, J., J. Bishop, A. Crowe, R. Kuckyr, and P. Wagner. 1976. Technique for estimating trawl efficiency in catching brown shrimp (Penaeus aztecus), Atlantic croaker (Micropogon undulatus), and spot (Leiostomus xanthurus). Gulf Res. Rept. 5(2): 29-33.

Mackett, D.J. 1973. Manual of methods for fisheries resource survey and appraisal. Part 3. Standard methods and techniques for demersal fisheries resource surveys. FAO Fish Tech. Paper No. 124. 39 pp.

Marcellus, K.L. 1972. Fishes of Barnegat Bay, New Jersey, with particular reference to seasonal influences and possible effects of thermal discharges. Ph.D. Dissertation. Rutgers Univ. 190 pp.

Marcy, B.C., Jr. 1974. Vulnerability and survival of entrained organisms at water intakes, with emphasis on young fishes. Presented at Amer. Soc. of Civil Engineers, Boulder, Colo., August 1974.

Marcy, B.C., J., 1976. Planktonic fish eggs and larvae of the lower Connecticut River and the effects of the Connecticut Yankee Plant including entrainment. Pages 115-139 in D. Merriman and L.M. Thorpe, eds. The Connecticut River ecological study. The impact of a nuclear power plant. Amer. Fish. Soc. Monograph No. 1.

Maryland State Fisheries Administration. 1974. Summary of 1974 fish kills. Dept. Nat. Res., Annapolis, MD.

. 1975. Summary of 1975 fish kills. Dept. Nat. Res., Annapolis, MD.

Mattice, J.S., and H.E. Zittel. 1976. Site-specific evaluation of power plant chlorination. J. Water Poll. Control Fed. 48(10): 2284-2308.

McErlean, A.J., S.C. O'Conner, J.A. Mihursky, and C.I. Gibson. 1073. Abundance, diversity, and seasonal patterns of estuarine fish populations. Estuarine and Coastal Marine Sci. (1973)I: 19-30.

McHugh, J.L. 1977. Fisheries and fishery resources of New York Bight. U.S. Dept. of Commerce, NOAA Tech. Rept., NMFS Circ. 401. 50 pp.

Meglitsch, P.A. 1967. Invertebrate zoology. Oxford Press, London, 961 pp.

Miller, R.W. 1978. Marine recreational fishing in Delaware. Del. Div. of Fish and Wildl., Document 40-05/78/01/18. 28 pp.

Milstein, C.B., D.L. Thomas, and Associates. 1976. Ecological studies in the bays and other waterways in the vicinity of the proposed site for Atlantic Generating Station, New Jersey. Progress report for the period January-December 1975. Ichthyological Assoc., Inc. Ithaca, NY. 572 pp.

___, ___, ___. 1977. Summary of ecological studies for 1972-1975 in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Ichthyological Assoc., Inc. Bull. No. 18. Ichthyological Assoc., Inc., Ithaca, NY. 757 pp.

Nicholson, W.R. 1972. Population structure and movements of Atlantic menhaden, Brevoortia tyrannus, as inferred from back-calculated length frequency. Chesapeake Sci. 13(3): 161-174.

___. 1975. Age and size composition of the Atlantic menhaden, Brevoortia tyrannus, purse seine catch, 1967-1971, with a brief discussion of the fishery. NOAA Tech. Rept. NMFS SSRF-684. 28 pp.

Oviatt, C.A. and S.W. Nixon. 1973. The demersal fish of Narragansett Bay: an analysis of community structure, diversity, and abundance. Estuarine and Coastal Marine Sci. (1973)I: 361-378.

Perlmutter, A. 1939. A biological survey of the salt water of Long Island. Section I. An ecological survey of young fish and eggs identified from two-net collections. Suppl. 28th Ann. Rept., 1938. N.Y. State Conserv. Dept. Albany. No. 15, Pt. 2: 11-71.

Phillips, R.J. 1914. Kingfish at Corson's Inlet, New Jersey. Copeia 1914(9): 3-4. (not seen, cited in Schafter 1965).

Raney, E.C. 1952. The life history of the striped bass, Roccus saxatilis (Walbaum). Bull. Bing. Oceanogr. Coll. 14(1): 5-97.

Reeve, M.R., and E. Cosper. 1970. The acute thermal effects of heated effluents on the copepod Acartia tonsa from a sub-tropical bay and some problems of assessment. FAO Tech. Conf. on marine pollution and its effects on living resources and fishing, Rome, Italy, 9-18 December. 8 pp.

Regnault, M., and J.D. Costlow. 1970. Influence de la temperature et de la salinite sur le developpement larvaire de Crangon septemspinosa sayi (Decapoda, Caridea). Vie et Milieu, Ser. A. 21(2-A): 453-466. (not seen, cited in Sandifer 1972).

Reintjes, J.W. 1969. Synopsis of biological data on the Atlantic menhaden, Brevoortia tyrannus. U.S. Fish and Wildl. Serv., Circ. 320. 30 pp.

Richards, S.W. 1959. Oceanography of Long Island Sound. VI. Pelagic fish eggs and larvae of Long Island Sound. Bull. Bing. Oceanogr. Coll. 17(1): 95-124.

Richards, C.E. and M. Castagna. 1970. Marine fishes of Virginia's eastern shore (inlet and marsh, seaside waters). Chesapeake Sci. 11(4): 235-248.

Sage, L.E., and S.S. Herman. 1972. Zooplankton of the Sandy Hook Bay area, New Jersey. Chesapeake Sci. 13(1): 29-39.

Sanifer, P.A. 1972. Morphology and ecology of Chesapeake Bay decapod crustacean larvae. Ph.D. Dissertation. Univ. Virginia. 531 pp.

Sandine, P.H. 1973. Zooplankton of Barnegat Bay: the effect of the Oyster Creek Nuclear Power Plant. M.S. Thesis. Rutgers Univ. 73 pp.

___, V.J. McDermott, and J.H. Chamblin. 1974. Zooplankton. Pages 52-74 in Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinty of the proposed site for the Atlantic Generating Station, New Jersey. Progress Report for the period January-December 1973. Vol. Three. Ichthyological Assoc., Inc., Ithaca, NY. 393 pp.

___, and F.A. Swiecicki. 1975. Zooplankton. Pages 72-94 in Ecological studies in the bays and other waterways near Little Egg Inlet and in ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress Report for the period January-December 1974. Vol. Two. Ichthylogical Assoc., Inc., Ithaca, NY. 463 pp.

Schlicht, F.G. 1976. Entrainment impact predictions: an overview of the state of Texas. Pages 139-157 in L.D. Jensen, ed. Third Nat. Workshop on Entrainment and Impingement. Ecological Analysts, Inc., Melville, NY.

Scotton, L.N. 1970. Occurrence and distribution of larval fishes in the Indian River and Rehoboth Bays, Delaware, June 1968-March 1970. M.S. Thesis. Univ. Delaware. 65 pp.

Suchanek, T.H., Jr., and C. Grossman. 1971. Viability of zooplankton. Pages 61-74 in G.C. Williams (principal investigator). Studies ont he effects of a steam-electric generating plant in the marine environment at Northport, New York. Mar. Sci. Res. Center, State Univ. N.Y., Stony Brook. Tech Rept. No. 9.

'iecicki, D.P. 1976. Ichthyoplankton. Pages 61-67 in Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress report for the period January-December 1975. Ichthyological Assoc., Inc., Ithaca, NY.

Swiecicki, F.A., and P.A. Prendergast. 1976. Zooplankton. Pages 100-138 in Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress report for the period January-December 1975. Ichthyological Assoc., Inc., Ithaca, NY.

Tatham, T.R., D.J. Danila, D.L. Thomas, and Associates. 1977a. Ecological studies for the Oyster Creek Generating Station. Progress report for the period September 1975-August 1976. Vol. One, Fin- and shellfish. Ichthyological Assoc., Inc., Ithaca, NY. 338 pp.

___, P.H. Sandine, R.P. Smith, H.W. Hoffman, K.A. Tighe, and D.L. Thomas. 1977b. Ecological studies for the Oyster Creek Station. Progress report for the period September 1975-August 1976. Vol. Two. Plankton. Ichthyological Assoc., Inc., Ithaca, NY. 368 pp.

___, D.J. Danila, D.L. Thomas, and Associates. 1978a. Preliminary report of ecological studies for the Oyster Creek Generating Station. Progress report for the period September 1976-August 1977. Vol. One. Part I. Fin- and shellfish. Ichthyological Assoc., Inc., Ithaca, NY.

___, P.H. Sandine, R.P. Smith, K.A. Tighe, and F.A. Swiecicki. 1978b. Preliminary report of ecological studies for the Oyster Creek Generating Station. Progress report for the period September 1976-August 1977. Vol. Two. Part I. Plankton. Ichthyological Assoc., Inc., Ithaca, NY.

Texas Instruments, Inc. 1974. Indian Point impingement study report for the period 15 June 1972 through 31 December 1973. Texas Instruments, Inc., Ecol., Serv., Dallas TX.

Thomas, D.L., and C.B. Milstein. 1973. Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress report for the period January-December 1972. Part One. Ichthyological Assoc., Inc., Ithaca, NY. 666 pp.

___, ___, T.R. Tatham, R.C. Bieder, F.J. Margraf, D.J. Danila, H.K. Hoff, E.A. Illjes, M.M. McCullough, and F.A. Swiecicki. 1974. Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Progress report for the period January-December 1973. Vol. I. Fishes. Ichthyological Assoc., Inc., Ithaca, NY. 709 pp.

___, C.B. MIlstein, T.R. Tatham, R.C. Bieder, D.J. Danila, H.K. Hoff, D.P. Swiecicki, R.P. Smith, G.J. Miller, J.J. Gift, and M.C. Wyllie. 1975. Ecological studies in the bays and other waterways near Little Egg Inlet and in the ocean in the vicinity of the proposed site for the Atlantic Generating Station, New Jersey. Proposed report for the period January-December 1974. Vol. I. Fishes. Ichthyological Assoc., Inc., Ithaca, NY. 490 pp.

___, ___, ___, E. Van Eps, D.K. Stauble, and H.K. Hoff. 1972. Ecological consideration for ocean sites off New Jersey for proposed nuclear generating stations. Vol. One. Part One. Ichthyological Assoc., Inc., Ithaca, NY. January 1972. 115 pp.

Vennell, G. Undated. Use studies of the Great Egg Harbor River and Bay. Misc. Rept. No. 8M (mimeo). N. J. Dept. of Envir. Prot., Div. of Fish, Game, and Shellfish. Bur. Fish., Nacoite Creek Res. Sta.

Wheatland, S.B. 1956. Oceanography of Long Island Sound, 1952-1954. VII. Pelagic fish eggs and larvae. Bull. Bing. Oceanogra. Coll. 15: 234-314.

White, J.C., and M.L. Brehmer. 1977. Eighteen-month evaluation of the Ristroph traveling fish screens. Pages 367-380 in L.D. Jenseon, ed. Third Nat. Workshop on Entrainment and impingement. Ecological Analysis, Inc., Melville, NY.

Young, J.S., and A.B. Frame. 1976. Some effects of a power plant effluent on estuarine epibenthic organisms. Int. Revue Ges. Hydrobiol. 61(1): 37-61.

Table 4.1-1 Alphabetical listing by common name of all vertebrates collected by fish and impingement programs from September 1975 through August 1977.

Alewife - Alosa pseudoharengus
American eel - Anguilla rostrata
American shad - Alosa sapidissima
Atlantic croaker - Micropogon undulatus
Atlantic herring - Clupea harengus
Atlantic menhaden - Brevoortia tyrannus
Atlantic moonfish - Vomer setapinnis
Atlantic needlefish - Strongylura marina
Atlantic silverside - Menidia menidia
Atlantic spadefish - Chaetodipterus faber
Bay anchovy - Anchoa mitchilli
Bigeye scad - Selar crumenophthalmus
Black sea bass - Centropristis striata
Blackcheek tonguefish - Symphurus plagiusa
Blueback herring - Alosa aestivalis
Bluefish - Pomatomus saltatrix
Bluerunner - Caranx crysos
Bluespotted cornetfish - Fistularia tabacaria
Bluntnose stingray - Dasyatis sayi
Butterfish - Peprilus triacanthus
Chain pickerel - Esox niger
Chain pipefish - Syngnathus louisianae
Cobia - Rachycentron canadum
Conger eel - Conger oceanicus
Crevalle jack - Caranx hippos
Cunner - Tautogolabrus adspersus
Diamondback terrapin - Malaclemys terrapin
Feather blenny - Hypsoblennius hentzi
Flying gurnard - Dactylopterus volitans
Fourspine stickleback - Apeltes quadracus
Fowler's toad - Bufo fowleri
Gag - Mycteroperca microlepis
Gizzard shad - Dorosoma cepedianum
Golden shiner - Notemigonus crysoleucas
Gray snapper - Lutjanus griseus
Grubby - Myoxocephalus aenaeus
Halfbeak - Hyporhamphus unifasciatus
Hogchoker - Trinectes maculatus
Inshore lizardfish - Synodus foetens
Lined seahorse - Hippocampus erectus
Lookdown - Selene vomer
Mummichog - Fundulus heteroclitus
Naked goby - Gobiosoma bosci
Northern kingfish - Menticirrhus saxatilis
Northern pipefish - Syngnathus fuscus
Northern puffer - Sphoeroides maculatus
Northern searobin - Prionotus carolinus
Northern sennet - Sphyraena borealis
Northern stargazer - Astroscopus guttatus
Orange filefish - Aluterus schoepfi
Oyster toadfish - Opsanus tau
Permit - Trachinotus falcatus
Planehead filefish - Monacanthus hispidus
Pumpkinseed - Lepomis gibbosus
Rainwater killifish - Lucania parva
Red hake - Urophycis chuss
Rough silverside - Membras martinica
Sand lance - Ammodytes sp.
Scup - Stenotomus chrysops
Seaboard goby - Gobiosoma ginsburgi
Sheepshead minnow - Cyprinodon variegatus
Silver anchovy - Engraulis eurystole
Silver perch - Bairdiella chrysura
Smallmouth flounder - Etropus microstomus
Smooth dogfish - Mustelus canis
Smooth trunkfish - Lactophrys triqueter
Spiny dogfish - Squalus acanthias
Spot - Leiostomus xanthurus
Spotfin butterflyfish - Chaetodon ocellatus
Spotted hake - Urophycis regius
Striped anchovy - Anchoa hepsetus
Striped bass - Morone saxatilis
Striped blenny - Chasmodes bosquianus
Striped burrfish - Chilomycterus schoepfi
Striped cusk-eel - Rissola marginata
Striped killifish - Fundulus majalis
Striped mullet - Mugil cephalus
Striped searobin - Prionotus evolans
Summer flounder - Paralichthys dentatus
Tautog - Tautoga onitis
Threespine stickleback - Gasterosteus aculeatus
Tidewater silverside - Menidia beryllina
Weakfish - Cynoscion regalis
White mullet - Mugil curema
White perch - Morone americana
Windowpane - Scophthalmus aquosus
Winter flounder - Pseudopleuronectes americanus

Table 4.1-2 Alphabetical listing by scientific name of all vertebrate species collected by fish and impingement programs from September 1975 through August 1977.

Alosa aestivalis - Blueback herring
Alosa pseudoharengus - Alewife
Alosa sapidissima - American shad
Alutera schoepfi - Orange filefish
Ammodytes sp. - Sand lance
Anchoa hepsetus - Striped anchovy
Anchoa mitchilli - Bay anchovy
Anguilla rostrata - American eel
Apeltes quadracus - Fourspine stickleback
Astroscopus guttatus - Northern stargazer
Bairdiella chrysura - Silver perch
Brevoortia tyrannus - Atlantic menhaden
Bufo fowleri - Fowler's toad
Caranx crysos - Blue runner
Caranx hippos - Crevalle jack
Centropristis striata - Black sea bass
Chaetodipterus faber - Atlantic spadefish
Chaetodon ocellatus - Spotfin butterflyfish
Chasmodes bosquianus - Striped blenny
Chilomycterus schoepfi - Striped burrfish
Clupea harengus - Atlantic herring
Conger oceanicus - Conger eel
Cynoscion regalis - Weakfish
Cyprinodon variegatus - Sheepshead minnow
Dactylopterus volitans - Flying gurnard
Dasyatis sayi - Bluntnose stingray
Dorosoma cepedianum - Gizzard shad
Engraulis eruystole - Silver anchovy
Esox niger - Chain pickerel
Etropus microstomus - Smallmouth flounder
Fistularia tabacaria - Bluespotted cornetfish
Fundulus heteroclitus - Mummichog
Fundulus majalis - Striped killifish
Gasterosteus aculeatus - Threespine stickleback
Gobiosoma bosci - Naked goby
Gobiosoma ginsburgi - Seaboard goby
Hippocampus erectus - Lined seahorse
Hyporhamphus unifasciatus - Halfbeak
Hypsoblennius hentzi - Feather blenny
Lactophys triqueter - Smooth trunkfish
Leiostomus xanthurus - Spot
Lepomis gibbosus - Pumpkinseed
Lucania parva - Rainwater killifish
Lutjanus griseus - Gray snapper
Malaclemys terrapin - Diamondback terrapin
Membras martinica - Rough silverside
Menidia beryllina - Tidewater silverside
Menidia menidia - Atlantic silverside
Menticirrhus saxatilis - Northern kingfish
Micropogon undulatus - Atlantic croaker
Monacanthus hispidus - Planehead filefish
Morone americana - White perch
Morone saxatilis - Striped bass
Mugil cephalus - Striped mullet
Mugil curema - White mullet
Mustelus canis - Smooth dogfish
Mycteroperca microlepis - Gag
Myoxocephalus aenaeus - Grubby
Notemigonus crysoleucas - Golden shiner
Opsanus tau - Oyster toadfish
Paralichthys dentatus - Summer flounder
Peprilus triacanthus - Butterfish
Pomatomus saltatrix - Bluefish
Prionotus carolinus - Northern searobin
Prionotus evolans - Striped searobin
Pseudopleuronectes americanus - Winter flounder
Rachycentron canadum - Cobia
Rissola marginata - Striped cusk-eel
Scophthalmus aquosus - Windowpane
Selar crumenophthalmus - Bigeye scad
Selene vomer - Lookdown
Sphoeroides maculatus - Northern puffer
Sphyraena borealis - Northern sennet
Squalus acanthias - Spiny dogfish
Stenotomus chrysops - Scup
Strongylura marina - Atlantic needlefish
Symphurus plagiusa - Blackcheek tonguefish
Syngnathus fuscus - Northern pipefish
Syngnathus louisianae - Chain pipefish
Synodus foetens - Inshore lizardfish
Tautog onitis - Tautog
Tautogolabrus adspersus - Cunner
Trachinotus falcatus - Permit
Trinectes maculatus - Hogchoker
Urophycis chuss - Red hake
Urophycis regius - Spotted hake
Vomer setapinnis - Atlantic moonfish

Table 4.2-1 Estimated number with confidence interval ($P \leq 0.2$), and results of a three-way analysis of variance of selected fishes and macroinvertebrates impinged on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey during seven comparable months (September-December, March, April, and August) from 8 September 1975 through 2 September 1977. No samples were taken 24 December 1975 through 7 March 1976 and 14 May through 12 July 1977.

	1975 - 1976 Estimated Number	1976 - 1977 Estimated Number	Significant Difference ($P \leq 0.2$) Between Years
Alosa aestivalis	26,070 ± 9,564	26,113 ± 8,380	No
Alosa pseudoharengus	3,036 ± 726	3,767 ± 828	Yes
Brevoortia tyrannus	11,478 ± 3,616	91,614 ± 21,583	Yes
Anchoa mitchilli	1,275,132 ± 277,411	140,437 ± 26,276	Yes
Menidia menidia	56,567 ± 11,177	33,766 ± 5,239	No
Syngnathus fuscus	29,379 ± 4,425	8,780 ± 1,204	Yes
Pomatomus saltatrix	1,474 ± 433	3,313 ± 688	Yes
Cynoscion regalis	11,448 ± 2,610	26,899 ± 5,960	Yes
Leiostomus xanthurus	4,682 ± 1,605	60,153 ± 15,571	Yes
Prionotus evolans	34,251 ± 27,648	28,109 ± 8,985	No
Etropus microstomus	8,083 ± 2,916	57,074 ± 14,532	Yes
Paralichthys dentatus	3,147 ± 513	2,273 ± 497	Yes
Pseudopleuronectes americanus	1,214 ± 351	14,285 ± 6,235	Yes
Palemonetes vulgaris	171,904 ± 38,279	25,535 ± 4,071	Yes
Crangon septemspinosa	1,740,571 ± 422,778	526,618 ± 95,758	Yes
Callinectes sapidus	1,526,862 ± 487,070	212,995 ± 31,538	Yes
Total of all species	4,942,829 ± 715,802	1,355,903 ± 117,085	Yes

Table 4.2-2 Percent of fishes and macroinvertebrates impinged on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from 8 September 1975 through 2 September 1977. No samples were taken 24 December through 7 March 1976 and 14 May through 12 July 1977.

Species	% of Fishes	% of Fishes and Invertebrates
Alosa aestivalis	2.0	< 1
Brevoortia tyrannus	4.1	< 1
Anchoa mitchilli	72.0	15.1
Menidia menidia	3.5	< 1
Syngnathus fuscus	1.7	< 1
Leiostomus xanthurus	4.0	< 1
Prionotus evolans	2.2	< 1
Etropus microstomus	2.4	< 1
	% of Invertebrates	
Palaemonetes vulgaris	3.9	3.1
Crangon septemspinosa	38.5	30.4
Callinectes sapidus	57.2	45.2

Table 4.2-3 Total estimated number and weight (kg), with 80% confidence interval of selected fishes and macroinvertebrates impinged on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from 8 September 1975 through 3 September 1976 and from 4 September 1976 through 2 September 1977. No samples were taken 24 December through 7 March 1976 and 14 May through 12 July 1977.

	8 September 1975 - 3 September 1976		4 September 1976 - 2 September 1977	
Species	Estimated Number	Estimated Weight	Estimated Number	Estimated Weight
Alosa aestivalis	28,120 ± 9,511	268 ± 66	27,496 ± 8,584	197 ± 47
Alosa pseudoharengus	4,141 ± 772	301 ± 49	4,047 ± 857	142 ± 38
Brevoortia tyrannus	17,788 ± 4,023	1,218 ± 313	94,960 ± 22,275	5,003 ± 912
Anchoa mitchilli	1,811,550 ± 311,622	4,954 ± 868	147,202 ± 27,472	477 ± 100
Menidia menidia	61,272 ± 11,440	314 ± 57	35,051 ± 5,498	185 ± 31
Gasterosteus aculeatus	225 ± 61	.7 ± .2	189 ± 55	.5 ± .1
Syngnathus fuscus	36,066 ± 4,650	86 ± 10	11,220 ± 1,412	25 ± 3
Pomatomus saltatrix	14,086 ± 2,934	64 ± 14	3,935 ± 774	153 ± 51
Cynoscion regalis	11,790 ± 2,653	185 ± 60	27,297 ± 6,166	559 ± 145
Leiostomus xanthurus	48,059 ± 17,412	191 ± 50	61,573 ± 15,945	2,084 ± 546
Menticirrhus saxatilis	16 ± 12	2 ± 1	105 ± 50	39 ± 2
Prionotus evolans	32,254 ± 25,168	369 ± 137	28,371 ± 9,208	516 ± 192
Etropus microstomus	8,022 ± 2,838	54 ± 19	57,773 ± 14,980	359 ± 100
Paralichthys dentatus	4,266 ± 585	908 ± 136	2,380 ± 514	601 ± 132
Pseudopleuronectes americanus	3,908 ± 1,320	368 ± 113	18,618 ± 6,385	1,400 ± 370
Sphoeroides maculatus	3,313 ± 1,178	251 ± 97	1,516 ± 860	189 ± 170
Total of all Vertebrates	2,120,873 ± 311,958	11,135 ± 1,125	600,537 ± 76,935	14,586 ± 1,991
Palaemonetes vulgaris	373,288 ± 71,453	241 ± 49	29,885 ± 4,287	18 ± 2
Crangon septemspinosa	3,342,143 ± 687,672	2,883 ± 595	600,278 ± 100,860	606 ± 100
Callinectes sapidus	5,627,253 ± 1,264,146	51,399 ± 9,577	230,691 ± 33,337	10,837 ± 1,334
Total of all Invertebrates	9,365,228 ± 1,681,865	56,261 ± 9,767	879,842 ± 100,116	12,914 ± 1,332
Grand total of all species[a]	11,486,113 ± 1,749,394	67,396 ± 10,017	1,481,396 ± 132,597	27,500 ± 2,387

a Grand total of all species does not equal the total of all vertebrates and invertebrates because each total was a separate estimate.

Table 4.2-4 Total estimated number, weight (g), and total mortality (immediate and delayed) of Alosa aestivalis impinged by month on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from September 1975 through August 1977. No samples were taken 24 December 1975 through 7 March 1976 and 14 May through 12 July 1977.

				Mortality					
				Number		Weight		Total	
	Total Number	Total Weight	Immediate Mortality (%)	Immediate	Delayed[a]	Immediate	Delayed[a]	Number	Weight
September 1975	29	423	42[b]	12	7	178	103	19	281
October	27	603	42[b]	11	7	253	147	18	400
November	89	2,219	42[b]	37	22	932	541	59	1,473
December	16,044	63,165	49	7,862	3,436	30,951	13,530	11,298	44,481
March 1976	7,100	67,624	34	2,414	1,968	22,992	18,745	4,382	41,737
April	2,071	69,306	42[b]	870	504	29,109	16,883	1,374	46,992
May	1,934	43,777	42[b]	812	471	18,386	10,664	1,283	29,050
June	525	9,589	42[b]	221	128	4,027	2,336	349	6,363
July	3	15	42[b]	1	1	6	4	2	10
August	15	119	42[b]	6	4	50	29	10	79
September	9	108	42[b]	4	2	45	26	6	71
October	163	2,324	42[b]	68	40	976	566	108	1,542
November	340	3,880	42[b]	143	83	1,630	945	226	2,575
December	20,809	86,418	45	9,364	4,807	38,888	19,963	14,171	58,851
January 1977	66	337	42[b]	28	16	142	82	44	224
February	421	1,935	42[b]	177	102	813	471	279	1,284
March	1,917	23,240	18	345	660	4,183	8,004	1,005	12,187
April	1,860	63,350	23	428	601	14,571	20,487	1,029	35,058
May	54	3,293	42[b]	23	13	1,383	802	36	2,185
July	406	5,132	42[b]	171	99	2,155	1,250	270	3,405
August	254	2,896	42[b]	107	62	1,216	706	169	1,922
Total	54,136[c]	449,753[c]	42[b]	23,104	13,033	172,886	116,284	36,137	289,170

[a] Delayed mortality estimate from October 1975 through August 1977 for Alosa spp. held in ambient water was 42%.

[b] Estimate from 8 September 1975 through 2 September 1977.

[c] Total number and weight does not equal the total for 2 years (Table 3) because each total was a separate estimate (see Section 4.2.3.1).

Table 4.2-5 Total estimated number, mean mortality, and estimated number lost of selected fishes impinged from the vertical traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from September 1975 through August 1977 and projected losses with Ristroph Screens.[a]

		Vertical Traveling Screens		Ristroph Screens	
	Estimated Number Impinged[j]	Mean Mortality(%)	Estimated Number Lost	Mean Mortality (%)	Estimated Number Lost
Alosa aestivalis	55,616	42	23,104[b]	9.6	5,339
Brevoortia tyrannus	112,748	28	31,822[c]	5.1	5,750
Anchoa mitchilli	1,958,752	78	1,506,768[d]	18.0	352,575
Menidia menidia	96,323	38	39,073[e]	6.0	5,779
Pomatomus saltatrix	18,021	59	9,781[f]	14.7	2,649
Cynoscion regalis	39,087	59	23,836[g]	40.8	15,947
Leiostomus xanthurus	109,632	48	47,789[h]	3.3	3,618
Paralichthys dentatus	6,646	9	543[i]	2.8	186

[a] White and Brehmer 1977.
[b] Data from Table 4.
[c] Data from Table 6.
[d] Data from Table 7.
[e] Data from Table 8.
[f] Data from Table 10.
[g] Data from Table 11.
[h] Data from Table 12.
[i] Data from Table 15.
[j] Data from Table 3.

Table 4.2-7 Total estimated number, weight (g), and total mortality (immediate and delayed) of Anchoa mitchilli impinged by month on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from September 1975 through August 1977. No samples were taken 24 December 1975 through 7 March 1976 and 14 May through 12 July 1977.

	Total Number	Total Weight	Immediate Mortality (%)	Mortality: Number		Mortality: Weight		Mortality: Total	
				Immediate	Delayed[a]	Immediate	Delayed[a]	Number	Weight
September 1975	2,250	5,762	91	2,048	182	5,243	467	2,230	5,710
October	12,502	40,510	79	9,877	2,363	32,003	7,656	12,240	39,659
November	2,435	8,633	51	1,242	1,074	4,403	3,807	2,316	8,210
December	657	1,984	54	355	272	1,071	822	627	1,893
March 1976	38,420	108,236	68	26,126	11,065	73,600	31,172	37,191	104,772
April	1,084,658	3,045,787	73	791,800	263,572	2,223,425	740,126	1,055,372	2,963,551
May	564,044	1,466,908	89	501,999	55,841	1,305,548	145,224	557,840	1,450,772
June	36,949	76,679	90	33,254	3,326	69,011	6,901	36,580	75,912
July	6,207	12,518	98	6,083	112	12,268	225	6,195	12,493
August	12,882	29,601	99	12,753	116	29,305	266	12,869	29,571
September	18,871	44,595	96	18,116	680	42,811	1,606	18,796	44,417
October	62,116	216,372	82	50,935	10,063	177,425	35,052	60,998	212,477
November	9,660	29,524	71	6,859	2,521	20,962	7,706	9,380	28,668
December	244	943	78[b]	190	49	736	186	239	922
January 1977	20	20	78[b]	16	4	16	4	20	20
February	0	0	-	-	-	-	-	-	-
March	0	0	-	-	-	-	-	-	-
April	38,315	137,190	65	24,905	12,069	89,174	43,214	36,974	132,388
May	310	1,032	78[b]	242	61	805	204	303	1,009
July	4,402	12,424	85	3,742	594	10,560	1,678	4,336	12,238
August	18,867	53,163	86	16,226	2,377	45,720	6,699	18,603	52,419
Total	1,913,806[c]	5,291,881[c]	78[b]	1,506,768	366,341	4,144,086	1,033,015	1,873,109	5,177,101

[a] Delayed mortality estimate from October 1975 through August 1977 for specimens held in ambient water was 90%.
[b] Estimate from 8 September 1975 through 2 September 1977.
[c] Total number and weight does not equal the total for 2 years (Table 3) because each total was a separate estimate (see Section 4.2.3.1).

Table 4.2-7 Total estimated number, weight (g), and total mortality (immediate and delayed) of *Anchoa mitchilli* impinged by month on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from September 1975 through August 1977. No samples were taken 24 December 1975 through 7 March 1976 and 14 May through 12 July 1977.

	Total Number	Total Weight	Immediate Mortality (%)	Mortality: Number Immediate	Mortality: Number Delayed[a]	Mortality: Weight Immediate	Mortality: Weight Delayed[a]	Mortality: Total Number	Mortality: Total Weight
September 1975	2,250	5,762	91	2,048	182	5,243	467	2,230	5,710
October	12,502	40,510	79	9,877	2,363	32,003	7,656	12,240	39,659
November	2,435	8,633	51	1,242	1,074	4,403	3,807	2,316	8,210
December	657	1,984	54	355	272	1,071	822	627	1,893
March 1976	38,420	108,236	68	26,126	11,065	73,600	31,172	37,191	104,772
April	1,084,658	3,045,787	73	791,800	263,572	2,223,425	740,126	1,055,372	2,963,551
May	564,044	1,466,908	89	501,999	55,841	1,305,548	145,224	557,840	1,450,772
June	36,949	76,679	90	33,254	3,326	69,011	6,901	36,580	75,912
July	6,207	12,518	98	6,083	112	12,268	225	6,195	12,493
August	12,882	29,601	99	12,753	116	29,305	266	12,869	29,571
September	18,871	44,595	96	18,116	680	42,811	1,606	18,796	44,417
October	62,116	216,372	82	50,935	10,063	177,425	35,052	60,998	212,477
November	9,660	29,524	71	6,859	2,521	20,962	7,706	9,380	28,668
December	244	943	78[b]	190	49	736	186	239	922
January 1977	20	20	78[b]	16	4	16	4	20	20
February	0	0	-	-	-	-	-	-	-
March	0	0	-	-	-	-	-	-	-
April	38,315	137,190	65	24,905	12,069	89,174	43,214	36,974	132,388
May	310	1,032	78[b]	242	61	805	204	303	1,009
July	4,402	12,424	85	3,742	594	10,560	1,678	4,336	12,238
August	18,867	53,163	86	16,226	2,377	45,720	6,699	18,603	52,419
Total	1,913,806[c]	5,291,881[c]	78[b]	1,506,768	366,341	4,144,086	1,033,015	1,873,109	5,177,101

[a] Delayed mortality estimate from October 1975 through August 1977 for specimens held in ambient water was 90%.
[b] Estimate from 8 September 1975 through 2 September 1977.
[c] Total number and weight does not equal the total for 2 years (Table 3) because each total was a separate estimate (see Section 4.2.3.1).

Table 4.2-8 Total estimated number, weight (g), and total mortality (immediate and delayed) of Menidia menidia impinged by month on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from September 1975 through August 1977. No samples were taken 24 December 1975 through 7 March 1976 and 14 May through 12 July 1977.

	Total Number	Total Weight	Immediate Mortality (%)	Mortality: Number: Immediate	Mortality: Number: Delayed[a]	Mortality: Weight: Immediate	Mortality: Weight: Delayed[a]	Mortality: Total: Number	Mortality: Total: Weight
September 1975	2	6	38[b]	1	0	2	1	1	3
October	42	154	38[b]	16	7	59	26	23	85
November	759	2,889	38[b]	288	127	1,098	484	415	1,582
December	19,835	87,091	30	5,951	3,749	26,127	16,460	9,700	42,587
March 1976	26,119	138,625	51	13,321	3,455	70,699	18,340	16,776	89,039
April	5,724	35,505	61	3,492	603	21,658	3,739	4,095	25,397
May	4,745	30,103	81	3,843	244	24,383	1,544	4,087	25,927
June	292	1,821	38[b]	111	49	692	305	160	997
July	9	35	38[b]	3	2	13	6	5	19
August	0	0	-	-	-	-	-	-	-
September	24	78	38[b]	9	4	30	13	13	43
October	849	4,543	38[b]	323	142	1,726	761	465	2,487
November	10,402	50,552	44	4,577	1,573	22,243	7,643	6,150	29,886
December	4,248	19,778	41	1,742	677	8,109	3,151	2,419	11,260
January 1977	215	789	38[b]	82	36	300	132	118	432
February	401	1,972	38[b]	152	67	749	330	219	1,079
March	9,861	54,737	30	2,958	1,864	16,421	10,345	4,822	26,766
April	8,148	48,755	25	2,037	1,650	12,189	9,873	3,687	22,062
May	19	124	38[b]	7	3	47	21	10	68
July	79	193	38[b]	30	13	73	32	43	105
August	341	826	38[b]	130	57	314	138	187	452
Total	92,114[c]	478,576[c]	38[b]	39,073	14,322	206,932	73,344	53,395	280,276

[a] Delayed mortality estimate from October 1975 through August 1977 for specimens held in ambient water was 27%.

[b] Estimate from 8 September 1975 through 2 September 1977.

[c] Total number and weight does not equal the total for 2 years (Table 3) because each total was a separate estimate (see Section 4.2.3.1).

Table 4.2-9 Total estimated number, weight (g), and total mortality (immediate and delayed) of *Syngnathus fuscus* impinged by month on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from September 1975 through August 1977. No samples were taken 24 December 1975 through 7 March 1976 and 14 May through 12 July 1977.

	Total Number	Total Weight	Immediate Mortality (%)	Mortality: Number: Immediate	Mortality: Number: Delayed[a]	Mortality: Weight: Immediate	Mortality: Weight: Delayed[a]	Total: Number	Total: Weight
September 1975	29	126	5[b]	1	6	6	25	7	31
October	118	432	5[b]	6	24	22	86	30	108
November	3,924	7,881	4	157	791	315	1,589	948	1,904
December	10,557	21,654	4	422	2,128	866	4,365	2,550	5,231
March 1976	8,200	18,231	4	328	1,653	729	3,675	1,981	4,404
April	5,463	14,117	3	164	1,113	424	2,876	1,277	3,300
May	3,686	11,990	3	111	751	360	2,442	862	2,802
June	2,575	7,245	5[b]	129	514	362	1,445	643	1,807
July	486	1,221	5[b]	24	462	61	244	486	305
August	81	370	5[b]	4	16	19	74	20	93
September	131	276	5[b]	7	124	14	55	131	69
October	1,705	4,208	5[b]	85	340	210	840	425	1,050
November	3,169	6,602	5[b]	158	632	330	1,317	790	1,647
December	376	635	5[b]	19	75	32	106	94	138
January 1977	7	7	5[b]	0	1	0	1	1	1
February	0	0	-	-	-	-	-	-	-
March	310	726	5[b]	16	62	36	145	78	181
April	2,904	6,229	2	58	598	125	6,104	656	6,229
May	1,082	2,973	9	97	207	268	568	304	836
July	1,123	2,692	6	67	222	162	531	289	693
August	484	1,016	5[b]	24	97	51	203	121	254
Total	46,410[c]	108,631[c]	5[b]	1,877	9,816	4,392	26,691	11,093	31,083

[a] Delayed mortality estimate from October 1975 through August 1977 for specimens held in ambient water was 21%.
[b] Estimate from 8 September 1975 through 2 September 1977.
[c] Total number and weight does not equal the total for 2 years (Table 3) because each total was a separate estimate (see Section 4.2.3.1).

Table 4.2-10 Total estimated number, weight (g), and immediate mortality[a] of Pomatomus saltatrix impinged by month on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from September 1975 through August 1977. No samples were taken 24 December through 7 March 1976 and 14 May through 12 July 1977.

	Total Number	Total Weight	Immediate Mortality (%)	Immediate Mortality Number	Immediate Mortality Weight
September 1975	79	2,758	59[b]	47	1,627
October	77	2,717	59[b]	45	1,603
November	161	9,456	59[b]	95	5,579
December	24	2,571	59[b]	14	1,517
March 1976	0	0	-	-	-
April	0	0	-	-	-
May	3,354	3,065	58	1,945	1,778
June	7,645	12,873	60	4,587	7,724
July	693	6,099	59[b]	409	3,598
August	818	19,215	59[b]	483	11,337
September	551	23,993	59[b]	325	14,156
October	1,919	97,765	46	883	44,972
November	339	18,088	59[b]	200	10,672
December	0	0	-	-	-
January 1977	0	0	-	-	-
February	0	0	-	-	-
March	0	0	-	-	-
April	10	30	59[b]	6	18
May	0	0	-	-	-
July	555	5,925	59[b]	327	3,496
August	704	11,956	59[b]	415	7,054
Total	16,929[c]	216,511[c]	59[b]	9,781	115,131

[a] No delayed mortality estimate due to an insufficient number of specimens.
[b] Estimate from 8 September 1975 through 2 September 1977.
[c] Total number and weight does not equal the total for 2 years (Table 3) because each total was a separate estimate (see Section 4.2.3.1).

Table 4.2-11 Total estimated number, weight (g), and immediate mortality[a] of Cynoscion regalis impinged by month on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from September 1975 through August 1977. No samples were taken 24 December through 7 March 1976 and 14 May through 12 July 1977.

	Total Number	Total Weight	Immediate Mortality (%)	Immediate Mortality Number	Immediate Mortality Weight
September 1975	713	16,014	59[b]	421	9,448
October	1,360	16,767	51	694	8,551
November	2,758	84,630	38	1,048	32,159
December	88	1,886	59[b]	52	1,113
March 1976	0	0	-	-	-
April	3	2,069	59[b]	2	1,221
May	5	295	59[b]	3	174
June	265	4,504	59[b]	156	2,657
July	185	34,803	59[b]	109	20,534
August	6,229	28,671	80	4,983	22,937
September	2,521	39,030	64	1,613	24,979
October	18,183	460,789	61	11,092	281,081
November	1,289	70,988	59[b]	761	41,883
December	0	0	-	-	-
January 1977	0	0	-	-	-
February	0	0	-	-	-
March	0	0	-	-	-
April	0	0	-	-	-
May	0	0	-	-	-
July	36	420	59[b]	21	248
August	6,002	17,166	48	2,881	8,240
Total	39,637[c]	778,032[c]	59[b]	23,836	455,225

[a] No delayed mortality estimate due to an insufficient number of specimens.

[b] Estimate from 8 September 1975 through 2 September 1977.

[c] Total number and weight does not equal the total for 2 years (Table 3) because each total was a separate estimate (see Section 4.2.3.1).

Table 4.2-12 Total estimated number, weight (g), and immediate mortality[a] of Leiostomus xanthurus impinged by month on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from September 1975 through August 1977. No samples were taken 24 December through 7 March 1976 and 14 May through 12 July 1977.

	Total Number	Total Weight	Immediate Mortality (%)	Immediate Mortality Number	Immediate Mortality Weight
September 1975	2	137	48[b]	1	66
October	0	0	-	-	-
November	45	2,575	48[b]	22	1,236
December	12	1,295	48[b]	6	622
March 1976	0	0	-	-	-
April	0	0	-	-	-
May	0	0	-	-	-
June	27,488	73,965	77	21,166	56,953
July	11,313	55,303	57	6,448	31,523
August	4,079	39,512	64	2,611	25,288
September	792	16,094	48[b]	380	7,725
October	22,588	733,033	32	7,228	234,571
November	32,193	1,285,402	22	7,082	282,788
December	1,777	38,415	11	195	4,226
January 1977	12	198	48[b]	6	95
February	32	997	48[b]	15	479
March	44	1,136	48[b]	21	545
April	25	827	48[b]	12	397
May	0	0	-	-	-
July	531	3,163	48[b]	255	1,518
August	4,777	52,546	49	2,341	25,748
Total	105,710[c]	2,304,598[c]	48[b]	47,789	673,780

[a] No delayed mortality estimate due to an insufficient number of specimens.

[b] Estimate from 8 September 1975 through 2 September 1977.

[c] Total number and weight does not equal the total for 2 years (Table 3) because each total was a separate estimate (see Section 4.2.3.1).

Table 4.2-13 Total estimated number, weight (g), and total mortality[a] of Prionotus evolans impinged by month on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from September 1975 through August 1977. No samples were taken 24 December 1975 through 7 March 1976 and 14 May through 12 July 1977.

	Number	Weight	Immediate Mortality (%)	Immediate and Total Mortality Number	Immediate and Total Mortality Weight
September 1975	394	4,050	18[b]	71	729
October	2,197	32,141	14	308	4,500
November	1,562	30,333	6	94	1,820
December	302	6,433	18[b]	54	1,158
March 1976	0	0	-	-	-
April	13	973	18[b]	2	175
May	156	36,741	18[b]	28	6,613
June	222	29,457	18[b]	40	5,302
July	34	7,579	18[b]	6	1,364
August	18,480	152,549	57	10,534	86,953
September	5,824	101,731	23	1,340	23,398
October	24,858	431,607	13	3,232	56,109
November	1,833	21,437	20	367	4,287
December	43	676	18[b]	8	122
January 1977	0	0	-	-	-
February	0	0	-	-	-
March	0	0	-	-	-
April	0	0	-	-	-
May	0	0	-	-	-
July	2	738	18[b]	0	133
August	68	8,160	18[b]	12	1,469
Total	55,988[c]	864,605[c]	18[b]	16,096	194,132

[a] Delayed mortality estimate from October 1975 through August 1977 for specimens held in ambient water was 0%.
[b] Estimate from 8 September 1975 through 2 September 1977.
[c] Total number and weight does not equal the total for 2 years (Table 3) because each total was a separate estimate (see Section 4.2.3.1).

Table 4.2-6 Total estimated number, weight (g), and total mortality (immediate and delayed) of Brevoortia tyrannus impinged by month on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from September 1975 through August 1977. No samples were taken 24 December 1975 through 7 March 1976 and 14 May through 12 July 1977.

	Total Number	Total Weight	Immediate Mortality (%)	Mortality: Number: Immediate	Mortality: Number: Delayed[a]	Mortality: Weight: Immediate	Mortality: Weight: Delayed[a]	Mortality: Total: Number	Mortality: Total: Weight
September 1975	27	4,594	28[b]	8	18	1,286	3,143	26	4,429
October	16	945	28[b]	4	11	265	646	15	911
November	98	18,028	28[b]	27	67	5,048	12,331	94	17,379
December	8,992	612,258	26	2,338	6,321	159,187	430,417	8,659	589,604
March 1976	94	27,070	28[b]	26	65	7,580	18,516	91	26,096
April	1,153	179,179	28[b]	323	789	50,170	122,559	1,112	172,729
May	904	109,769	28[b]	253	618	30,735	75,082	871	105,817
June	651	77,453	28[b]	182	446	21,687	52,978	628	74,665
July	4,584	47,545	54	2,475	2,004	25,674	20,777	4,479	46,451
August	952	39,800	28[b]	267	651	11,144	27,223	918	38,367
September	1,031	81,165	73	753	264	59,250	20,819	1,017	80,069
October	36,145	1,635,647	25	9,036	25,754	408,912	1,165,398	34,790	1,574,310
November	45,448	1,868,832	25	11,362	32,382	467,208	1,331,543	43,744	1,798,751
December	6,763	1,108,977	19	1,285	5,204	210,706	853,357	6,489	1,064,063
January 1977	94	4,353	28[b]	26	65	1,219	2,977	91	4,196
Feburary	530	25,481	28[b]	148	363	7,135	17,429	511	24,564
March	1,745	187,513	13	227	1,442	24,377	154,979	1,669	179,356
April	454	86,953	28[b]	127	311	24,347	59,476	438	83,823
May	6	1,857	28[b]	2	4	520	1,270	6	1,790
July	1,254	10,648	67	840	393	7,134	3,338	1,233	10,472
August	3,643	55,529	58	2,113	1,454	32,207	22,156	3,567	54,363
Total	114,584[c]	6,183,596[c]	28[b]	31,822	78,626	1,555,791	4,396,414	110,448	5,952,205

[a] Delayed mortality estimate from October 1975 through August 1977 for specimens held in ambient water was 95%.

[b] Estimate from 8 September 1975 through 2 September 1977.

[c] Total number and weight does not equal the total for 2 years (Table 3) because each total was a separate estimate (see Section 4.2.3.1).

Table 4.2-14 Total estimated number, weight (g), and immediate mortality[a] of Etropus microstomus impinged by month on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from September 1975 through August 1977. No samples were taken 24 December through 7 March 1976 and 14 May through 12 July 1977.

	Total Number	Total Weight	Immediate Mortality (%)	Immediate Mortality Number	Immediate Mortality Weight
September 1975	2	19	26[b]	1	5
October	5	76	26[b]	1	20
November	1,308	9,702	18	235	1,746
December	7,537	48,610	17	1,281	8,264
March 1976	4	30	26[b]	1	8
April	25	111	26[b]	7	29
May	7	65	26[b]	2	17
June	0	0	-	-	-
July	0	0	-	-	-
August	5	51	26[b]	1	13
September	22	126	26[b]	6	33
October	1,835	10,469	26[b]	477	2,722
November	50,351	324,022	30	15,105	97,207
December	6,373	30,153	25	1,593	7,538
January 1977	12	25	26[b]	3	7
February	2	12	26[b]	1	3
March	0	0	-	-	-
April	0	0	-	-	-
May	0	0	-	-	-
July	0	0	-	-	-
August	0	0	-	-	-
Total	67,488[c]	423,471[c]	26[b]	18,714	117,612

a No delayed mortality estimate due to an insufficient number of specimens.
b Estimate from 8 September 1975 through 2 September 1977.
c Total number and weight does not equal the total for 2 years (Table 3) because each total was a separate estimate (see Section 4.2.3.1)

Table 4.2-15 Total estimated number, weight (g), and immediate mortality[a] of Paralichthys dentatus impinged by month on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from September 1975 through August 1977. No samples were taken 24 December 1975 through 7 March 1976 and 14 May through 12 July 1977.

	Total Number	Total Weight	Immediate Mortality (%)	Immediate Mortality	
				Number	Weight
September 1975	120	15,227	9[b]	11	1,370
October	572	101,291	9[b]	51	9,116
November	1,248	207,620	2	25	4,152
December	508	18,030	9[b]	46	1,623
March 1976	45	5,055	9[b]	4	455
April	148	29,488	9[b]	13	2,654
May	446	131,292	9[b]	40	11,816
June	451	129,694	9[b]	41	11,672
July	193	62,547	9[b]	17	5,629
August	713	222,547	9[b]	64	20,029
September	367	80,833	9[b]	33	7,275
October	1,502	415,834	9[b]	135	37,425
November	120	37,706	9[b]	11	3,394
December	21	8,937	9[b]	2	804
January 1977	0	0	-	-	-
February	0	0	-	-	-
March	0	0	-	-	-
April	124	25,734	9[b]	11	2,316
May	0	0	-	-	-
July	80	13,558	9[b]	7	1,220
August	353	60,382	9[b]	32	5,434
Total	7,011[c]	1,565,775[c]	9[b]	543	126,384

[a] No delayed mortality estimate due to an insufficient number of specimens.

[b] Estimate from 8 September 1975 through 2 September 1977.

[c] Total number and weight does not equal the total for 2 years (Table 3) because each total was a separate estimate (see Section 4.2.3.1).

Table 4.2-16 Total estimated number, weight (g), and total mortality (immediate and delayed) of Pseudopleuronectes americanus impinged by month on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from September 1975 through August 1977. No samples were taken 24 December 1975 through 7 March 1976 and 14 May through 12 July 1977.

	Total Number	Total Weight	Immediate Mortality (%)	Mortality: Number: Immediate	Mortality: Number: Delayed[a]	Mortality: Weight: Immediate	Mortality: Weight: Delayed[a]	Mortality: Total: Number	Mortality: Total: Weight
September 1975	0	0	-	-	-	-	-	-	-
October	3	440	15[b]	0	0	66	30	0	96
November	172	28,244	15[b]	26	12	4,237	1,921	38	6,158
December	376	80,756	15[b]	56	26	12,113	5,491	82	17,604
March 1976	282	49,130	15[b]	42	19	7,370	3,341	61	10,711
April	118	64,522	15[b]	18	8	9,678	4,388	26	14,066
May	258	71,034	15[b]	39	18	10,655	4,830	57	15,485
June	2,131	50,481	15[b]	320	145	7,572	3,433	465	11,005
July	122	509	15[b]	18	8	76	35	26	111
August	118	694	15[b]	18	8	104	47	26	151
September	16	550	15[b]	2	1	83	37	3	120
October	94	16,101	15[b]	14	6	2,415	1,095	20	3,510
November	1,876	62,407	15[b]	281	128	9,361	4,244	409	13,605
December	9,873	719,316	15	1,481	671	107,897	48,914	2,152	156,811
January 1977	2,449	118,225	8	196	180	9,458	8,701	376	18,159
February	1,506	289,483	15[b]	226	102	43,422	19,685	328	63,107
March	1,747	112,026	0	0	140	0	8,962	140	8,962
April	781	66,404	15[b]	117	664	9,961	4,515	781	14,476
May	0	0	-	-	-	-	-	-	-
July	348	2,011	15[b]	52	24	302	137	76	439
August	19	1,114	15[b]	3	1	167	76	4	243
Total	22,289[c]	1,733,447[c]	15[b]	2,909	2,161	234,937	119,882	5,070	354,819

[a] Delayed mortality estimate from October 1975 through August 1977 for specimens held in ambient water was 8%.
[b] Estimate from 8 September 1975 through 2 September 1977.
[c] Total number and weight does not equal the total fro 2 years (Table 3) because each total was a separate estimate (see Section 4.2.3.1).

Table 4.2-17 Total estimated number, weight (g), and immediate mortality[a] of Sphoeroides maculatus impinged by month on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from September 1975 through August 1977. No samples were taken 24 December 1975 through 7 March 1976 and 14 May through 12 July 1977.

	Total Number	Total Weight	Immediate Mortality (%)	Immediate Mortality Number	Immediate Mortality Weight
September 1975	54	3,993	7[b]	4	280
October	43	3,030	7[b]	3	212
November	11	1,441	7[b]	1	101
December	0	0	-	-	-
March 1976	0	0	-	-	-
April	76	12,165	7[b]	5	852
May	2,398	203,946	7[b]	168	14,276
June	262	21,397	7[b]	18	1,498
July	51	5,289	7[b]	4	370
August	445	10,960	7[b]	31	767
September	179	23,382	7[b]	13	1,637
October	1,044	155,322	7[b]	73	10,873
November	28	4,940	7[b]	2	346
December	0	0	-	-	-
January 1977	0	0	-	-	-
February	0	0	-	-	-
March	0	0	-	-	-
April	5	685	7b	-	48
May	4	542	7[b]	-	38
July	100	1,221	7[b]	7	85
August	225	4,774	7b	16	334
Total	4,925[c]	453,087[c]	7b	345	31,717

[a] No delayed mortality estimate due to an insuffient number of specimens.
[b] Estimate from 8 September through 2 September 1977.
[c] Total number and weight does not equal the total for 2 years (Table 3) because each total was a separate estimate (see Section 4.2.3.1).

Table 4.2-18 Total estimated number, weight (g), and immediate mortality[a] of Palaemonetes vulgaris impinged by month on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from September 1975 through August 1977. No samples were taken 24 December 1975 through 7 March 1976 and 14 May through 12 July 1977.

	Total Number	Total Weight	Immediate Mortality (%)	Immediate Mortality Number	Immediate Mortality Weight
September 1975	15	10	8[b]	1	1
October	115	66	8[b]	9	5
November	4,817	3,052	8	385	244
December	37,258	22,229	9	3,353	2,001
March 1976	75,034	44,446	7	5,252	3,111
April	40,376	25,398	2	808	508
May	37,751	30,231	8[b]	3,020	2,418
June	144,512	94,610	5	7,226	4,731
July	3,411	2,485	8[b]	273	199
August	18	18	8[b]	1	1
September	7	7	8[b]	1	1
October	3,538	1,686	8[b]	283	135
November	3,376	2,120	8[b]	270	170
December	5,407	3,364	8[b]	433	269
January 1977	2,294	1,242	8[b]	184	99
February	1,270	829	8[b]	102	66
March	8,188	4,826	7	573	338
April	5,020	3,333	8[b]	402	267
May	317	230	8[b]	25	18
July	275	188	8[b]	22	15
August	124	92	8[b]	10	7
Total	373,123[c]	240,462[c]	8[b]	22,633	14,604

[a] No delayed mortality estimate due to an insufficient number of specimens.

[b] Estimate from 8 September 1975 through 2 September 1977.

[c] Total number and weight does not equal the total for 2 years (Table 3) because each total was a separate estimate (see Section 4.2.3.1).

Table 4.2-19 Total estimated number, weight (g), and total mortality (immediate and delayed) of Crangon septemspinosa impinged by month on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from September 1975 through August 1977. No samples were taken 24 December 1975 through 7 March 1976 and 14 May through 12 July 1977.

	Total Number	Total Weight	Immediate Mortality (%)	Mortality: Number Immediate	Mortality: Number Delayed[a]	Mortality: Weight Immediate	Mortality: Weight Delayed[a]	Mortality: Total Number	Mortality: Total Weight
September 1975	0	0	-	-	-	-	-	-	-
October	299	297	14[b]	42	33	42	33	75	75
November	13,371	15,550	18	2,407	1,425	2,799	1,658	3,832	4,457
December	1,184,278	1,005,566	15	177,642	130,863	150,835	111,115	308,505	261,950
March 1976	174,143	153,147	10	17,414	20,375	15,315	17,918	37,789	33,233
April	317,298	282,943	9	28,557	37,536	25,465	33,472	66,093	58,937
May	772,904	638,256	5	38,645	95,454	31,913	78,825	134,099	110,738
June	779,717	695,673	4	31,189	97,309	27,827	86,820	128,498	114,647
July	1,603	1,191	14[b]	224	179	167	133	403	300
August	18	16	14[b]	3	2	2	2	5	4
September	21	21	14[b]	3	2	3	2	5	5
October	1,295	1,833	14[b]	181	145	257	205	326	462
November	97,958	88,304	16	15,673	10,697	14,129	9,643	26,370	23,772
December	256,280	249,859	18	46,130	27,320	44,975	26,635	73,450	71,610
January 1977	51,542	50,735	19	9,793	5,427	9,640	5,342	15,220	14,982
February	16,202	16,936	17	2,754	1,748	2,879	1,827	4,502	4,706
March	94,312	104,129	13	12,261	10,667	13,537	11,777	22,928	25,314
April	77,080	88,209	11	8,479	8,918	9,703	10,206	17,397	19,909
May	1,763	1,727	21	370	181	363	177	551	540
July	11	8	14[b]	2	1	1	1	3	2
August	7	4	14[b]	1	1	1	0	2	1
Total	3,840,102[c]	3,394,404[c]	14[b]	391,770	448,283	349,853	395,791	840,053	745,644

[a] Delayed mortality estimate from October 1975 through August 1977 for specimens held in ambient water was 13%.
[b] Estimate from 8 September 1975 through 2 September 1977.
[c] Total number and weight does not equal the total for 2 years (Table 3) because each total was a separate estimate (see Section 4.2.3.1).

Table 4.2-20 Total estimated number, weight (g), and total mortality (immediate and delayed) of Callinectes sapidus impinged by month on the traveling screens at the Oyster Creek Generating Station, Forked River, New Jersey from September 1975 through August 1977. No samples were taken 24 December 1975 through 7 March 1976 and 14 May through 12 July 1977.

	Total Number	Total Weight	Immediate Mortality (%)	Mortality: Number Immediate	Mortality: Number Delayed[a]	Mortality: Weight Immediate	Mortality: Weight Delayed[a]	Mortality: Total Number	Mortality: Total Weight
September 1975	28,901	920,399	12	3,468	1,017	110,448	32,398	4,485	142,846
October	44,101	1,167,239	9	3,969	1,605	105,052	42,487	5,574	147,539
November	25,970	154,998	3	779	1,008	4,650	6,014	1,787	10,664
December	5,731	8,208	4	229	220	328	315	449	643
March 1976	65,462	124,707	1	655	2,592	1,247	4,938	3,247	6,185
April	204,571	730,908	0	0	8,183	0	29,236	8,183	29,236
May	562,810	3,315,428	6	33,769	21,162	198,926	124,660	54,931	323,586
June	2,093,695	12,998,376	7	146,559	77,885	909,886	483,540	224,444	1,393,426
July	1,094,193	13,170,511	9	98,477	39,829	1,185,346	479,407	138,306	1,664,753
August	920,410	13,661,551	11	101,245	32,767	1,502,771	486,351	134,012	1,989,122
September	135,960	4,316,544	7	9,517	5,058	302,158	160,575	14,575	462,733
October	52,129	1,965,090	4	2,085	2,002	78,604	75,459	4,087	154,063
November	1,151	57,172	7[b]	81	43	4,002	2,127	124	6,129
December	21	320	7[b]	1	1	22	12	2	34
January 1977	8	56	7[b]	1	0	4	2	1	6
February	24	386	7[b]	2	1	27	14	3	41
March	583	10,719	3	17	23	322	416	40	738
April	5,460	115,816	0	0	218	0	4,633	218	4,633
May	1,231	30,712	6	74	46	1,843	1,155	120	2,998
July	14,142	814,918	6	849	532	48,895	30,641	1,381	79,536
August	59,855	4,199,114	3	1,796	2,322	125,973	162,926	4,118	288,899
Total	5,316,408[c]	57,763,172[c]	7[b]	403,573	196,514	4,580,504	2,127,306	600,087	6,707,810

[a] Delayed mortality estimate from October 1975 through August 1977 for specimens held in ambient water was 4%.
[b] Estimate from 8 September 1975 through 2 September 1977.
[c] Total number and weight does not equal the total for 2 years (Table 3) because each total was a separate estimate (see Section 4.2.3.1).

Table 4.2-21 Estimated population in the Bay, number impinged, percent of population impinged and number killed of selected fishes and macroinvertebrates taken from the vicinity of Oyster Creek Generating Station, Forked River, New Jersey from September 1975 through August 1977.

Species	Survey Dates	Impingement Month	Population Estimate	Estimated Number Impinged (Month of Estimate)	% of Population Impinged	Estimated Number Killed (Month of Estimate)
Anchoa mitchilli	13, 14, 21 May 1976	May 1976	5, 770, 401 ± 2, 310, 352	564, 044	10%	557, 840
	22, 25, 28, 29 October 1976	October 1976	2, 616, 646 ± 908, 668	62, 116	2%	60, 998
Syngnathus fuscus	23, 24, 28, 29 June, 1 July 1976	June 1976	East 513, 735 ± 150, 165	2, 575	<1%	643
			West 60, 732 ± 58, 039		4%	643
	26, 27, 28, 29 July 2, 4, 5 August 1977	August 1977	East 1, 757, 622 ± 474, 487	484	<1%	121
			West 280, 428 ± 445, 360		<1%	121
Pseudopleuronectes americanus	6, 7, 8, 15, 16 April 1976	April 1976	194, 370 ± 43, 047	118	<1%	26
	14, 15, 16, 21 March 1977	March 1977	111, 005 ± 23, 174	1, 747	2%	140
Crangon septemspinosa			Double Creek-Waretown			
	18, 19, 20 April 1977	April 1977	68, 000 ± 16, 000	77, 080	113%	17, 397
			Waretown-Cedar Creek			
			44, 000 ± 35, 000		175%	17, 397
Callinectes sapidus	8, 9, 15, 16, 19, 20 July 1976	July 1976	East 3, 671, 889 ± 570, 200	1, 094, 193	30%	138, 306
			West 260, 667 ± 70, 078		419%	138, 306
	26, 27, 28, 29 July, 2, 4, 5 August 1977	August 1977	East 603, 530 ± 234, 299	59, 855	10%	4, 118
			West 102, 385 ± 42, 643		58%	4, 118

Table 4.2-22 Estimated number and loss of fishes that would have been impinged at the Oyster Creek Nuclear Generating Station (OCNGS) and the Forked River Nuclear Generating Station (FRNGS) from September 1975 through August 1977.

	Vertical traveling screens, OCNGS[a]	Ristroph Screens		
		OCNGS[a]	FRNGS[b]	Total
Alosa aestivalis	23,104	5,339	481	5,820
Brevoortia tyrannus	31,822	5,750	518	6,268
Anchoa mitchilli	1,506,768	352,575	31,732	384,307
Menidia menidia	39,073	5,779	520	6,299
Pomatomus saltatrix	9,781	2,649	238	2,887
Cynoscion regalis	23,836	15,947	1,435	17,382
Leiostomus xanthurus	47,789	3,618	326	3,944
Paralichthys dentatus	543	186	17	203

[a] See Table 5

[b] Calculated as 9% of OCNGS loss based on ratio of flow at the FRNGS (40,000 GPM) to that at the OCNGS (460,000 GPM).

Table 4.3-1 Mean monthly water temperature in the OCGS condenser intake and the condenser discharge and the difference between these temperatures (Δt) from September 1975 through August 1976.

	No. of Observations	Mean Temp. Condenser Intake (C)	Mean Temp. Condenser Discharge (C)	Δt
September 1975	30	20.1	28.9	8.8
October	31	16.4	22.8	6.4
November	30	11.8	21.4	9.6
December	31	4.4	13.7	9.3
January 1976[a]	31	0.6	1.2	0.6
February[a]	29	4.1	4.4	0.3
March	31	8.9	13.8	4.9
April	30	14.3	22.5	8.2
May	31	20.0	28.7	8.7
June	30	25.8	35.4	9.6
July	31	26.7	34.4	7.7
August	31	26.6	36.3	9.7

a. OCGS not in operation; only dilution pumps operating.

Table 4.3-2 Mean monthly water temperature in the OCGS condenser intake and the condenser discharge and the difference between these temperatures (Δ t) from September 1976 through August 1977.

	No. of Observations	Mean Temp. Condenser Intake (C)	Mean Temp. Condenser Discharge (C)	Δ t
September	30	23.3	31.5	8.2
October	31	14.9	23.7	8.8
November	30	6.8	16.6	9.8
December	31	0.1	10.0	9.9
January	31	0.1	10.1	10.0
February	28	2.1	12.2	10.1
March	31	8.5	17.1	8.6
	30	14.1	20.7	6.6
May	31[a]	18.4	19.8	1.4
June	30[b]	20.2	22.7	2.5
July	31[a]	25.8	27.0	1.2
August	31	26.4	36.3	9.9

[a] OCGS in operation only part of month.
[b] OCGS shutdown.

Table 4.3-3 Estimated entrainment, with confidence interval, of common and important microzooplankton at the OCGS from September 1975 through August 1977.

Form	September 1975 through August 1976	September 1976 through August 1977
Total Microzooplankton	$5.16 \times 10^{13} \pm 7.90 \times 10^{12}$	$4.03 \times 10^{13} \pm 6.40 \times 10^{12}$
Total Meroplankton	$6.98 \times 10^{12} \pm 1.14 \times 10^{12}$	$6.69 \times 10^{12} \pm 1.53 \times 10^{12}$
Total Holoplankton	$4.17 \times 10^{13} \pm 6.80 \times 10^{12}$	$3.36 \times 10^{13} \pm 5.80 \times 10^{12}$
Total Copepods	$9.01 \times 10^{12} \pm 1.79 \times 10^{12}$	$1.21 \times 10^{13} \pm 2.80 \times 10^{12}$
Copepod nauplii	$2.21 \times 10^{13} \pm 4.60 \times 10^{12}$	$1.98 \times 10^{13} \pm 4.00 \times 10^{12}$
Acartia clausi	$1.30 \times 10^{12} \pm 5.90 \times 10^{11}$	$8.73 \times 10^{11} \pm 4.47 \times 10^{11}$
Acartia tonsa	$9.30 \times 10^{11} \pm 2.20 \times 10^{11}$	$1.02 \times 10^{12} \pm 3.00 \times 10^{11}$
Acartia spp.	$3.88 \times 10^{12} \pm 7.50 \times 10^{11}$	$2.53 \times 10^{12} \pm 7.10 \times 10^{11}$
Oithona colcarva	$4.73 \times 10^{11} \pm 1.54 \times 10^{11}$	$3.67 \times 10^{12} \pm 1.44 \times 10^{12}$
Oithona spp.	$1.04 \times 10^{12} \pm 4.00 \times 10^{11}$	$3.08 \times 10^{12} \pm 9.20 \times 10^{11}$
Paracalanus crassirostris	$1.77 \times 10^{11} \pm 6.50 \times 10^{10}$	$2.76 \times 10^{11} \pm 1.05 \times 10^{11}$
Rotifers	$4.81 \times 10^{12} \pm 1.26 \times 10^{12}$	$1.21 \times 10^{12} \pm 5.90 \times 10^{11}$
Total Bivalve larvae	$1.40 \times 10^{12} \pm 3.50 \times 10^{11}$	$9.46 \times 10^{11} \pm 2.44 \times 10^{11}$
Mercenaria mercenaria larvae	$1.14 \times 10^{11} \pm 9.70 \times 10^{10}$	$1.86 \times 10^{9} \pm 4.22 \times 10^{9}$
Barnacle larvae	$7.31 \times 10^{12} \pm 2.32 \times 10^{12}$	$1.48 \times 10^{12} \pm 4.20 \times 10^{11}$
Polychaete larvae	$4.34 \times 10^{12} \pm 8.00 \times 10^{11}$	$2.73 \times 10^{12} \pm 1.17 \times 10^{12}$
Polydora spp. larvae	$6.98 \times 10^{9} \pm 4.42 \times 10^{9}$	$1.26 \times 10^{12} \pm 1.12 \times 10^{12}$
Gastropod larvae	$8.61 \times 10^{11} \pm 1.89 \times 10^{11}$	$6.44 \times 10^{11} \pm 1.69 \times 10^{11}$

Table 4.3-4 Annual estimate, with confidence interval ($P \leq 0.05$), of important and common macrozooplankton entrained at Oyster Creek Generating Station from 8 September 1975 through August 1977.

	8 September 1975-3 September 1976 Entrainment Estimate	4 September 1976-30 August 1977 Entrainment Estimate
Total Macrozooplankton	$4.25 \times 10^{10} \pm 4.61 \times 10^{9}$	$9.98 \times 10^{10} \pm 2.20 \times 10^{9}$
Polychaeta larvae	$8.00 \times 10^{8} \pm 2.45 \times 10^{8}$	$1.17 \times 10^{9} \pm 3.61 \times 10^{8}$
Palaemonetes spp. zoeae	$1.12 \times 10^{9} \pm 2.72 \times 10^{8}$	$2.40 \times 10^{8} \pm 1.35 \times 10^{8}$
Crangon septemspinosa zoeae	$9.98 \times 10^{9} \pm 3.20 \times 10^{9}$	$1.61 \times 10^{9} \pm 6.10 \times 10^{8}$
Xanthidae zoeae	$1.67 \times 10^{10} \pm 3.77 \times 10^{9}$	$5.51 \times 10^{9} \pm 3.25 \times 10^{9}$
Callinectes sapidus megalopae	$5.18 \times 10^{7} \pm 2.78 \times 10^{8}$	$1.89 \times 10^{8} \pm 7.26 \times 10^{7}$
Other Brachyuran megalopae	$2.08 \times 10^{7} \pm 1.17 \times 10^{7}$	$2.42 \times 10^{8} \pm 7.84 \times 10^{7}$
Beroe ovata	$2.83 \times 10^{7} \pm 1.72 \times 10^{7}$	$2.00 \times 10^{7} \pm 1.63 \times 10^{7}$
Mnemiopsis leidyi	$9.79 \times 10^{8} \pm 3.83 \times 10^{8}$	$3.41 \times 10^{7} \pm 1.52 \times 10^{7}$
Sarsia spp.	$4.11 \times 10^{8} \pm 1.96 \times 10^{8}$	$1.52 \times 10^{10} \pm 5.06 \times 10^{9}$
Rathkea octopunctata	$2.30 \times 10^{7} \pm 2.08 \times 10^{7}$	$4.20 \times 10^{10} \pm 1.72 \times 10^{10}$
Nereis spp. epitokes	$3.83 \times 10^{7} \pm 1.11 \times 10^{7}$	$1.75 \times 10^{7} \pm 7.93 \times 10^{6}$
Leucon americanus	$1.07 \times 10^{9} \pm 3.09 \times 10^{8}$	$2.41 \times 10^{8} \pm 4.09 \times 10^{7}$
Oxyurostylis smithi	$8.62 \times 10^{8} \pm 2.16 \times 10^{8}$	$1.27 \times 10^{8} \pm 3.86 \times 10^{7}$
Edotea triloba	$4.01 \times 10^{8} \pm 7.79 \times 10^{7}$	$1.63 \times 10^{8} \pm 5.31 \times 10^{7}$
Ampelisca spp.	$2.11 \times 10^{9} \pm 4.42 \times 10^{8}$	$1.70 \times 10^{8} \pm 3.38 \times 10^{7}$
Microdeutopus gryllotalpa	$1.23 \times 10^{9} \pm 3.49 \times 10^{8}$	$1.01 \times 10^{8} \pm 4.27 \times 10^{7}$
Corophium spp.	$7.92 \times 10^{8} \pm 2.47 \times 10^{8}$	$1.72 \times 10^{8} \pm 5.30 \times 10^{7}$
Jassa falcata	$2.68 \times 10^{9} \pm 8.38 \times 10^{8}$	$6.73 \times 10^{9} \pm 9.43 \times 10^{8}$
Other Amphipoda	$1.96 \times 10^{9} \pm 3.53 \times 10^{8}$	$1.03 \times 10^{9} \pm 1.37 \times 10^{8}$
Mysidopsis bigelowi[a]	$6.36 \times 10^{8} \pm 1.11 \times 10^{8}$	$1.38 \times 10^{9} \pm 4.06 \times 10^{8}$
Mysidopsis bigelowi gravid	$4.21 \times 10^{6} \pm 2.12 \times 10^{6}$	$3.69 \times 10^{7} \pm 1.66 \times 10^{7}$
Neomysis americana[a]	$1.19 \times 10^{10} \pm 1.99 \times 10^{9}$	$2.29 \times 10^{10} \pm 3.24 \times 10^{9}$
Neomysis americana gravid	$2.98 \times 10^{8} \pm 7.63 \times 10^{7}$	$3.10 \times 10^{8} \pm 7.93 \times 10^{7}$
Palaemonetes spp.	$5.09 \times 10^{7} \pm 1.32 \times 10^{7}$	$2.75 \times 10^{7} \pm 8.49 \times 10^{6}$
Crangon septemspinosa	$1.04 \times 10^{8} \pm 1.97 \times 10^{7}$	$6.37 \times 10^{7} \pm 1.39 \times 10^{7}$

[a] Adult males, non-gravid females, and juveniles

Table 4.3-5 Estimated yearly entrainment, with confidence interval of important and common ichthyoplankton at the Oyster Creek Generating Station from 8 September 1975 through 30 August 1977.

Species	Life Stage	8 September 1975-3 September 1976 Entrainment Estimate	4 September 1976-30 August 1977 Entrainment Estimate
Anchoa mitchilli	eggs	$2.43 \times 10^{10} \pm 5.48 \times 10^{9}$	$4.32 \times 10^{8} \pm 3.45 \times 10^{8}$
Anchoa mitchilli	larvae and juveniles	$1.61 \times 10^{9} \pm 3.82 \times 10^{8}$	$1.02 \times 10^{9} \pm 3.49 \times 10^{8}$
Atherinidae	larvae and juveniles	$1.38 \times 10^{7} \pm 4.29 \times 10^{6}$	$9.81 \times 10^{6} \pm 3.75 \times 10^{6}$
Syngnathus fuscus	juveniles	$6.94 \times 10^{7} \pm 1.47 \times 10^{7}$	$1.53 \times 10^{7} \pm 4.74 \times 10^{6}$
Ammodytes sp.	larvae	$4.04 \times 10^{7} \pm 2.14 \times 10^{7}$	$1.74 \times 10^{8} \pm 5.63 \times 10^{7}$
Gobiidae	larvae	$7.70 \times 10^{8} \pm 1.62 \times 10^{8}$	$1.84 \times 10^{8} \pm 7.88 \times 10^{7}$
Psuedopleuronectes americanus	larvae	$1.61 \times 10^{8} \pm 7.31 \times 10^{7}$	$1.92 \times 10^{9} \pm 6.85 \times 10^{8}$
Total	eggs	$2.48 \times 10^{10} \pm 5.50 \times 10^{9}$	$7.50 \times 10^{8} \pm 3.53 \times 10^{8}$
Total	larvae	$2.66 \times 10^{9} \pm 4.69 \times 10^{8}$	$3.15 \times 10^{9} \pm 7.17 \times 10^{8}$

Table 4.3-6 Estimated entrainment, with confidence interval, and results of analysis of variance ($P \leq 0.2$) of common and important microzooplankton at OCGS during six comparable months (September through November, March, April, and August).

	8 September 1975-3 September 1976 Entrainment Estimate	4 September 1976-30 August 1977 Entrainment Estimate	Significance ($P \leq 0.2$)
Total Microzooplankton	$3.03 \times 10^{13} \pm 7.10 \times 10^{12}$	$2.87 \times 10^{13} \pm 4.8 \times 10^{12}$	Yes
Total Meroplankton	$3.88 \times 10^{12} \pm 7.70 \times 10^{11}$	$4.84 \times 10^{12} \pm 1.22 \times 10^{12}$	Yes
Total Holoplankton	$2.44 \times 10^{13} \pm 6.10 \times 10^{12}$	$2.39 \times 10^{13} \pm 4.40 \times 10^{12}$	Yes
Total Copepods	$5.81 \times 10^{12} \pm 1.26 \times 10^{12}$	$8.10 \times 10^{12} \pm 2.05 \times 10^{12}$	Yes
Copepod nauplii	$1.32 \times 10^{13} \pm 4.10 \times 10^{12}$	$1.45 \times 10^{13} \pm 3.00 \times 10^{12}$	Yes
Acartia clausi	$1.12 \times 10^{12} \pm 6.00 \times 10^{11}$	$6.08 \times 10^{11} \pm 3.22 \times 10^{11}$	Yes
Acartia tonsa	$5.34 \times 10^{11} \pm 1.24 \times 10^{11}$	$6.94 \times 10^{11} \pm 2.21 \times 10^{11}$	Yes
Acartia spp.	$2.69 \times 10^{12} \pm 6.70 \times 10^{11}$	$1.72 \times 10^{12} \pm 5.50 \times 10^{11}$	Yes
Oithona colcarva	$2.35 \times 10^{11} \pm 7.50 \times 10^{10}$	$2.32 \times 10^{12} \pm 1.05 \times 10^{12}$	Yes
Oithona spp.	$5.11 \times 10^{11} \pm 7.90 \times 10^{10}$	$2.01 \times 10^{12} \pm 6.60 \times 10^{11}$	Yes
Paracalanus crassirostris	$7.62 \times 10^{10} \pm 2.81 \times 10^{10}$	$1.50 \times 10^{11} \pm 4.80 \times 10^{10}$	Yes
Rotifers	$2.29 \times 10^{12} \pm 5.60 \times 10^{11}$	$8.91 \times 10^{11} \pm 4.46 \times 10^{11}$	No
Total Bivalve larvae	$9.49 \times 10^{11} \pm 3.25 \times 10^{11}$	$7.04 \times 10^{11} \pm 1.89 \times 10^{11}$	No
Mercenaria mercenaria larvae	$1.09 \times 10^{11} \pm 1.04 \times 10^{11}$	$1.29 \times 10^{9} \pm 6.40 \times 10^{8}$	Yes
Barnacle larvae	$4.28 \times 10^{12} \pm 2.05 \times 10^{12}$	$1.08 \times 10^{12} \pm 3.2 \times 10^{11}$	Yes
Polychaete larvae	$2.32 \times 10^{12} \pm 4.60 \times 10^{11}$	$2.02 \times 10^{12} \pm 9.40 \times 10^{11}$	No
Polydora spp. larvae	$6.68 \times 10^{9} \pm 4.64 \times 10^{9}$	$9.62 \times 10^{11} \pm 9.02 \times 10^{11}$	Yes
Gastropod larvae	$3.79 \times 10^{11} \pm 7.50 \times 10^{10}$	$4.37 \times 10^{11} \pm 1.28 \times 10^{11}$	Yes

Table 4.3-7 Mean monthly densities (n/m^3) and percent composition of numerous and important microzooplankton collected at the Oyster Creek Generating Station discharge from September 1975-September 1976 (year one) and from September 1976-September 1977 (year two).[a] NE = not enumerated.

Form	Year	September n/m^3	September %	October n/m^3	October %	November n/m^3	November %	December n/m^3	December %	March n/m^3	March %	April n/m^3	April %
Copepod nauplii	1	8,573	26	7,433	43	2,039	31	19,618	30	30,911	39	80,545	45
	2	72,962	59	22,343	59	1,623	5	NS	-	17,721	70	38,320	49
Total copepods	1	3,601	11	5,146	30	2,569	39	7,127	11	46,748	59	20,083	11
	2	40,083	32	9,892	26	1,807	5	NS	-	3,408	13	15,117	19
Acartia clausi	1	0	0	93	< 1	26	< 1	1,180	2	20,823	26	4,828	3
	2	0	0	0	0	215	1	NS	-	747	3	9,197	12
Acartia tonsa	1	710	2	1,472	9	769	12	1,715	3	557	1	124	< 1
	2	4,841	4	727	2	299	1	NS	-	70	< 1	32	< 1
Acartia spp.	1	585	2	2,280	13	937	14	2,866	4	18,803	24	13,056	7
	2	12,984	10	2,256	6	216	1	NS	-	493	2	2,874	4
Oithona colcarva	1	257	1	373	2	136	2	116	< 1	118	< 1	54	< 1
	2	5,146	4	1,416	4	226	1	NS	-	26	< 1	0	0
Oithona spp.	1	322	1	197	1	210	3	333	< 1	0	0	24	< 1
	2	12,893	10	3,885	10	94	< 1	NS	-	9	1	49	< 1
Paracalanus crassirostris	1	15	<1	45	< 1	0	0	0	0	35	< 1	53	< 1
	2	620	<1	205	< 1	86	< 1	NS	-	0	0	0	0
Rotifers	1	11,317	34	78	< 1	433	7	34,698	52	133	< 1	11,256	6
	2	1,439	1	80	< 1	26,041	76	NS	-	171	1	149	< 1
Total bivalve larvae	1	1,376	4	325	2	127	2	163	< 1	48	< 1	7,708	4
	2	3,693	3	1,753	5	2,067	6	NS	-	6	< 1	1,207	2
Mercenaria mercenaria larvae	1	0	0	0	0	0	0	6	< 1	0	0	1,249	1
	2	0	0	31	< 1	0	0	NS	-	0	0	0	0
Mulinia lateralis larvae	1	833	3	290	2	0	0	0	0	0	0	114	< 1
	2	1,380	1	316	1	0	0	NS	-	0	0	0	0
Total polychaete larvae	1	2,131	6	746	4	172	3	442	1	247	< 1	12,840	7
	2	3,710	3	2,258	6	1,558	5	NS	-	406	2	15,124	19
Barnacle larvae	1	1,643	5	1,016	6	611	9	3,590	5	1,420	2	43,781	25
	2	651	< 1	595	2	225	1	NS	-	3,185	13	7,248	9
Gastropod larvae	1	1,552	5	544	3	171	3	69	< 1	15	< 1	381	< 1
	2	990	1	213	< 1	19	< 1	NS	-	23	< 1	200	1
Cyphonaute larvae	1	622	2	429	2	38	< 1	26	< 1	0	0	0	0
	2	58	< 1	46	< 1	25	< 1	NS	-	7	< 1	43	< 1
Trochophores	1	168	< 1	12	< 1	126	2	139	< 1	0	0	885	< 1
	2	699	< 1	282	1	726	2	NS	-	0	0	0	0
Total Microzooplankton	1	33,232	-	17,202	-	6,650	-	66,310	-	79,555	-	177,640	-
	2	124,562	-	37,689	-	34,223	-	NS	-	25,372	-	77,625	-

Table 4.3-7 (cont.)

Form	Year	May n/m^3	May %	June n/m^3	June %	July n/m^3	July %	August n/m^3	August %	September n/m^3	September %	Mean n/m^3	Mean %
Copepod nauplii	1	25,275	24	51,772	53	48,635	55	15,984	45	42,452	43	30,294	41
	2	20,952	36	34,010	45	36,733	30	13,648	26	8,918	26	26,723	42
Total copepods	1	5,702	5	18,136	19	30,204	34	9,743	27	42,185	43	17,386	24
	2	18,206	31	22,327	29	68,174	57	26,168	50	8,915	26	21,410	33
<u>Acartia clausi</u>	1	195	< 1	179	< 1	0	0	0	0	0	0	2,484	3
	2	5,757	10	43	< 1	0	0	0	0	140	< 1	1,610	3
<u>Acartia tonsa</u>	1	17	< 1	2,835	3	3,680	4	1,567	4	6,158	6	1,782	2
	2	1,802	3	7,148	9	5,449	5	1,924	4	3,711	11	2,600	4
<u>Acartia</u> spp.	1	1,732	2	6,925	7	6,938	8	3,572	10	15,658	16	6,668	9
	2	896	2	4,106	5	6,766	6	3,883	7	3,027	9	3,750	6
<u>Oithona colcarva</u>	1	49	< 1	546	1	3,221	4	941	3	2,512	3	757	1
	2	284	< 1	3,899	5	31,059	26	16,819	32	2,271	7	6,115	10
<u>Oithona</u> spp.	1	179	< 1	641	< 1	6,975	8	2,596	7	13,108	13	2,235	3
	2	395	1	2,930	4	20,711	17	4,799	9	784	2	4,655	6
<u>Paracalanus crassirostris</u>	1	26	< 1	877	1	840	1	48	< 1	1,992	2	357	< 1
	2	6	< 1	241	< 1	5,214	4	517	1	0	0	689	1
Rotifers	1	21,318	20	2,844	3	335	< 1	2,423	7	2,542	3	7,943	11
	2	2,199	4	1,413	2	138	< 1	490	1	6,280	18	3,840	6
Total bivalve larvae	1	3,350	3	1,971	2	792	< 1	1,842	5	3,215	3	1,902	3
	2	631	1	2,165	3	1,059	1	1,127	2	2,794	8	1,650	3
<u>Mercenaria mercenaria</u>	1	81	< 1	24	< 1	0	0	97	< 1	307	< 1	160	< 1
	2	3	< 1	15	< 1	6	< 1	0	0	0	0	6	-
<u>Mulinia lateralis</u>	1	1,051	1	225	< 1	190	< 1	297	< 1	644	< 1	331	< 1
	2	164	< 1	70	< 1	50	< 1	54	< 1	0	0	203	< 1
Total polychaete larvae	1	12,126	12	8,601	9	2,890	3	2,256	6	3,245	3	4,154	6
	2	8,153	14	2,077	3	2,496	2	2,297	4	2,115	6	4,019	6
Barnacle larvae	1	28,321	27	8,956	9	735	< 1	170	< 1	0	0	8,204	11
	2	3,697	6	1,479	2	303	< 1	372	1	86	< 1	1,784	3
Gastropod larvae	1	3,288	3	1,487	2	2,316	3	1,416	4	641	< 1	1,080	1
	2	4,250	7	10,157	13	7,167	6	3,057	6	1,729	5	2,781	4
Cyphonaute larvae	1	0	0	21	< 1	75	< 1	108	< 1	0	0	120	< 1
	2	58	< 1	205	< 1	2,018	2	4,522	9	2,701	8	968	2
Trochophores	1	4,257	4	2,872	3	1,914	2	1,804	5	3,522	4	1,427	2
	2	3,449	6	1,383	2	1,815	2	54	< 1	0	0	841	1
Total Microzooplankton	1	104,827	-	98,054	-	88,562	-	35,838	-	98,448	-	73,302	-
	2	58,200	-	75,972	-	120,570	-	52,866	-	34,213	-	64,129	-

[a] Year one includes September-December and 2 March-September 1976; year two includes 9 September 1976-November 1976, 1 March-September 1977. During the second year, the dilution discharge was sampled instead of the condenser discharge from 16 May through 18 July when the plant was not in operation. Densities from the dilution discharge are included in the monthly and yearly totals.

Table 4.3-8 Estimated entrainment, with confidence interval P≤ 0.2), and results of analysis of variance (P≤ 0.2) of important and common macrozooplankton at Oyster Creek Generating S ion during seven comparable months (September through December, March, April, and August) from 8 September 1975 through 30 ugust 1977.

	8 September 1975-3 September 1976 Entrainment Estimate	4 September 1976-30 August 1977 Entrainment Estimate	Significance ($P \leq 0.2$)
Total Macrozooplankton	$2.67 \times 10^{10} \pm 3.29 \times 10^{9}$	$7.42 \times 10^{10} \pm 1.82 \times 10^{10}$	Yes
Polychaeta larvae	$5.87 \times 10^{8} \pm 2.27 \times 10^{8}$	$8.95 \times 10^{8} \pm 2.86 \times 10^{8}$	Yes
Palaemonetes spp. zoeae	$7.11 \times 10^{8} \pm 1.80 \times 10^{8}$	$1.75 \times 10^{8} \pm 9.78 \times 10^{7}$	Yes
Crangon septemspinosa zoeae	$6.53 \times 10^{9} \pm 2.25 \times 10^{9}$	$1.11 \times 10^{9} \pm 4.28 \times 10^{8}$	Yes
Xanthidae zoeae	$9.94 \times 10^{9} \pm 2.34 \times 10^{9}$	$3.93 \times 10^{9} \pm 2.28 \times 10^{9}$	No
Brachyura megalopae	$1.39 \times 10^{7} \pm 7.80 \times 10^{6}$	$1.74 \times 10^{8} \pm 5.57 \times 10^{7}$	Yes
Beroe ovata	$2.29 \times 10^{7} \pm 1.56 \times 10^{7}$	$1.60 \times 10^{7} \pm 1.40 \times 10^{7}$	Yes
Mnemiopsis leidyi	$7.49 \times 10^{8} \pm 3.35 \times 10^{8}$	$2.42 \times 10^{7} \pm 1.06 \times 10^{7}$	Yes
Sarsia spp.	$3.48 \times 10^{8} \pm 1.86 \times 10^{8}$	$1.15 \times 10^{10} \pm 4.05 \times 10^{9}$	Yes
Rathkea octopunctata	$2.15 \times 10^{7} \pm 2.07 \times 10^{7}$	$3.29 \times 10^{10} \pm 1.45 \times 10^{10}$	Yes
Nereis spp. epitoke	$2.56 \times 10^{7} \pm 7.46 \times 10^{6}$	$1.35 \times 10^{7} \pm 6.31 \times 10^{6}$	Yes
Leucon americanus	$7.08 \times 10^{8} \pm 2.07 \times 10^{8}$	$1.66 \times 10^{8} \pm 2.85 \times 10^{7}$	Yes
Oxyurostylis smithi	$5.47 \times 10^{8} \pm 1.42 \times 10^{8}$	$9.08 \times 10^{7} \pm 2.87 \times 10^{7}$	No
Edotea triloba	$2.26 \times 10^{8} \pm 4.33 \times 10^{7}$	$1.23 \times 10^{8} \pm 4.72 \times 10^{7}$	Yes
Ampelisca spp.	$1.41 \times 10^{9} \pm 2.96 \times 10^{8}$	$1.21 \times 10^{8} \pm 2.43 \times 10^{7}$	No
Microdeutopus gryllotalpa	$7.22 \times 10^{8} \pm 2.25 \times 10^{8}$	$6.95 \times 10^{7} \pm 3.03 \times 10^{7}$	Yes
Corophium spp.	$3.15 \times 10^{8} \pm 8.18 \times 10^{7}$	$1.42 \times 10^{8} \pm 4.49 \times 10^{7}$	Yes
Jassa falcata	$1.60 \times 10^{9} \pm 6.70 \times 10^{8}$	$4.93 \times 10^{9} \pm 7.70 \times 10^{8}$	Yes
Total Amphipoda	$5.13 \times 10^{9} \pm 9.63 \times 10^{8}$	$6.02 \times 10^{9} \pm 8.66 \times 10^{8}$	Yes
Mysidopsis bigelowi[a]	$4.42 \times 10^{8} \pm 7.81 \times 10^{7}$	$9.78 \times 10^{8} \pm 2.83 \times 10^{8}$	Yes
Mysidopsis bigelowi gravid	$2.91 \times 10^{6} \pm 1.43 \times 10^{6}$	$2.58 \times 10^{7} \pm 1.15 \times 10^{7}$	No
Neomysis americana[a]	$8.17 \times 10^{9} \pm 1.58 \times 10^{9}$	$1.59 \times 10^{10} \pm 2.23 \times 10^{9}$	Yes
Neomysis americana gravid	$2.11 \times 10^{8} \pm 6.28 \times 10^{8}$	$2.17 \times 10^{8} \pm 5.51 \times 10^{7}$	Yes
Palaemonetes spp.	$3.65 \times 10^{7} \pm 1.03 \times 10^{7}$	$2.14 \times 10^{7} \pm 7.29 \times 10^{6}$	No
Crangon septemspinosa	$7.18 \times 10^{7} \pm 1.44 \times 10^{7}$	$4.33 \times 10^{7} \pm 9.60 \times 10^{6}$	No
Callinectes sapidus megalopae	$3.57 \times 10^{7} \pm 1.87 \times 10^{7}$	$1.35 \times 10^{8} \pm 5.06 \times 10^{7}$	Yes

[a] Adult males, non-gravid females, and juveniles

Table 4.3-9 Percentage of abundant macrozooplankton (> 1%) of the forms collected at the Oyster Creek Generating Station from 8 September 1975 to 31 August 1976 and from 1 September 1976 to 31 August 1977.

8 September 1975 - 31 August 1976		1 September 1976 - 31 August 1977	
Neomysis americana	33.0	Rathkea octopunctata	32.0
Neopanope texana (zoeae)	13.5	Neomysis americana	25.4
Crangon septemspinosa (zoeae)	8.6	Sarsia spp.	11.9
Sagitta elegans	6.7	Jassa falcata	6.9
Jassa falcata	4.5	Neopanope texana (zoeae)	5.6
Ampelisca spp.	3.8	Panopeus herbstii (zoeae)	2.8
Leucon americanus	2.7	Crangon septemspinosa (zoeae)	2.0
Microdeutopus gryllotalpa	2.3	Mysidopsis bigelowi	1.2
Mysidopsis bigelowi	2.1		
Oxyurostylis smithi	1.8		
Corophium spp.	1.5		
Order Caprellidea	1.4		
Sarsia spp.	1.2		
Polychaeta (larvae)	1.2		
Unidentified Amphipoda	1.2		

Table 4.3-10 Monthly mean density (weighted for day and night collections) of common (annual mean density >1000/1000m^3) macrozooplankton from collections at the Oyster Creek Generating Station from September 1975 through August 1977. Densities are expressed as No./1000m^3.

		September	October	November	December	January	February	March	April	May	June	July	August	Year
Neomysis americana	1975/76	6,961	9,113	13,816	18,251	6,121	22,836	55,240	6,007	4,148	25,622	15,096	27,987	17,600
	1976/77	23,232	19,418	16,955	54,401	8,968	43,701	59,230	62,702	21,886	14,252	17,455	9,364	29,297
Neopanope texana zoeae	1975/76	905	0	0	0	0	0	0	13	17,843	37,307	24,721	5,779	7,215
	1976/77	275	5	0	0	0	0	0	0	11,386	25,336	37,081	4,114	6,516
Crangon septemspinosa zoeae	1975/76	0	142	74	991	138	631	6,597	13,035	16,485	15,484	1,229	305	4,593
	1976/77	12	126	1,405	122	0	23	177	5,825	8,134	8,831	2,711	29	2,283
Sagitta spp.	1975/76	0	0	0	202	8,445	23,593	10,807	0	0	0	0	0	3,588
	1976/77	556	74	0	1,462	1,704	1,238	378	97	0	0	0	0	459
Jassa falcata	1975/76	17	85	115	179	1,013	88	25	112	105	2,755	10,794	13,681	2,414
	1976/77	16,776	14,736	11,800	14,298	3,089	5,907	4,519	9,311	9,560	1,243	4,108	413	7,980
Ampelisca spp.	1975/76	917	210	220	560	13	640	1,878	4,072	5,457	5,618	4,052	701	2,029
	1976/77	441	121	0	55	0	0	290	474	1,212	3,571	6,358	313	1,070
Leucon americanus	1975/76	97	339	320	135	21	172	313	341	573	10,546	3,590	878	1,444
	1976/77	447	599	368	240	0	196	379	548	128	197	478	725	359
Microdeutopus gryllotalpa	1975/76	57	44	167	283	4	124	205	740	9,732	2,100	1,088	100	1,220
	1976/77	77	0	0	0	14	106	24	153	5,068	1,421	1,782	251	741
Mysidopsis bigelowi	1975/76	2,546	2,307	1,608	684	1,633	269	233	27	1	396	1,678	1,849	1,103
	1976/77	1,410	2,411	1,397	1,515	12	13	4	0	0	30	3,346	6,811	1,412
Oxyurostylis smithi	1975/76	980	279	58	224	16	41	304	644	2,178	4,634	1,761	266	949
	1976/77	96	60	21	15	0	38	44	869	1,229	1,017	514	372	356
Caprellidea	1975/76	40	8	32	50	7	5	0	254	874	1,988	3,244	2,670	764
	1976/77	1,209	560	154	76	42	130	162	441	743	557	461	6,586	927
Sarsia spp.	1975/76	0	0	0	0	0	465	5,954	1,254	0	0	0	0	640
	1976/77	0	0	0	0	16	23,072	77,202	64,541	127	0	0	0	13,747
Panopeus herbstii	1975/76	2	0	0	0	0	0	0	0	896	2,545	1,626	524	466
	1976/77	15	0	0	0	0	0	0	0	32	7,746	25,795	4,753	3,195
Rathkea octopunctata	1975/76	-	-	-	-	-	-	-	-	-	-	-	-	44
	1976/77	33	0	74	706	3,233	23,084	126,051	290,343	13	0	8	0	36,926

Table 4.3-11 Ichthyoplankton entrained at OCGS from September 1975 to August 1977 with yearly mean densities (n/1000m^3) and percent composition of eggs, juveniles, and larval life stages for both years.

	Yearly Mean Density (n/1000m^3)			
Larvae & Juveniles	1975 to 1976	% Composition	1976 to 1977	% Composition
Anguilla rostrata	61.35	2.35	9.75	0.26
Brevoortia tyrannus	5.56	0.21	-	-
Clupea harengus harengus	1.59	0.06	-	-
Anchoa mitchilli	1261.96	48.38	2034.95	54.88
Opsanus tau	0.64	0.02	-	-
Enchelyopus cimbrius	0.09	0.01	-	-
Pollachius virens	1.76	0.07	-	-
Strongylura marina	-	-	0.33	0.01
Membras martinica, Menidia menidia } Atherinidae	22.71	0.87	34.73	0.94
Apeltes quadracus	7.27	0.28	-	-
Hippocampus erectus	0.17	0.01	0.46	0.01
Syngnathus fuscus	49.66	1.90	50.04	1.35
Cynoscion regalis	12.92	0.50	3.15	0.09
Micropogon undulatus	1.27	0.05	9.71	0.26
Family Blennidae	8.96	0.34	35.76	0.96
Ammodytes sp.	341.54	13.09	126.08	3.40
Gobiosoma bosci, Gobiosoma ginsburgi } Gobiidae	593.71	22.76	310.51	8.37
Myoxocephalus sp.	1.85	0.07	-	-
Paralichthys dentatus	1.72	0.07	-	-
Scophthalmus aquosus	-	-	0.19	0.01
Pseudopleuronectes americanus	231.12	8.86	1084.09	29.24
Trinectes maculatus	0.44	0.02	1.50	0.04
Sphoeroides maculatus	2.20	0.08	6.64	0.18
Unidentified	0.21	0.01	-	-
Total	2608.7	100%	3707.89	100%

Eggs	1975 to 1976	% Composition	1976 to 1977	% Composition
Brevoortia tyrannus	0.91	0.01	20.87	0.42
Anchoa mitchilli	18730.50	96.06	4489.85	89.75
Enchelyopus cimbrius	2.18	0.01	-	-
Tautoga onitis	127.77	0.66	149.17	2.98
Tautogolabrus adspersus	264.97	1.36	237.89	4.76
Scophthalmus aquosus	7.40	0.04	-	-
Trinectes maculatus	33.92	0.17	21.92	0.44
Unidentified	328.64	1.69	82.82	1.66
Total	19498.53	100%	5002.70	100%

Table 4.3-12 Estimated entrainment, with confidence interval and results of analysis of variance ($P \leq 0.2$) of important and common ichthyoplankton at the Oyster Creek Generating Station during seven comparable months (September through December, March, April, and August) from 8 September 1975 through 30 August 1977.

Species	Life Stage	8 September 1975-3 September 1976 Entrainment Estimate	4 September 1976-30 August 1977 Entrainment Estimate	Significance
Anchoa mitchilli	eggs	$1.30 \times 10^{10} \pm 3.00 \times 10^{9}$	$3.23 \times 10^{8} \pm 3.24 \times 10^{8}$	No
Anchoa mitchilli	larvae and juveniles	$8.92 \times 10^{8} \pm 1.89 \times 10^{8}$	$5.20 \times 10^{8} \pm 1.54 \times 10^{8}$	Yes
Atherinidae	larvae and juveniles	$8.90 \times 10^{6} \pm 2.86 \times 10^{6}$	$6.07 \times 10^{6} \pm 2.50 \times 10^{6}$	No
Syngnathus fuscus	juveniles	$4.11 \times 10^{7} \pm 9.22 \times 10^{6}$	$1.08 \times 10^{7} \pm 3.75 \times 10^{6}$	No
Ammodytes sp.	larvae	$3.63 \times 10^{7} \pm 1.96 \times 10^{7}$	$1.31 \times 10^{8} \pm 4.83 \times 10^{7}$	Yes
Gobiidae	larvae	$4.73 \times 10^{8} \pm 1.05 \times 10^{8}$	$1.32 \times 10^{8} \pm 7.25 \times 10^{7}$	No
Pseudopleuronectes americanus	larvae	$1.41 \times 10^{8} \pm 6.50 \times 10^{7}$	$1.59 \times 10^{9} \pm 5.91 \times 10^{8}$	Yes
Total	eggs	$1.31 \times 10^{10} \pm 3.01 \times 10^{9}$	$5.13 \times 10^{8} \pm 3.27 \times 10^{8}$	No
Total	larvae	$1.60 \times 10^{9} \pm 2.53 \times 10^{8}$	$2.29 \times 10^{9} \pm 5.92 \times 10^{8}$	Yes

Table 4.3-13 Monthly mean density (weighted for day and night collections) of common (annual mean density >.1/m^3) ichthyoplankton from collections at the Oyster Creek Generating Station from September 1975 through August 1977. Densities are expressed as No./m^3.

		September	October	November	December	January	February	March	April	May	June	July	August	Year
Anchoa mitchilli (eggs)	1975-1976	0	0	0	0	0	0	0	0.002	36.074	81.478	98.421	8.795	18.731
	1976-1977	0.208	0.007	0	0	0	0	0	0.014	2.829	18.948	28.604	3.268	4.490
Anchoa mitchilli (larvae & juveniles)	1975-1976	1.078	0.072	0.061	0.006	0	0	0	0	0.045	2.031	8.973	2.877	1.262
	1976-1977	1.146	0.279	0.067	0.139	0	0	0	0	0.137	0.769	18.803	3.079	2.035
Ammodytes sp. (larvae)	1975-1976	0	0	0	0	2.020	1.445	0.614	0.020	0	0	0	0	0.342
	1976-1977	0	0	0	0	0.151	0.302	0.792	0.268	0	0	0	0	0.126
Gobiidae (larvae)	1975-1976	0.269	0.014	0	0	0	0	0	0	0.370	3.024	2.507	0.882	1.167
	1976-1977	0.912	0.027	0	0	0	0	0	0	0.073	0.739	1.547	0.376	0.306
Pseudopleuronectes americanus (larvae)	1976-1976	0	0	0	0	0	0.152	2.578	0.043	0	0	0	0	0.231
	1976-1977	0	0	0	0	0.008	1.451	8.964	2.586	0	0	0	0	1.084

Table 4.3-14 Percentage of time the average daily discharge temperature (C) at Oyster Creek Generating Station exceeded various temperatures under a normal delta T (10 C) and a maximum delta T (13 C) from June through August[a] 1976.

OCGS Discharge Temp. (delta T of 10 C)		Maximum OCGS Discharge Temp. (delta T of 13 C)	
40.0	0%	43.0	0%
38.8	8	41.8	8
37.8	21	40.8	21
36.7	46	39.7	46
35.6	66	38.6	66
34.4	77	37.4	77
33.3	90	36.3	90
32.2	93	35.2	93
31.1	93	34.1	93
30.6	100	33.6	100

[a] When OCGS operated, the average delta T during June was 9.6 C, July 9.3 C, and August 9.7 C.

Table 4.3-15 Estimated number of macrozooplankton dead immediately after entrainment at OCGS from 8 September 1975 to 31 August 1976.

	September	October	November	December	January	February	March	April	May	June	July	August	Total Number Dead [a]	Total Number Entrained	Percent Dead
Xanthidae (zoeae)	0	0	0	0	-	-	0	0	0	1.86×10^9	9.65×10^8	2.12×10^7	2.85×10^9	1.21×10^{10}	24
Palaemonetes spp. (zoeae)	0	0	0	0	-	-	0	0	0	8.81×10^7	9.89×10^7	2.39×10^7	2.11×10^8	7.95×10^8	27
Crangon septemspinosa (zoeae)	3.55×10^4	0	0	0	-	-	0	2.66×10^8	2.22×10^9	1.46×10^9	1.00×10^8	1.05×10^7	4.06×10^9	8.48×10^9	48
Neomysis americana	6.01×10^7	5.32×10^7	6.95×10^7	8.93×10^7	-	-	2.16×10^8	6.04×10^8	8.25×10^7	1.51×10^9	1.07×10^9	1.99×10^9	5.74×10^9	1.06×10^{10}	54
Crangon septemspinosa	5.50×10^5	0	0	0	-		0	5.34×10^5	2.41×10^6	3.86×10^6	6.32×10^6	1.98×10^7	3.35×10^7	8.89×10^7	38
Palaemonetes spp.	0	0	0	0	-	-	0	0	0	4.67×10^5	2.95×10^6	1.57×10^7	1.91×10^7	4.53×10^7	42
Amphipoda	0	0	0	0	-	-	0	0	0	2.88×10^8	6.40×10^8	9.34×10^8	1.86×10^9	7.46×10^9	25
Nereis spp. (epitokes)	1.25×10^5	0	0	0	-	-	0	2.35×10^5	1.91×10^6	1.92×10^6	2.14×10^6	9.60×10^5	7.30×10^6	3.05×10^7	24
Callinectes sapidus (megalopae)	0	0	0	0	-	-	0	0	0	0	0	0	0	4.59×10^7	0

[a] Estimate of total number entrained differs from that in Table 25 because of different estimating techniques (see Section 4.3.3.2).

Table 4.3-16 Comparison of mean density of common and important macrozooplankton between the intake canal (sta. 6) and discharge canal (50) from March 1976 through March 1977.

Form	Months Analyzed	Mean Density (No./1000m^3) Intake Canal	Discharge Canal	Percent Difference
Xanthidae zoeae	March 1976, October through March	-	-	-
	April through September	88,153	49,488	-44
Neomysis americana		38,893	13,683	-65
		25,087	1,806	-93
Unidentified Amphipoda		2,721	3,164	+14
		18,156	3,643	-80
Sarsia spp.		23,328	10,202	-56
		-	-	-
Rathkea octopunctata	'	23,326	3,952	-83
		-	-	-
Crangon septemspinosa	'	9,296	4,950	-47
zoeae		4,305	1,746	-59
Ampelisca spp.	'	-	-	-
		7,964	580	-93
Oxyurostylis smithi	'	1,098	87	-92
		6,429	1,118	-83
Palaemonetes spp. zoeae		-	-	-
		1,994	8,600	+77
Polychaete larvae		4,830	1,029	-79
		922	114	-88
Caprellidea		98	15	-85
		3,024	933	-69
Mysidopsis bigelowi	'	919	319	-65
		2,107	550	-74
Leucon americanus		596	595	0
		2,263	1,097	-51
Edotea triloba		101	169	+40
		1,886	295	-84
Mnemiopsis leidyi	'	-	-	-
		430	136	-68
Nereis spp. epitokes	'	-	-	-
		383	107	-72
Callinectes sapidus megalopae		-	-	-
		223	64	-71

Table 4.3-17 Comparison of seasonal population estimates with seasonal entrainment estimates for winter flounder larvae for the 1976 breeding season.

Size Class	Duration of Size Class (Days)	Seasonal Population Estimate	Seasonal Entrainment Estimate [b]	Percent of Population Entrained	Percent of Population Entrained Per 24-h Day
2.5 - 3.7	7.3	1.62×10^9	3.16×10^7	2.0	.3
3.8 - 4.0	1.6	2.48×10^9	2.58×10^7	1.0	.7
4.1 - 4.3	1.5	2.06×10^9	1.31×10^7	.6	.4
4.4 - 4.6	1.4	1.40×10^9	6.87×10^6	.5	.35
4.7 - 4.9	1.3	6.58×10^8	2.30×10^6	.35	.3
5.0 - 5.2	1.2	4.78×10^8	2.50×10^6	.5	.4
5.3 - 5.5	1.15	2.61×10^8	1.46×10^6	.6	.5
5.6 - 5.8	1.1	1.91×10^8	7.80×10^5	.4	.4
5.9 - 6.1	1.0	1.64×10^8	7.47×10^5	.45	.45
6.2 - 6.4	1.0	4.70×10^7	5.47×10^5	1.2	1.2
6.5 - 6.7	3.3	8.78×10^6	4.82×10^5	5.5	1.7
6.8 - 7.0	3.15	3.60×10^6	2.57×10^5	7.1	2.3
>7.0	6.0	1.29×10^6	5.47×10^5	42.4	7.1
Total		1.88×10^{10}[a]	8.70×10^7	0.5	

[a] Total number of larvae hatched estimated from the exponential regression of the seasonal abundance of each size class on the estimated age of each size class. Upper and lower 95% confidence limits of this estimate are 7.76×10^{10} and 1.33×10^{10}, respectively.

[b] Seasonal entrainment estimates were calculated by multiplying the monthly entrainment estimate of all larvae by the monthly size-frequency distribution and then adding the monthly entrainment estimates of each size class. The total seasonal entrainment estimate was calculated by adding the seasonal estimates of all size classes. This estimate differs from the annual entrainment estimate (Table 26).

Table 4.3-18 Comparison of seasonal population estimates with seasonal entrainment estimates for winter flounder larvae for the 1977 breeding season.

Size Class	Duration of Size Class (Days)	Seasonal Population Estimate	Seasonal Entrainment Estimate [b]	Percent of Population Entrained	Percent of Population Entrained Per 24-h Day
2.5 - 3.4	5.5	1.11×10^9	1.36×10^8	12.3	2.2
3.5 - 3.7	1.7	4.08×10^9	1.79×10^8	4.4	2.6
3.8 - 4.0	1.6	4.18×10^9	1.56×10^8	3.7	2.3
4.1 - 4.3	1.5	3.65×10^9	1.07×10^8	2.9	1.9
4.4 - 4.6	1.4	3.53×10^9	9.93×10^7	2.8	2.0
4.7 - 4.9	1.3	4.31×10^9	1.01×10^8	2.3	1.8
5.0 - 5.2	1.2	4.62×10^9	1.02×10^8	2.2	1.8
5.3 - 5.5	1.15	4.30×10^9	1.00×10^8	2.3	2.0
5.6 - 5.8	1.1	4.49×10^9	9.96×10^7	2.2	2.0
5.9 - 6.1	1.0	3.83×10^9	8.72×10^7	2.3	2.3
6.2 - 6.4	1.0	3.36×10^9	7.43×10^7	2.2	2.2
6.5 - 6.7	3.3	8.00×10^8	6.69×10^7	8.4	2.5
6.8 - 7.0	3.15	4.95×10^8	4.73×10^7	9.6	3.0
>7.0	6.0	2.90×10^8	4.16×10^7	14.3	2.4
Total		1.35×10^{10} [a]	1.40×10^9	10.4	

[a] Total number of larvae hatched estimated from the exponential regression of the seasonal abundance of each size class on the estimated age of each size class. Upper and lower 95% confidence limits of this estimate are 3.10×10^{10} and 5.87×10^9, respectively.

[b] Seasonal entrainment estimates were calculated by multiplying the monthly entrainment estimate of all larvae by the monthly size-frequency distribution and then adding the monthly entrainment estimates of each size class. The total seasonal entrainment estimate was calculated by adding the seasonal estimates of all size classes. This estimate differs from the annual entrainment estimate (Table 26).

Table 4.3-19 Comparison of estimated populations of selected macrozooplankton in Barnegat Bay with estimated number entrained per 12 h day at the Oyster Creek Generating Station from 11 March 1977 through 21 July 1977.

	Date	Population Estimate ± C.I.	12 h Entrainment Estimate ± C.I.	Percent of Population Entrained
Rathkea octopunctata	11 Mar	$7.22 \times 10^9 \pm 2.81 \times 10^9$	$1.34 \times 10^8 \pm 3.58 \times 10^7$	1.9
	28 Mar	$2.11 \times 10^{10} \pm 0.55 \times 10^{10}$	$6.41 \times 10^7 \pm 3.32 \times 10^7$	0.3
Sarsia sp.	11 Mar	$1.33 \times 10^{10} \pm 0.36 \times 10^{10}$	$1.09 \times 10^8 \pm 6.12 \times 10^7$	0.8
	28 Mar	$2.23 \times 10^{10} \pm 0.70 \times 10^{10}$	$1.67 \times 10^8 \pm 3.33 \times 10^7$	0.7
Barnacle larvae (cypris)	11 Mar	$3.95 \times 10^9 \pm 1.87 \times 10^9$	$4.88 \times 10^6 \pm 4.76 \times 10^6$	0.1
	28 Mar	$1.89 \times 10^8 \pm 0.69 \times 10^8$	$3.68 \times 10^6 \pm 1.20 \times 10^6$	1.9
Crangon septemspinosa (zoeae)	11 Mar	$2.41 \times 10^6 \pm 1.51 \times 10^6$	$2.03 \times 10^5 \pm 2.30 \times 10^5$	8.4
	28 Mar	$4.42 \times 10^7 \pm 1.43 \times 10^7$	$4.86 \times 10^5 \pm 6.26 \times 10^5$	1.1
	18 May	$2.07 \times 10^8 \pm 0.84 \times 10^8$	$6.51 \times 10^6 \pm 2.53 \times 10^6$	3.1
	8 Jun	$3.12 \times 10^8 \pm 0.97 \times 10^8$	$1.28 \times 10^7 \pm 3.40 \times 10^5$	4.1
	22 Jun	$1.19 \times 10^8 \pm 0.47 \times 10^8$	$8.11 \times 10^6 \pm 1.38 \times 10^6$	6.8
	6 Jul	$4.69 \times 10^7 \pm 1.84 \times 10^7$	$3.39 \times 10^6 \pm 9.30 \times 10^5$	7.2
Palaemonetes spp. (zoeae)	8 Jun	$2.08 \times 10^8 \pm 1.46 \times 10^8$	$8.12 \times 10^5 \pm 3.67 \times 10^5$	0.4
	22 Jun	$1.88 \times 10^8 \pm 1.12 \times 10^8$	$7.65 \times 10^5 \pm 4.15 \times 10^5$	0.4
	6 Jul	$7.95 \times 10^7 \pm 2.96 \times 10^7$	$1.52 \times 10^6 \pm 1.05 \times 10^6$	1.9
	21 Jul	$1.15 \times 10^8 \pm 0.35 \times 10^8$	$3.45 \times 10^6 \pm 1.06 \times 10^6$	3.0
Neopanope texana (zoeae)	8 Jun	$5.91 \times 10^9 \pm 6.14 \times 10^9$	$1.07 \times 10^6 \pm 7.90 \times 10^5$	< 0.1
	22 Jun	$1.81 \times 10^9 \pm 1.13 \times 10^9$	$1.63 \times 10^7 \pm 6.81 \times 10^6$	0.9
	6 Jul	$6.64 \times 10^8 \pm 3.86 \times 10^8$	$3.03 \times 10^7 \pm 9.24 \times 10^6$	4.6
	21 Jul	$6.80 \times 10^8 \pm 1.92 \times 10^8$	$4.27 \times 10^7 \pm 8.50 \times 10^6$	6.3
Panopeus herbstii (zoeae)	8 Jun	$1.27 \times 10^7 \pm 1.20 \times 10^7$	$2.45 \times 10^7 \pm 8.82 \times 10^6$	> 100
	22 Jun	$1.21 \times 10^8 \pm 1.34 \times 10^8$	$1.37 \times 10^6 \pm 7.00 \times 10^5$	1.1
	6 Jul	$1.02 \times 10^8 \pm 8.10 \times 10^7$	$1.14 \times 10^7 \pm 8.10 \times 10^6$	11.2
	21 Jul	$1.64 \times 10^8 \pm 0.73 \times 10^8$	$5.96 \times 10^7 \pm 1.26 \times 10^7$	36.3
Pagurus spp. (zoeae)	8 Jun	$1.24 \times 10^7 \pm 9.14 \times 10^6$	$1.36 \times 10^5 \pm 8.91 \times 10^5$	1.1
	22 Jun	$7.38 \times 10^6 \pm 3.60 \times 10^6$	$1.26 \times 10^5 \pm 8.50 \times 10^4$	1.7
	6 Jul	$1.51 \times 10^7 \pm 1.43 \times 10^7$	$1.59 \times 10^6 \pm 7.73 \times 10^5$	10.5
	21 Jul	$4.74 \times 10^7 \pm 2.93 \times 10^7$	$4.38 \times 10^5 \pm 6.89 \times 10^5$	0.9
Libinia spp. (zoeae)	8 Jun	$2.91 \times 10^6 \pm 1.53 \times 10^6$	$5.13 \times 10^5 \pm 3.87 \times 10^5$	17.6
	22 Jun	$8.58 \times 10^6 \pm 7.31 \times 10^6$	$2.35 \times 10^5 \pm 2.49 \times 10^5$	2.7
	6 Jul	$9.22 \times 10^7 \pm 7.92 \times 10^7$	$9.77 \times 10^5 \pm 7.99 \times 10^5$	1.1
	21 Jul	$8.77 \times 10^6 \pm 5.65 \times 10^6$	$2.50 \times 10^5 \pm 3.42 \times 10^5$	2.9
Upogebia affinis (zoeae)	22 Jun	$3.76 \times 10^7 \pm 2.30 \times 10^7$	$6.55 \times 10^5 \pm 2.84 \times 10^5$	1.7
	6 Jul	$4.54 \times 10^7 \pm 2.51 \times 10^7$	$3.74 \times 10^6 \pm 1.30 \times 10^6$	8.2
	21 Jul	$4.51 \times 10^7 \pm 1.30 \times 10^7$	$4.24 \times 10^5 \pm 3.10 \times 10^5$	0.9
Rhithropanopeus harrisii (zoeae)	22 Jun	$2.44 \times 10^7 \pm 1.74 \times 10^7$	$8.95 \times 10^5 \pm 4.01 \times 10^5$	3.7
	21 Jul	$3.15 \times 10^6 \pm 2.40 \times 10^6$	$1.24 \times 10^6 \pm 1.00 \times 10^6$	39.4
Hippolyte spp. (zoeae)	22 Jun	$4.37 \times 10^6 \pm 1.94 \times 10^6$	$8.63 \times 10^4 \pm 5.85 \times 10^4$	2.0
	6 Jul	$5.81 \times 10^5 \pm 4.47 \times 10^5$	$1.44 \times 10^5 \pm 6.31 \times 10^4$	24.8
	21 Jul	$2.25 \times 10^7 \pm 8.11 \times 10^6$	$3.05 \times 10^5 \pm 2.96 \times 10^5$	1.4
	19 Sep	$2.63 \times 10^7 \pm 1.17 \times 10^7$	$9.30 \times 10^5 \pm 4.08 \times 10^5$	3.5
Callinectes sapidus (zoeae)	6 Jul	$1.48 \times 10^6 \pm 1.61 \times 10^6$	$3.10 \times 10^5 \pm 4.45 \times 10^5$	20.9
	21 Jul	$1.94 \times 10^7 \pm 1.10 \times 10^7$	$5.31 \times 10^5 \pm 5.61 \times 10^5$	2.7
Uca spp. (zoeae)	6 Jul	$2.99 \times 10^6 \pm 3.14 \times 10^6$	$8.09 \times 10^5 \pm 8.91 \times 10^5$	27.1
	21 Jul	$7.40 \times 10^6 \pm 3.16 \times 10^6$	$5.25 \times 10^5 \pm 9.34 \times 10^5$	7.1
Turritopsis nutricola	19 Sep	$6.53 \times 10^8 \pm 7.65 \times 10^8$	$1.53 \times 10^6 \pm 6.31 \times 10^5$	0.2
Neomysis americana	19 Sep	$1.09 \times 10^9 \pm 5.47 \times 10^8$	$1.69 \times 10^7 \pm 4.55 \times 10^6$	1.6
	28 Sep	$2.60 \times 10^9 \pm 1.07 \times 10^9$	$2.10 \times 10^7 \pm 4.32 \times 10^6$	0.8
Mysidopsis bigelowi	19 Sep	$2.76 \times 10^8 \pm 1.07 \times 10^8$	$8.84 \times 10^6 \pm 3.87 \times 10^6$	3.2
	28 Sep	$2.16 \times 10^8 \pm 1.99 \times 10^8$	$1.10 \times 10^7 \pm 5.58 \times 10^6$	5.1
Callinectes sapidus (megalopae)	19 Sep	$1.74 \times 10^8 \pm 4.23 \times 10^7$	$7.11 \times 10^5 \pm 6.82 \times 10^5$	0.2
	28 Sep	$1.01 \times 10^8 \pm 5.86 \times 10^7$	$2.77 \times 10^5 \pm 2.16 \times 10^5$	0.3
Libinia spp. (megalopae)	19 Sep	$4.57 \times 10^7 \pm 3.31 \times 10^7$	$6.36 \times 10^5 \pm 5.20 \times 10^5$	1.4
	28 Sep	$9.28 \times 10^7 \pm 1.31 \times 10^8$	$2.27 \times 10^5 \pm 1.71 \times 10^5$	0.3

Table 4.3-20 Comparison of estimated populations of abundant ichthyoplankton in Barnegat Bay with estimated number entrained per 12 h day at the Oyster Creek Generating Station from 11 March 1977 through 21 July 1977.

Organism	Date	Population Estimate ± C.I.	12 h Entrainment Estimate ± C.I.	Percent of Population Entrained
Pseudopleuronectes americanus larvae	11 March	$1.53 \times 10^{9} \pm 7.65 \times 10^{8}$	$1.60 \times 10^{7} \pm 6.50 \times 10^{6}$	1.1
	28 March	$1.30 \times 10^{9} \pm 3.37 \times 10^{8}$	$1.29 \times 10^{7} \pm 2.71 \times 10^{6}$	1.0
Anchoa mitchilli eggs	18 May	$9.76 \times 10^{8} \pm 3.07 \times 10^{8}$	$1.03 \times 10^{6} \pm 4.61 \times 10^{5}$	0.1
	8 June	$4.94 \times 10^{8} \pm 9.95 \times 10^{7}$	$1.30 \times 10^{6} \pm 4.06 \times 10^{5}$	0.3
	22 June	$5.68 \times 10^{9} \pm 7.86 \times 10^{8}$	$1.84 \times 10^{7} \pm 6.33 \times 10^{6}$	0.3
	6 July	$5.72 \times 10^{9} \pm 1.71 \times 10^{9}$	$8.51 \times 10^{7} \pm 2.72 \times 10^{7}$	1.5
	21 July	$5.08 \times 10^{9} \pm 7.96 \times 10^{8}$	$1.46 \times 10^{7} \pm 3.01 \times 10^{6}$	0.3
Anchoa mitchilli larvae	8 June	$7.47 \times 10^{6} \pm 2.29 \times 10^{6}$	$1.21 \times 10^{5} \pm 4.52 \times 10^{4}$	1.6
	22 June	$2.62 \times 10^{7} \pm 1.19 \times 10^{7}$	$1.99 \times 10^{6} \pm 3.34 \times 10^{5}$	7.6
	6 July	$1.09 \times 10^{8} \pm 3.78 \times 10^{7}$	$1.67 \times 10^{7} \pm 3.32 \times 10^{6}$	15.3
	21 July	$7.73 \times 10^{8} \pm 1.08 \times 10^{8}$	$8.65 \times 10^{6} \pm 1.69 \times 10^{6}$	1.1
Syngnathus fuscus juveniles	18 May	$4.17 \times 10^{6} \pm 1.77 \times 10^{6}$	$9.75 \times 10^{4} \pm 1.07 \times 10^{5}$	2.3
	8 June	$4.26 \times 10^{6} \pm 2.11 \times 10^{6}$	$1.70 \times 10^{5} \pm 5.09 \times 10^{4}$	4.0
	22 June	$5.06 \times 10^{6} \pm 2.22 \times 10^{6}$	$1.66 \times 10^{5} \pm 9.22 \times 10^{4}$	3.3
	6 July	$3.14 \times 10^{6} \pm 2.01 \times 10^{6}$	$6.99 \times 10^{5} \pm 2.83 \times 10^{5}$	22.3
	21 July	$5.28 \times 10^{6} \pm 2.72 \times 10^{6}$	$6.38 \times 10^{4} \pm 1.44 \times 10^{5}$	1.2
Gobiidae larvae	8 June	$2.28 \times 10^{5} \pm 3.26 \times 10^{5}$	$1.24 \times 10^{5} \pm 5.37 \times 10^{4}$	54.4
	22 June	$1.09 \times 10^{6} \pm 1.21 \times 10^{6}$	$2.58 \times 10^{5} \pm 8.35 \times 10^{4}$	23.7
	6 July	$1.39 \times 10^{6} \pm 1.23 \times 10^{6}$	$3.71 \times 10^{6} \pm 7.29 \times 10^{5}$	>100.00
	21 July	$1.76 \times 10^{6} \pm 1.83 \times 10^{6}$	$6.34 \times 10^{5} \pm 1.95 \times 10^{5}$	36.0

Table 4.3-21 Comparison of seasonal population estimates with seasonal entrainment estimates for eggs and larvae of the bay anchovy for the 1976 breeding season.

Size Class	Duration of Size Class (Days)	Seasonal Population Estimate	Seasonal Entrainment Estimate [b]	Percent of Population Entrained	Percent of Population Entrained Per Day
Eggs	1.5	3.77×10^{11}	1.79×10^{10}	4.7	3.2
1.0 - 6.9	10.1	5.82×10^{9}	7.86×10^{8}	13.5	1.3
7.0 - 7.9	1.8	2.12×10^{9}	1.05×10^{8}	5.0	2.8
8.0 - 8.9	1.8	1.60×10^{9}	6.78×10^{7}	4.2	2.4
9.0 - 9.9	1.8	1.05×10^{9}	4.60×10^{7}	4.4	2.4
10.0 - 10.9	1.8	9.17×10^{8}	3.54×10^{7}	3.9	2.1
11.0 - 11.9	1.8	9.33×10^{8}	2.88×10^{7}	3.1	1.7
12.0 - 12.9	1.8	9.06×10^{8}	2.60×10^{7}	2.9	1.6
13.0 - 13.9	1.8	1.06×10^{9}	2.54×10^{7}	2.4	1.3
14.0 - 14.9	1.8	8.11×10^{8}	2.16×10^{7}	2.7	1.5
15.0 - 15.9	1.8	5.83×10^{8}	1.86×10^{7}	3.2	1.8
>16.0	19.8	4.85×10^{8}	1.32×10^{8}	27.2	1.4
Total					
Egg		3.77×10^{11}	1.79×10^{10}	4.7	
Larvae		5.79×10^{10} [a]	1.29×10^{9}	2.2	

[a] Total number of larvae at hatching (mean age 1.5 days) estimated from the exponental regression of the seasonal abundance of eggs and each size class of larvae (>7.0 mm) on the estimated age of each size class. Upper and lower 95% confidence limits of estimate are 1.14×10^{12} and 2.95×10^{9}, respectively.

[b] Seasonal entrainment estimates were calculated by multiplying the monthly entrainment estimate of all larvae by the monthly size-frequency distribution and then adding the monthly entrainment estimates of each size class. The total seasonal entrainment estimate was calculated by adding the seasonal estimates of all size classes. This estimate differs from the annual entrainment estimate (Table 26).

Table 4.3-22 Estimated number of common and important microzooplankton entrained at the Oyster Creek Generating Station (OCGS), with confidence interval (P 0.05), and the projected number that would have been entrained at the Forked River Generating Station (FRGS) from September 1975 through August 1977.

	September 1975 through August 1976			September 1976 through August 1977		
	OCGS [a]	FRGS [b]	Total	OCGS	FRGS	Total
Total Microzooplankton	$5.16 \times 10^{13} \pm 7.90 \times 10^{12}$	4.49×10^{12}	5.61×10^{13}	$4.03 \times 10^{13} \pm 6.40 \times 10^{12}$	3.51×10^{12}	4.38×10^{13}
Total Meroplankton	$6.98 \times 10^{12} \pm 1.14 \times 10^{12}$	6.07×10^{11}	7.59×10^{12}	$6.69 \times 10^{12} \pm 1.53 \times 10^{12}$	5.82×10^{11}	7.27×10^{12}
Total Holoplankton	$4.17 \times 10^{13} \pm 6.80 \times 10^{12}$	3.63×10^{12}	4.53×10^{13}	$3.36 \times 10^{13} \pm 5.80 \times 10^{12}$	2.92×10^{12}	3.65×10^{13}
Total Copepods	$9.01 \times 10^{12} \pm 1.79 \times 10^{12}$	7.84×10^{11}	9.79×10^{12}	$1.21 \times 10^{13} \pm 2.80 \times 10^{12}$	1.05×10^{12}	1.32×10^{13}
Copepod nauplii	$2.21 \times 10^{13} \pm 4.60 \times 10^{12}$	1.92×10^{12}	2.40×10^{13}	$1.98 \times 10^{13} \pm 4.00 \times 10^{12}$	1.72×10^{12}	2.15×10^{13}
Acartia clausi	$1.30 \times 10^{12} \pm 5.90 \times 10^{11}$	1.13×10^{11}	1.41×10^{12}	$8.73 \times 10^{11} \pm 4.47 \times 10^{11}$	7.60×10^{10}	9.49×10^{11}
Acartia tonsa	$9.30 \times 10^{11} \pm 2.20 \times 10^{11}$	8.09×10^{10}	1.01×10^{12}	$1.02 \times 10^{12} \pm 3.00 \times 10^{11}$	8.87×10^{10}	1.11×10^{12}
Acartia spp.	$3.88 \times 10^{12} \pm 7.50 \times 10^{11}$	3.38×10^{11}	4.22×10^{12}	$2.53 \times 10^{12} \pm 7.10 \times 10^{11}$	2.20×10^{11}	2.75×10^{12}
Oithona colcarva	$4.73 \times 10^{11} \pm 1.54 \times 10^{11}$	4.12×10^{10}	5.14×10^{11}	$3.67 \times 10^{12} \pm 1.44 \times 10^{12}$	3.19×10^{11}	3.99×10^{12}
Oithona spp.	$1.04 \times 10^{12} \pm 4.00 \times 10^{11}$	9.05×10^{10}	1.13×10^{12}	$3.08 \times 10^{12} \pm 9.20 \times 10^{11}$	2.68×10^{11}	3.35×10^{12}
Paracalanus crassirostris	$1.77 \times 10^{11} \pm 6.50 \times 10^{10}$	1.54×10^{10}	1.92×10^{11}	$2.76 \times 10^{11} \pm 1.05 \times 10^{11}$	2.40×10^{10}	3.00×10^{11}
Rotifers	$4.81 \times 10^{12} \pm 1.26 \times 10^{12}$	4.19×10^{11}	5.23×10^{12}	$1.21 \times 10^{12} \pm 5.90 \times 10^{11}$	1.05×10^{11}	1.32×10^{12}
Total Bivalve larvae	$1.40 \times 10^{12} \pm 3.50 \times 10^{11}$	1.22×10^{11}	1.52×10^{12}	$9.46 \times 10^{11} \pm 2.44 \times 10^{11}$	8.23×10^{10}	1.03×10^{12}
Mercenaria mercenaria larvae	$1.14 \times 10^{11} \pm 9.70 \times 10^{10}$	9.92×10^{9}	1.24×10^{11}	$1.86 \times 10^{9} \pm 4.22 \times 10^{9}$	1.62×10^{8}	2.02×10^{9}
Barnacle larvae	$7.31 \times 10^{12} \pm 2.32 \times 10^{12}$	6.36×10^{11}	7.95×10^{12}	$1.48 \times 10^{12} \pm 4.20 \times 10^{11}$	1.29×10^{11}	1.61×10^{12}
Polychaete larvae	$4.34 \times 10^{12} \pm 8.00 \times 10^{11}$	3.78×10^{11}	4.72×10^{12}	$2.73 \times 10^{12} \pm 1.17 \times 10^{12}$	2.38×10^{11}	2.97×10^{12}
Polydora spp. larvae	$6.98 \times 10^{9} \pm 4.42 \times 10^{9}$	6.07×10^{8}	7.59×10^{9}	$1.26 \times 10^{12} \pm 1.12 \times 10^{12}$	1.10×10^{11}	1.37×10^{12}
Gastropod larvae	$8.61 \times 10^{11} \pm 1.89 \times 10^{11}$	7.49×10^{10}	9.36×10^{11}	$6.44 \times 10^{11} \pm 1.69 \times 10^{11}$	5.60×10^{10}	7.00×10^{11}

[a] From Table 24.

[b] Calculated as 8.7% of those entrained at the OCGS.

Table 4.3-23 Estimated number of common and important macrozooplankton entrained at the Oyster Creek Generating Station (OCGS), with confidence interval ($P \leq 0.05$), and the projected number that would have been entrained at the Forked River Generating Station (FRGS) from September 1975 through August 1977.

	September 1975 through August 1976			September 1976 through August 1977		
	OCGS[b]	FRGS[c]	Total	OCGS	FRGS	Total
Total Macrozooplankton	$4.25 \times 10^{10} \pm 4.61 \times 10^{9}$	3.70×10^{9}	4.62×10^{10}	$9.98 \times 10^{10} \pm 2.20 \times 10^{9}$	8.68×10^{9}	1.08×10^{11}
Polychaeta larvae	$8.00 \times 10^{8} \pm 2.45 \times 10^{8}$	6.96×10^{7}	8.70×10^{8}	$1.17 \times 10^{9} \pm 3.61 \times 10^{8}$	1.02×10^{8}	1.27×10^{9}
Palaemonetes spp. zoeae	$1.12 \times 10^{9} \pm 2.72 \times 10^{8}$	9.74×10^{7}	1.22×10^{9}	$2.40 \times 10^{8} \pm 1.35 \times 10^{8}$	2.09×10^{7}	2.61×10^{8}
Crangon septemspinosa zoeae	$9.98 \times 10^{9} \pm 3.20 \times 10^{9}$	8.68×10^{8}	1.08×10^{10}	$1.61 \times 10^{9} \pm 6.10 \times 10^{8}$	1.40×10^{8}	1.75×10^{9}
Xanthidae zoeae	$1.67 \times 10^{10} \pm 3.77 \times 10^{9}$	1.45×10^{9}	1.82×10^{10}	$5.51 \times 10^{9} \pm 3.25 \times 10^{9}$	4.79×10^{8}	5.99×10^{9}
Callinectes sapidus megalopae	$5.18 \times 10^{7} \pm 2.78 \times 10^{8}$	4.51×10^{6}	5.63×10^{7}	$1.89 \times 10^{8} \pm 7.26 \times 10^{7}$	1.64×10^{7}	2.05×10^{8}
Other Brachyuran megalopae	$2.08 \times 10^{7} \pm 1.17 \times 10^{7}$	1.81×10^{6}	2.26×10^{7}	$2.42 \times 10^{8} \pm 7.84 \times 10^{7}$	2.11×10^{7}	2.63×10^{8}
Beroe ovata	$2.83 \times 10^{7} \pm 1.72 \times 10^{7}$	2.46×10^{7}	3.08×10^{7}	$2.00 \times 10^{7} \pm 1.63 \times 10^{7}$	1.74×10^{6}	2.17×10^{7}
Mnemiopsis leidyi	$9.79 \times 10^{8} \pm 3.83 \times 10^{8}$	8.52×10^{7}	1.06×10^{9}	$3.41 \times 10^{7} \pm 1.52 \times 10^{7}$	2.97×10^{6}	3.71×10^{7}
Sarsia spp.	$4.11 \times 10^{8} \pm 1.96 \times 10^{8}$	3.58×10^{7}	4.47×10^{8}	$1.52 \times 10^{10} \pm 5.06 \times 10^{9}$	1.32×10^{9}	1.65×10^{10}
Rathkea octopunctata	$2.30 \times 10^{7} \pm 2.08 \times 10^{7}$	2.00×10^{6}	2.50×10^{7}	$4.20 \times 10^{10} \pm 1.72 \times 10^{10}$	3.65×10^{9}	4.57×10^{10}
Nereis spp. epitokes	$3.83 \times 10^{7} \pm 1.11 \times 10^{7}$	3.33×10^{6}	4.16×10^{7}	$1.75 \times 10^{7} \pm 7.93 \times 10^{6}$	1.52×10^{6}	1.90×10^{7}
Leucon americanus	$1.07 \times 10^{9} \pm 3.09 \times 10^{8}$	9.31×10^{7}	1.16×10^{9}	$2.41 \times 10^{8} \pm 4.09 \times 10^{7}$	2.10×10^{7}	2.62×10^{8}
Oxyurostylis smithi	$8.62 \times 10^{8} \pm 2.16 \times 10^{8}$	7.50×10^{7}	9.37×10^{8}	$1.27 \times 10^{8} \pm 3.86 \times 10^{7}$	1.10×10^{7}	1.38×10^{8}
Edotea triloba	$4.01 \times 10^{8} \pm 7.79 \times 10^{7}$	3.49×10^{7}	4.36×10^{8}	$1.63 \times 10^{8} \pm 5.31 \times 10^{7}$	1.42×10^{7}	1.77×10^{8}
Ampelisca spp.	$2.11 \times 10^{9} \pm 4.42 \times 10^{8}$	1.84×10^{8}	2.29×10^{9}	$1.70 \times 10^{8} \pm 3.38 \times 10^{7}$	1.48×10^{7}	1.85×10^{8}
Microdeutopus gryllotalpa	$1.23 \times 10^{9} \pm 3.49 \times 10^{8}$	1.07×10^{8}	1.34×10^{9}	$1.01 \times 10^{8} \pm 4.27 \times 10^{7}$	8.79×10^{6}	1.10×10^{8}
Corophium spp.	$7.92 \times 10^{8} \pm 2.47 \times 10^{8}$	6.89×10^{7}	8.61×10^{8}	$1.72 \times 10^{8} \pm 5.30 \times 10^{7}$	1.50×10^{7}	1.87×10^{8}
Jassa falcata	$2.68 \times 10^{9} \pm 8.38 \times 10^{8}$	2.33×10^{8}	2.91×10^{9}	$6.73 \times 10^{9} \pm 9.43 \times 10^{8}$	5.86×10^{8}	7.32×10^{9}
Other Amphipoda	$1.96 \times 10^{9} \pm 3.53 \times 10^{8}$	1.71×10^{8}	2.13×10^{9}	$1.03 \times 10^{9} \pm 1.37 \times 10^{8}$	8.96×10^{7}	1.12×10^{9}
Mysidopsis bigelowi[a]	$6.36 \times 10^{8} \pm 1.11 \times 10^{8}$	5.53×10^{7}	6.91×10^{8}	$1.38 \times 10^{9} \pm 4.06 \times 10^{8}$	1.20×10^{8}	1.50×10^{9}
Mysidopsis begelowi gravid	$4.21 \times 10^{6} \pm 2.12 \times 10^{6}$	3.66×10^{5}	4.58×10^{6}	$3.69 \times 10^{7} \pm 1.66 \times 10^{7}$	3.21×10^{6}	4.01×10^{7}
Neomysis americana[a]	$1.19 \times 10^{10} \pm 1.99 \times 10^{9}$	1.04×10^{9}	1.29×10^{10}	$2.29 \times 10^{10} \pm 3.24 \times 10^{9}$	1.99×10^{9}	2.49×10^{10}
Neomysis americana gravid	$2.98 \times 10^{8} \pm 7.63 \times 10^{7}$	2.59×10^{7}	3.24×10^{8}	$3.10 \times 10^{8} \pm 7.93 \times 10^{7}$	2.70×10^{7}	3.37×10^{8}
Palaemonetes spp.	$5.09 \times 10^{7} \pm 1.32 \times 10^{7}$	4.43×10^{6}	5.53×10^{7}	$2.75 \times 10^{7} \pm 8.49 \times 10^{6}$	2.39×10^{6}	2.99×10^{7}
Crangon septemspinosa	$1.04 \times 10^{8} \pm 1.97 \times 10^{7}$	9.05×10^{6}	1.13×10^{8}	$6.37 \times 10^{7} \pm 1.39 \times 10^{7}$	5.54×10^{6}	6.92×10^{7}

[a] Adults and juveniles.
[b] From Table 25.
[c] Calculated as 8.7% of those entrained at the OCGS.

Table 4.3-24 Estimated number of common ichthyoplankton entrained at the Oyster Creek Generating Station (OCGS), with confidence interval ($P \leq 0.05$), and the projected number that would have been entrained at the Forked River Generating Station (FRGS) from September 1975 through August 1977.

	Life Stage	September 1975 through August 1976 OCGS[a]	FRGS[b]	Total	September 1976 through August 1977 OCGS	FRGS	Total
Anchoa mitchilli	eggs	$2.43 \times 10^{10} \pm 5.48 \times 10^{9}$	2.11×10^{9}	2.64×10^{10}	$4.32 \times 10^{8} \pm 3.45 \times 10^{8}$	3.76×10^{7}	4.70×10^{8}
Anchoa mitchilli	larvae and juveniles	$1.61 \times 10^{9} \pm 3.82 \times 10^{8}$	1.40×10^{8}	1.75×10^{9}	$1.02 \times 10^{9} \pm 3.49 \times 10^{8}$	8.87×10^{7}	1.11×10^{9}
Atherinidae	larvae and juveniles	$1.38 \times 10^{7} \pm 4.29 \times 10^{6}$	1.20×10^{6}	1.50×10^{7}	$9.81 \times 10^{6} \pm 3.75 \times 10^{6}$	8.53×10^{5}	1.07×10^{7}
Syngnathus fuscus	juveniles	$6.94 \times 10^{7} \pm 1.47 \times 10^{7}$	6.04×10^{6}	7.54×10^{7}	$1.53 \times 10^{7} \pm 4.74 \times 10^{6}$	1.33×10^{6}	1.66×10^{7}
Ammodytes sp.	larvae	$4.04 \times 10^{7} \pm 2.14 \times 10^{7}$	3.51×10^{6}	4.39×10^{7}	$1.74 \times 10^{8} \pm 5.63 \times 10^{7}$	1.51×10^{7}	1.89×10^{8}
Gobiidae	larvae	$7.70 \times 10^{8} \pm 1.62 \times 10^{8}$	6.70×10^{7}	8.37×10^{8}	$1.84 \times 10^{8} \pm 7.88 \times 10^{7}$	1.60×10^{7}	2.00×10^{8}
Pseudopleuronectes americanus	larvae	$1.61 \times 10^{8} \pm 7.31 \times 10^{7}$	1.40×10^{7}	1.75×10^{8}	$1.92 \times 10^{9} \pm 6.85 \times 10^{8}$	1.67×10^{8}	2.09×10^{9}
Total	eggs	$2.48 \times 10^{10} \pm 5.50 \times 10^{9}$	2.16×10^{9}	2.70×10^{10}	$7.50 \times 10^{8} \pm 3.53 \times 10^{8}$	6.53×10^{7}	8.15×10^{8}
Total	larvae	$2.66 \times 10^{9} \pm 4.69 \times 10^{8}$	2.31×10^{8}	2.89×10^{9}	$3.15 \times 10^{9} \pm 7.17 \times 10^{8}$	2.74×10^{8}	3.42×10^{9}

[a] From Table 26.

[b] Calculated as 8.7% of those entrained at the OCGS.

Table 4.3-25 Estimated number of common and important zoo- and ichthyoplankton killed at the Oyster Creek Nuclear Generating Station (OCNGS) and the projected number that should have been killed at the Forked River Nuclear Generating Station from September 1975 through August 1976 or during 1977.

	No. Lost At OCNGS	No. Lost At FRNGS [c]	Total No. Lost	Total No. Entrained	% Increase	Increased % of population entrained during 12-h period [e]	Total % of population entrained during 12-h period
Microzooplankton[a]							
M. mercenaria - larvae	1.14×10^{10}	9.92×10^{9}	2.13×10^{10}	1.24×10^{11}	87		
Macrozooplankton[b]							
Xanthidae - zoeae	2.85×10^{9}	1.05×10^{9}	3.90×10^{9}	1.31×10^{10}	37	< 0.1 - 3.2	< 0.1 - 39.5
Callinectes sapidus - megalopae	0	4.0×10^{6}	4.0×10^{6}	4.99×10^{7}	-	< 0.1	0.2 - 0.3
Nereis spp. - epitokes	7.30×10^{6}	2.65×10^{6}	9.95×10^{6}	3.31×10^{7}	36		
Amphipods	1.86×10^{9}	6.49×10^{8}	2.51×10^{9}	8.10×10^{9}	35		
Neomysis americana	5.74×10^{9}	9.22×10^{8}	6.66×10^{9}	1.15×10^{10}	16	0.1	0.9 - 1.7
Palaemonetes spp. - zoeae	2.11×10^{8}	6.92×10^{7}	2.80×10^{8}	8.64×10^{8}	33	< 0.1 - 0.3	0.4 - 3.3
Palaemonetes spp. - adults	1.91×10^{7}	3.94×10^{6}	2.30×10^{7}	4.92×10^{7}	21		
Crangon septemspinosa - adults	3.35×10^{7}	7.73×10^{6}	4.12×10^{7}	9.66×10^{7}	23		
Crangon septemspinosa - zoeae	4.06×10^{9}	7.38×10^{8}	4.80×10^{9}	9.22×10^{9}	18	0.1 - 0.8	1.2 - 9.2
Ichthyoplankton[d]							
Anchoa mitchilli - eggs	2.43×10^{10}	2.11×10^{9}	2.64×10^{10}	2.64×10^{10}	8.7	< 0.1 - 0.1	0.3 - 1.6
Anchoa mitchilli - larvae and juveniles	1.61×10^{9}	1.40×10^{8}	1.75×10^{9}	1.75×10^{9}	8.7	< 0.1 - 1.3	1.1 - 16.6
Atherinidae - larvae and juveniles	1.38×10^{7}	1.20×10^{6}	1.50×10^{7}	1.50×10^{7}	8.7		
Syngnathus fuscus - juveniles	6.94×10^{7}	6.04×10^{6}	7.54×10^{7}	7.54×10^{7}	8.7	0.1 - 1.9	1.3 - 24.2
Ammodytes spp. - larvae	4.04×10^{7}	3.51×10^{6}	4.39×10^{7}	4.39×10^{7}	8.7		
Gobiidae larvae	7.70×10^{8}	6.70×10^{7}	8.37×10^{8}	8.37×10^{8}	8.7		
Pseudopleuronectes americanus							
larvae (63% mortality of large larvae)	1.34×10^{8}	1.40×10^{7}	1.48×10^{8}	1.75×10^{8}	10.4	0.1	1.0 - 1.1
larvae (33% mortality)	5.31×10^{7}	1.40×10^{7}	6.71×10^{7}	1.75×10^{8}	26.4	0.1	1.0 - 1.1

[a] Based on Table 43.
[b] Based on Table 36.
[c] 8.7% of total number entrained at the OCNGS.
[d] Number lost at the OCNGS estimated from the annual number entrained (Table 26) and the mortality of various-sized winter flounder larvae. Percent of larvae larger than 5 mm determined from data in Table 38.
[e] Based on Tables 40 and 41.

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During the several years that OCNGS has been operating and in the course of this study, several aspects of OCNGS and FRNGS operation have been identified which may cause adverse impacts on the aquatic populations, or individuals of Barnegat Bay. These range from shipworm population growth in Oyster Creek, to impingement mortality, and thermal shock mortalities in Oyster Creek.

In response, JCP&L has revised OCNGS design by installing new equipment, or adopted revised operational procedures, to minimize these effects. For example, revised OCNGS operating procedures for circulating water and dilution water pumps have been adopted. These have reduced the over-wintering population in Oyster Creek and moderated the rates of temperature change in Oyster Creek following OCNGS shutdown. As a consequence, thermal shock mortalities in Oyster Creek have been reduced substantially.

JCP&L has under consideration a variety of other alternatives to further reduce station effects. These include changes to both the cooling water systems, to reduce the effect of the stations' thermal discharges and plant entrainment, and the intake structures, to minimize the occurrence and mortalities of species impingement and entrainment.

The following chapter reviews the alternatives which have been investigated and which are presently being studied. Alternative systems for controlling thermal discharges, by limiting discharge temperature or volume or relocating the point of discharge, are considered first. The alternatives for OCNGS are based on an analysis performed by Ebasco Services, Inc. (Appendix E1). The FRNGS discharge flows of approximately 24,000 to 26,000 gpm (average conditions) appearing in this chapter and in the Alternate Cooling Water System Study (Appendix E1) were based on initial design estimates for this system. These values recently were revised during further development of system design to the 31,200 to 33,200 gpm (average summer and winter seasonal conditions, respectively), discussed in Chapter 1 and Appendix A3 to more accurately reflect currently projected operating conditions. However, as noted in Chapter 1, the latest design values are themselves subject to modification depending upon the results of an optimization study presently being performed. Although it is anticipated that the optimization study will not significantly affect the presently predicted discharge characteristics of this system, revision of the information used in from the Alternate Cooling Water System Study would be premature until the study and final system design are complete.

The principal effect of the increased blowdown rates would be to increase the heat rejected to the discharge canal and the temperature in the discharge canal after complete mixing. However, considering the relative volumes of the OCNGS and FRNGS discharges and the dilution pump flow, the temperature rise shown in Tables 5.1-2, 5.1-3, 5.1-4, 5.1-10 and 5.1-11 is not expected to increase by more than 0.1 to 0.2°C (0.18 to 0.36°F). Appropriate revisions to this report will be made upon finalization of system design and will be submitted to EPA and NJDEP as report amendments.

Alternative intake systems are reviewed next. Relatively little data are available at the time this report is submitted concerning the efficacy and operational feasibility of intake systems to reduce entrainment of larval organisms. Such systems are relatively new and have not been subject to substantial testing, either for source waters where the fouling potential is relatively high (i.e., Barnegat Bay-Forked River) or for sole-source intakes for a nuclear generating station,(i.e., the intakes for OCNGS and FRNGS). However, studies are now underway by JCP&L to determine the applicability of such alternatives to OCNGS and FRNGS, and JCP&L intends to submit the study results later as a supplement to this analysis.

The relative costs and benefits of the alternative systems reviewed are discussed here and in Section 6.2.

As discussed in earlier chapters, many perceived effects of OCNGS operation are subject to remedy or mitigation without substantial structural and system changes at OCNGS. JCP&L believes that the following chapters demonstrate that more substantial and more expensive changes possible for the discharge systems (e.g. cooling towers of various types) are not cost effective for JCP&L and its rate payers.

5.1 Discharge/Cooling System Alternatives

A variety of system alternatives are available for handling thermal discharges from steam electric generating stations. These include relocation of the point of discharge, cooling of the discharge by transfer of heat to the atmosphere, or some combination of both. For existing generating units, the reasonably available alternatives to retrofit may be fewer, and more expensive, because of the need to match cooling system alternatives to the operating specifications of the existing equipment.

For the OCNGS, JCP&L has examined the feasibility of all reasonably available alternatives, including several different types of closed-cycle cooling systems and ocean discharge. The design of FRNGS was based upon an extensive consideration of alternative cooling systems by the U.S. Atomic Energy Commission (now the Nuclear Regulatory Commission), and includes a natural draft, salt water cooling tower. Two alternatives to minimize or reduce the effects of that system are reviewed below.

5.1.1 Discharge/Cooling Systems for OCNGS

The Alternative Cooling Water System Study which evaluates various discharge/cooling system alternatives at the OCNGS was developed on the basis of studies conducted by two independent consultants.

The first study evaluated 16 possible alternative discharge/cooling systems considering engineering, environmental, economic and regulatory factors (Table 5.1-1). From these 16 possible alternatives four "preferred" systems were identified for further evaluation. These preferred systems included a natural draft cooling tower, fan-assisted natural draft cooling towers, round mechanical draft cooling towers and an artificial discharge canal to Barnegat Bay.

The environmental effects of the preferred cooling tower systems were found to be similar in most respects. The major differences noted were visual impact and noise. The natural draft tower would be the tallest of the preferred cooling towers and, therefore, have the greatest esthetic impact. However, the natural draft tower would require the acquisition of less additional land as a noise buffer to meet New Jersey noise standards than the round mechanical draft or fan-assisted natural draft towers. The noise impacts, esthetic impacts, and salt deposition effects caused by each of the tower systems would be adverse environmental effects not associated with the existing system.

Based solely on its study of engineering, licensing, and environmental factors, JCP&L concluded that the natural draft cooling tower system would be the optimum closed-cycle discharge/cooling alternate, if such a system were required at OCNGS. The capital cost of the natural draft tower system would be approximately $61 million.

However, before selecting any system, other factors must be considered in order to compare the total benefits to be derived from a system against the total costs of that system. Therefore, a second study was prepared which evaluated the total economic and environmental benefits and costs of the preferred discharge/cooling systems. This study, a socio-economic analysis, indicated that the total costs would exceed the total benefits by a substantial margin for each of the alternatives. The most likely total net levelized annual cost of the natural draft cooling tower system would be $20.4 million.

A discharge/cooling alternative which would be less costly than the cooling tower systems is the artificial canal to Barnegat Bay alternative. Should an alternative discharge system be required to mitigate the effects of the thermal discharge, the artificial canal-to-bay system could satisfy some of the criticisms which have been leveled at OCNGS and would be the most cost effective alternative. However, even this alternative would have a total net levelized annual cost of $9.1 million. The socio-economic analyses for the preferred discharge/cooling systems for OCNGS are described in detail in Appendix F1.

Appendix E1 contains a complete analysis of the 16 discharge/cooling systems evaluated.

<u>Canal-to-Bay System</u>

(a) Design

Figure 5.1-1 presents a conceptual design for the artificial discharge canal to Barnegat Bay alternative. The canal would be an open structure constructed with a seven in. thick, reinforced concrete base underlaid with an impervious flexible liner. The flexible liner, accounting for a high proportion of the cost of this alternative, would be necessary to prevent saltwater intrustion and to prevent extensive damage due to differential settling and water pressure buildup beneath the canal during operation and when the canal is dewatered.

The canal would be connected to the existing OCNGS cooling water discharge tunnel and would terminate at Barnegat Bay with a discharge drop structure. Since only condensor cooling water from OCNGS would be carried in the canal

(FRNGS blowdown would be discharged to Oyster Creek along with a required dilution water flow of approximately 520,000 gpm), a new channel and pumphouse would be constructed near Barnegat Bay to provide approximately 480,000 gpm of dilution water from Oyster Creek to the cooling water flow at the drop structure. The drop structure would act as a diffuser for the dilution water, mixing it with the condenser cooling water and creating some turbulence in the bay to help mixing. However, the structure would be designed to maintain a discharge velocity in the bay below one fps so that pleasure boating would not be disrupted. In addition, the drop structure would elevate the discharge so that fish are prevented from swimming up the canal.

The dilution flow in Oyster Creek provided by the existing OCNGS dilution pumps and FRNGS blowdown would aid in preventing the recirculation of heated water through the new dilution pumphouse when the tide is rising. This flow would also maintain acceptable water quality conditions in Oyster Creek.

Figure 5.1-2 shows typical flows for the existing dilution system, canal-to-bay discharge and new canal dilution system.

Construction time for this alternative is estimated to be 20 months. Connection with the existing system would take place during two plant refueling periods.

The design and construction schedule of the canal-to-bay alternative are discussed in detail in Appendix E1.

(b) Environmental Effects

(1) Atmospheric Effects

Use of the canal-to-bay system would not produce any significant atmospheric effects.

(2) Hydrothermal Effects

When the Alternative Cooling Water System Study was prepared, the analysis of hydrothermal effects was based on several assumptions. First, the assumption of 100 percent load factor for OCNGS and FRNGS was made. Second, the natural draft cooling tower (Appendix A3) was assumed to be the discharge/cooling alternative in operation at FRNGS. However, the use of any of the FRNGS cooling tower system alternatives with blowdown to Oyster Creek would have similar blowdown temperatures and flow rates.

The design configuration of the canal-to-bay alternative for the OCNGS will result in a different discharge location for the OCNGS discharge than for the discharge of the FRNGS. The FRNGS blowdown would be discharged to Oyster Creek while the OCNGS condenser discharge would be directed to Barnegat Bay through the discharge canal.

Tables 5.1-2 and 5.1-3 present the discharge flow rate from each station, the required dilution flow (existing dilution system), the magnitude of the total combined flow to Barnegat Bay and the resultant temperature rise at the canal outlet during average and extreme monthly conditions, respectively.

The temperature rise of the diluted FRNGS blowdown as measured at the U.S. Route 9 bridge would always satisfy thermal water quality criteria in Oyster Creek and no heat dissipation area would be required for this blowdown in Barnegat Bay. However, when OCNGS is not operating, the Oyster Creek Station's existing dilution pumps would still be required to operate in order for the combined flow to meet the thermal criteria in Oyster Creek.

The temperature rise in Oyster Creek as measured at the U.S. Route 9 bridge would be as predicted in Table 5.1-4 which assumes a FRNGS blowdown flow and the flow from two existing dilution pumps.

A heat dissipation zone would be required in Barnegat Bay to allow reduction from the temperature rise that would be associated with the new OCNGS discharge canal. The areal extent of the thermal plume in the bay would be similar to that of the existing system (Chapter 2) and would comply with the present water quality criteria for Barnegat Bay.

(3) Impacts on Water Resources

The construction of the canal-to-bay system would involve the excavation of land parallel to Oyster Creek on the east and west of U.S. Route 9 for a length of approximately 3.2 km (two miles). Suspended solids concentrations in Oyster Creek and Barnegat Bay could be increased significantly during excavation, dredging and dredge spoil disposal operations. However, these impacts can be minimized through the use of proper construction, soil erosion and sediment control practices.

The canal-to-bay alternative should have operational water quality characteristics in Barnegat Bay similar to the existing once-through cooling system. Chemical, biocide and sanitary wastes from OCNGS would be discharged to Oyster Creek after treatment. The dilution flow would mix with these effluents prior to entering the natural boundaries of Oyster Creek and Barnegat Bay.

(4) Noise Impact

The noise impact of each of the alternative cooling water systems was evaluated by considering the magnitude of the predicted noise and its source relative to the nearest residential areas. These predictions were compared with the New Jersey Noise Control Regulations (N.J.A.C. Chapter 20), which specify maximum allowable noise levels from industrial or commercial operations, measured at the nearest residential property line (Appendix E1). The most restrictive limit for continuous airborne sound is 50 dB(A).

The important sources of noise in the canal-to-bay cooling water system would be the drop structure and the dilution pump motors located near the mouth of Oyster Creek.

The estimated sound level produced by the fall of water in the drop structure would be 63 dB(A) at the nearest residential property line (Figure 5.1-3) approximately 183 m (600 ft) north of the structure. However, the level of noise reduction necessary to meet the 50 dB(A) limit could be achieved by raising the height of the embankment near the drop structure to3.4 m (11 ft) and extending a wall of the same height into the bay on the south side of the structure. These structural modifications would intercept the line of sight between the source of noise and potential receivers to the north and south creating an effective noise barrier. With these mitigating measures, the estimated sound level at the nearest residential property line would be reduced to 48 dB(A).

(5) Visual Impact

The canal-to-bay system would have an extremely low visual impact since there would be virtually no elevated structures associated with it. Observers on Barnegat Bay would see what would appear to be a long, low waterfall and a small pumphouse in the vicinity of the discharge drop structure.

(6) Aquatic Ecology Effects

As discussed in Section 3.1, an increase in the shipworm populations in Oyster Creek has been alleged to have resulted from OCNGS circulation, with an extended breeding season for one species permitted by the warmer temperatures in Oyster Creek produced by the OCNGS thermal discharge.

Assuming this to be true, relocation of the OCNGS discharge away from Oyster Creek may further reduce present shipworm populations. Population levels already have been reduced by the removal from Oyster Creek of wood capable of harboring a resident breeding population of shipworms. The addition of the thermal discharge from FRNGS would provide little further enhancement of shipworm breeding.

Barnegat Bay water temperatures with use of the canal-to-bay alternative would be similar to those of the present OCNGS system, where delta Ts across the circulating water system, range from 4 to 11°C (7.2 to 19.8°F) with a dilution flow from OCNGS of 0 to 520,000 gpm. Much of the area influenced by the new canal's discharge would be warmed enough to possibly extend shipworm breeding, but since little habitat exists in this area, no population growth as a consequence of the thermal discharge is likely.

The confluence of the canal with the bay would be nearer to Forked River than the Oyster Creek mouth. Since this difference in discharge location would cause a small increase in recirculation to Forked River, area G (Figure 5.1-4) which is adjacent to the Forked River could hypothetically incur conditions enhancing shipworm population increases. However, the potential change is not possible to quantify because of the small difference in delta Ts.

Changes in salinity, water volume and velocity, and dissolved oxygen and pH, due to the operation of the canal-to-bay alternative would not have a significant effect on shipworm viability and propagation in Oyster Creek, Barnegat Bay or the Forked River.

Cold shock effects resulting from the operation of the OCNGS with the canal-to-bay alternative would be essentially eliminated in Oyster Creek. Since no significant change in temperature is predicted in Forked River for operation of the canal-to-bay system, present biological functions would continue in the Forked River, with the canal-to-bay alternative.

A potential for cold shock in the lagoon system designated as G in Figure 5.1-4 would exist if the canal-to-bay alternative is chosen. The discharge location for the new canal would be closer to this lagoon system and consequently, slightly higher delta Ts would result at its mouth. Since this artificial body of water is a dead-end system and the only effective flushing potential is by tidal action, the lagoon water would tend to be warmer than the bay water. The result is water that would attract and hold fish such as Atlantic menhaden and bluefish past their expected migration time in the fall.

If permitted by NJDEP and the Corps of Engineers, a bulkhead along the north side of the plume from the canal would provide some direction for the plume. Directing the plume toward the southeast, toward Barnegat Inlet along with the natural bay circulation, could substantially minimize this recirculation potential. The feasibility of licensing such a structure has not yet been investigated.

Stress and mortality to organisms secondarily entrained in the OCNGS discharge also would be reduced due to lower residence time. With relocation of the discharge to the canal, organisms impinged at both OCNGS and FRNGS could be transferred to Oyster Creek and released in water at near ambient temperature.

Condenser entrainment for the canal-to-bay system would be the same as that for the existing system. Dilution pump entrainment would increase because of the additional pumps near the mouth of Oyster Creek. Passage through a second set of dilution pumps may cause some additional stress.

Impingement at the circulating water intake would be similar to present rates. Impingement would not be a factor at the dilution pumps at the mouth of Oyster Creek, since screens would not be required.

(7) Terrestrial Ecology Effects

A canal-to-bay system could potentially affect terrestrial and wetland communities through land clearing and the consequential removal of vegetation and wildlife habitat. The canal would traverse approximately 3.2 km (two mi) of farmland and displace approximately 15 acres of marsh habitat. Wetland maps prepared by the New Jersey Department of Environmental Protection classify most of this habitat lost as "Phragmites (common reed)/predominately open ground".

(c) Licensing Considerations

The permits required for construction of the canal-to-bay system are described in Appendix El. Approximate processing times and licensing fees are summarized in Table 5.1-5.

Construction of the canal-to-bay system would require removal of a small wetlands area near the shore of Barnegat Bay. Under CAFRA and the NJDEP's Wetlands Act, wetland areas are classified as environmentally sensitive and suitable for preservation.

Based upon available data, water quality regulations regarding thermal criteria would be satisfied in Barnegat Bay. Estimates of other water quality parameter concentrations in the discharge show that all values would be well below allowable limits.

The expected noise levels produced by the drop structure would exceed the New Jersey nighttime noise regulations unless mitigating measures were taken. However, the regulations could be met if the structural modifications described in the previous section on noise impacts were added to the canal-to-bay design.

(d) System Costs and Plant Performance

The total investment cost for the canal-to-bay alternative is estimated to be $34 million (excluding structural modification and property acquisition costs for noise attenuation). This includes a 1976 material and installation cost of $14.1 million, an escalation cost (based on system operation starting in 1984) of $7.4 million, and an indirect cost of $12.5 million (Table 5.1-6). The total comparable annual system cost for the canal alternative, including adjustment for differential net capability and net annual generation, is estimated to be $9.1 million. The components of this cost figure are shown in Table 5.1-7.

The canal-to-bay system would cause a loss in net annual generation of about 17,000 MWh/yr and a loss in station net capability at average summer conditions of 2.1 MW. By comparision, losses with use of any of the preferred cooling tower systems would be on the order of 100,000 MWh/yr and 21.3 MW for net annual generation and station net capability, respectively.

<u>Natural Draft Cooling Tower</u>

Should it be determined that a closed-cycle system is required at OCNGS, the counterflow natural draft cooling tower is the best alternative system. In determining the appropriate system, however, careful consideration should be given to the margin and value of benefits which a closed-cycle system affords, and the disadvantages and adverse effects consequent to both construction and operation. While a natural draft tower undoubtedly will to some extent reduce stress on the aquatic community, especially by reducing certain entrainment and impingement mortalities, it is expensive to construct and operate, is noisy and visually obtrusive, and will increase salt deposition rates in the surrounding area. Moreover, as discussed elsewhere in this report, there are less expensive alternatives to mitigate individual problems which the cooling tower appears to address. On the whole, JCP&L believes that a closed-cycle system is not cost effective for OCNGS.

(a) Design and Performance Parameters

All thermal design parameters for the natural draft tower were based on economic and engineering optimization studies with adjustment made where necessary to make the cooling tower system compatible with non-replaceable components of the existing system. However, back-fitting the existing system with any of the closed-cycle alternatives, including the Natural Draft Tower System, will require the replacement of several major plant components. An example of components that will have to be replaced should the natural draft tower be chosen for construction at OCNGS includes the circulating water conduit in the turbine generator building and plant yard. A new set of four vertical circulating water pumps also would have to be installed close to the tower base to overcome the cooling system's increased static head.

The design of the natural draft cooling tower has several advantages over the other closed-cycle discharge/cooling system alternatives considered. First, the natural draft tower has no moving parts. Thus, maintenance costs are lower and the system is more reliable. Second, due to the tower's height (approximately 165 m, 540 ft) low level fogging and icing effects are negligible. Also, salt deposition is less concentrated at ground level. Finally, recirculation of warm air is nearly impossible with the natural draft tower, and its winter performance is better than most other closed-cycle cooling tower systems.

A schematic drawing of the counterflow natural draft cooling tower is shown in Figure 5.1-5. Its flow diagram is depicted in Figure 5.1-6 and the layout of the system is shown in Figure 5.1-7. The optimum design parameters and approximate dimensions are as follows:

Design Approach to T_{wb} = 23.3°C (74°F)	7.8°C (14°F)
Cooling Range	11.8°C (21.2°F)
Circulating Water Flow	433,300 gpm
Circulating Water Temperature Entering/Leaving Cooling Tower	42.9°C/31.1°C 109.2°/88°F
Base Diameter/Height	131 m/165 m 430 ft/540 ft
Drift Rate	0.001

Condenser pressure, turbine generator output and plant net output at full load operation with a natural draft cooling tower system were calculated to be as follows:

Ambient Conditions	Condenser Pressure (in. HgA)	Turbine Generator (MW)	Net Plant Output (MW)
Maximum Meteorological	3.86	608.6	581.9
Design	3.61	613.7	587.0
Average Summer	3.02	625.8	599.1
Average Spring/Fall	2.03	648.1	621.4
Average Winter	1.52	655.2	628.5

There are, however, disadvantages to the closed cycle design of the natural draft cooling tower as compared to both the existing once-through system and the canal-to-bay alternative. A cooling tower system would be operated with significantly higher cooling water temperatures than the once-through systems, and would provide favorable conditions for biofouling. Therefore, increased chlorine usage may be required. Other agents such as sulfuric acid may have to be added to the circulating water in the cooling tower system to prevent scale formation due to a buildup of solids resulting from evaporation. Salt deposition would occur in the vicinity of the facility due to drift losses, possibly causing some damage to vegetation and neighboring buildings. Most aquatic species will experience 100 percent entrainment mortaility with a closed-cycle system, compared to lower entrainment mortalities with the present open-cycle system at OCNGS. Finally, the use of a closed-cycle design will significantly increase plant operating costs and cause a substantial plant derating due to higher unit back pressure.

The construction period for the natural draft cooling tower system would be 36 months. Six weeks would be required to connect a closed-cycle cooling system with the existing circulating water tunnels; but if construction were carefully phased, and carried out on schedule, this could be accomplished during OCNGS's annual shutdown for refueling. Should it not be possible to complete during the annual refueling, OCNGS would have to be shut down for approximately six weeks, and more expensive coal or oil generated power purchased as makeup. This would be particularily expensive for JCP&L's rate payers were it to occur during peak summer months.

(b) Environmental Effects

The environmental effects of the closed-cycle natual draft tower alternative were assessed assuming operation of both OCNGS and FRNGS. The operating characteristics of the FRNGS natural draft cooling tower were, therefore, used as the base case for this discussion.

(1) Atmospheric Effects

Table 5.1-8 presents the predicted annual frequencies of elevated plumes that would be associated with the operation of the natural draft tower at OCNGS. The analysis indicated that the plumes generally would be found at heights of 457 to 762 m (1500-2500 ft) above grade and, thus, ground level impacts are not anticipated.

Elevated visible plumes also would be created by the operation of the FRNGS tower. The plumes from OCNGS and FRNGS would remain separate during most of the year. Even if the wind direction were proper for plume merger, in most cases the downwind end of the plumes would disappear (evaporate) before merger of the plumes could occur.

No analysis was performed for tower-induced ground level fogging and icing due to the operation of a natural draft tower at OCNGS, since these phenomena are not associated with the operation of tall natural draft towers.

Use of salt water for evaporative makeup would result in some emission of particulate salts from the tower. Table 5.1-9 presents the maximum short-term, near-ground, airborne concentrations of salt that would result from operation.

The impact of salts released during the operation of a cooling tower can also be estimated in terms of the amount of salt deposited on a unit square area in a given time period. Estimates of the maximum amount of salt that would be deposited by a natural draft tower at OCNGS can be summarized as follows:

Ambient Conditions	Location (km in stated direction)	Deposition Rate (kg/km^2--month)
Annual	0.80 East-southeast	80
Summer	0.80 North	73

The significance of these deposition rates is discussed in the section on the terrestrial ecological effects of the Natural Draft Cooling Tower System.

Figures 5.1-8 and 5.1-9 indicate the spatial distribution of salt deposition rates (annual) and near-ground air salt concentrations (summer season) that would be associated with the operation of a natural draft tower at OCNGS.

(2) Hydrothermal Effects

Tables 5.1-10 and 5.1-11 present the predicted discharge flow rate under average and extreme conditions from both the OCNGS and FRNGS for each month. These tables indicate also the dilution flow required for the combined flow to meet the thermal criteria for temperature rise in Oyster Creek as measured at the U.S. Route 9 bridge and the magnitude of the total combined flow and its resultant temperature rise. Under average conditions, operation of only one dilution pump would be sufficient for the discharge to meet New Jersey thermal criteria at the U.S. Route 9 bridge in every month except January, during which two dilution pumps would be required. During extreme conditions, the thermal criteria could be met by operating only one dilution pump during May, September and October, and by operating two dilution pumps during the remaining nine months. It should be noted, however, that even with the operation of the natural draft tower at FRNGS and a natural draft tower at OCNGS, the New Jersey Surface Water Quality Standards' (N.J.A.C. 7:9-4 et. seq.) thermal criteria in Oyster Creek cannot be met without the operation during every month of the year of at least one dilution pump (260,000 gpm).

The temperature rise at the point of discharge into Barnegat Bay would be the same as the temperature rises presented in Tables 5.1-10 and 5.1-11. Because these temperature rises would satisfy the thermal criteria, no mixing zone in the bay would be required.

(3) Impacts on Water Resources

The construction of a natural draft cooling tower would involve the excavation of approximately five acres of land west of U.S. Route 9. The effects of such construction on the quality of water flowing through the Forked River-Oyster Creek system are expected to be minor.

Operational effects upon water quality associated with a natural draft cooling tower system at OCNGS can be divided into four categories: changes to intake water quality resulting from cooling system operation, effects due to biocide additions, effects due to corrosion inhibitors and effects due to plant wastewater discharges. None of these changes is expected to be significant, either in relation to ambient conditions or OCNGS's present operating characteristics.

The operation of this closed-cycle system would concentrate the natural salts and other dissolved solids in the circulating water flow due to evaporative losses. The increase in total dissolved solids (TDS) would be limited to a factor of 1.5 by regulation of blowdown (non-consumptive) flow. The resulting impact on water quality of Oyster Creek and Barnegat Bay is expected to be negligible for either one or two dilution pump operation.

The addition of sulfuric acid (H_2SO_4) may be required with the operation of the natural draft cooling tower alternative to control scaling. The projected use of 0.25 mg/l H_2SO_4 would increase the blowdown sulfate (SO_4) concentration above the makeup water SO_4 concentration by 20 mg/l. This increase would be negligible (1.1 percent) when compared to the average SO_4 concentration of 1820 mg/l found in the intake water.

Wastewater discharges from the OCNGS equipped with a natural draft cooling tower would be similar to those from the existing station; and although the average daily addition of chlorine would have to be increased to prevent biofouling during operation of the natural draft tower, the discharge of free available chlorine would be limited to the present rate of 0.2 mg/l (average) and 0.5 mg/l (maximum) in the station effluent. Neither free available nor total residual chlorine would be discharged for more than a total of two hours per condenser section in any one day.

(4) Noise Impact

The noise impact of this alternative cooling water system was evaluated using the same methodology employed for the canal-to-bay system.

The nearest residential area is located approximately 366 m (1200 ft) northeast of the design location for the natural draft cooling tower. The estimated unattenuated sound level produced by the tower at this residential boundary would be 54 dB(A). Reduction of noise by engineering solutions is not reasonably available although the natural draft tower could be operated in compliance with New Jersey noise regulations if JCP&L purchased a noise buffer zone extending approximately 396 m (1300 ft) beyond the existing site boundary in the north-northeast direction. This buffer zone would include about 30 acres of residentially zoned land for which private development presently is envisaged. Several residences already exist on portions of these 30 acres.

It should be noted that the costs of acquiring this land and the residences have not been factored into the cost projections discussed in this section, but are included in the cost/benefit analysis for the cooling tower, as discussed in Section 6.2.

An additional parcel of land west of U.S. Route 9 is presently being held for residential development by a commerical development firm. However, since the land is not now zoned for residential construction, and licensing for eventual construction not certain, noise impact on this area has not been considered here.

(5) Visual Impact

Although the hyperbolic shaped natural draft cooling tower would be graceful in form, it was considered to be the most physically intrusive of the preferred alternatives due to its dominating size. The tower structure, which would be approximately 165 m (540 ft) in height and have a base diameter of 131 m (430 ft), would dwarf all existing station elements. A photographic analysis of the natural draft tower structure is presented in Appendix E1.

(6) Aquatic Ecology Effects

Both the positive and negative effects of a closed-cycle cooling system on the aquatic population of the Oyster Creek-Barnegat Bay area were evaluated. Specific effects considered included shipworm growth in Oyster Creek, heat and cold shock mortalities, impingement mortalities and stresses, and entrainment mortalities.

Life histories, environmental requirements, and the present impact of OCNGS discharges are discussed for several species of shipworm (Teredo spp) in Section 3.1. This information combined with the operational characteristics of the natural draft cooling tower system was used to predict the tower's effect on shipworms in the vicinity of OCNGS. Temperature, salinity, and habitat availability were considered to be the major environmental parameters which control shipworm viability and propagation.

Installation of closed-cycle cooling would most likely reduce the number of days during which shipworms in Oyster Creek are capable of breeding. Under extreme conditions, the temperature rise above ambient (delta T) in Oyster Creek resulting from OCNGS and FRNGS blowdown and the operation of two dilution pumps would range from 1.4 to 3.5°C (2.5 to 6.3°F). This would, in theory, extend the shipworm's natural breeding season over that which would be available without any thermal discharge, by about ten days. As a practical matter, it is unlikely that more than three days (which represent a 2.0 percent increase) would be added to their optimum breeding season. This would, however, represent a reduction in the breeding season which in theory is currently possible with shipworms inhabiting Oyster Creek.

The consideration of a breeding season is meaningful only if the other control conditions -- salinity and habitat (untreated wood) -- are sufficient to sustain breeding. Salinity will not change and, therefore, is not a factor for consideration. Considering the fact that nearly all wood capable of supporting a resident breeding population of shipworms has been removed from Oyster Creek, very little or no change in shipworm populations would be expected in Oyster Creek or Barnegat Bay consequent to a reduction in the thermal discharge by installation of closed-cycle cooling.

Several fish kills have occurred at the OCNGS due to planned or unplanned station shutdowns and the resultant change in water temperatures that have resulted from these shutdowns. Such cold shock effects should be greatly reduced with the operation of the Natural Draft Tower System. Two dilution pump operation will reduce fall temperatures in Oyster Creek and reduce the potential for attracting overwintering fish.

The incremental value of such a change is difficult to assess, however. Relatively recent changes in operation of OCNGS's dilution pumps have reduced markedly mortalities consequent to winter shutdown (Section 3.2.4). Additionally, operation of FRNGS will provide some temperature stability during OCGNS shutdown, which should reduce mortalities even further.

Using measured entrainment rates and the highest rates of circulating water flow for existing OCNGS operation, a prediction of entrainment for the natural draft tower was made assuming a linear relationship between entrainment and water flow. A sizeable reduction in entrainment would, of course, result with the operation of the Natural Draft Cooling Tower System due to reduced cooling water intake flows. Entrainment rates and mortalities are presented by month for selected important species in Exhibit 175 of Appendix E1. Operation of the cooling tower would result in decreased mortalities in some species, but increased mortalities in others.

Predicted impingement rates for the operation of the natural draft tower were based on impingement data taken during 1975 and 1976, and from impingement field data from 15 other generating stations located along the eastern seaboard of the United States.

Assuming a linear relationship between flow and impingement, the results indicated that the average maximum fish impingement rates would decrease by about 95 percent with the operation of the Natural Draft Cooling Tower System, correlating to a 95 percent reduction in intake flow. Macroinvertebrate impingement rates, however, may not decrease as much as those for fish, since most of these organisms cannot avoid the intake area.

The significance of reduced impingement rates may not be great, however, because of the relatively low mortality rate experienced by most species, and the further reduction in mortality and stress which will result from the recent modification of intake screen No. 1 according to the Ristroph design (Appendix A2). A further reduction in both entrainment and impingement rates and mortalities may be possible with alternative intake technology without resort to closed-cycle cooling (Section 5.2.1).

(7) Terrestrial and Avian Ecology Effects

The major terrestrial ecological impacts resulting from a Natural Draft Cooling Tower System at the OCNGS would be salt deposition effects and bird hazard effects. Neither of these effects occur with the existing system.

Short-term and long-term salt deposition rates and airborne concentrations predicted for operation of a natural draft cooling tower at OCNGS would be lower than postulated injury thresholds for vegetation available in the literature (Exhibit 153 of Appendix E1). However, these thresholds apply to natural vegetation, presumably adapted to a coastal environment, and may not be directly applicable to landscape or garden plants.

As discussed in Section 6.2, salt deposition from an OCNGS tower would have an adverse effect on building materials, causing more rapid deterioration and requiring more frequent maintenance.

The natural draft tower would be 165 m (540 ft) tall and extend into airspace utilized by migrating birds. While this problem cannot be eliminated, selection of an appropriate lighting system should minimize levels of bird mortality.

The construction and operation of the natural draft cooling tower system would preempt approximately five acres of land adjacent to the existing facility.

(c) Licensing Considerations

The permits required for construction of the Natural Draft Cooling Tower System are described in Appendix El. Approximate processing times and licensing fees are summarized in Table 5.1-5. This alternative could be constructed without violation or amendment of any land use or water quality regulations.

Noise emissions from the natural draft cooling tower would exceed the New Jersey regulations during nighttime hours (Appendix El). The noise regulations could be met by enlarging the buffer zone surrounding the tower until the noise level at the boundary drops below the nighttime limit of 50 dB(A). For the natural draft cooling tower, approximately 30 acres of residentially zoned land would have to be acquired adjacent to the site to achieve compliance with noise regulations. Approximately 15 residential units or improved lots are located on these 30 acres. In addition, a parcel of land west of U.S. Route 9 and adjacent to the OCNGS site is owned by a commerical development firm which has plans to develop it as a residential community. If development plans were to proceed, a portion of this property would be subject to noise from the cooling tower in excess of the New Jersey standards.

Particulate emissions from the natural draft cooling tower would exceed the New Jersey air emission standards. The emission rate calculated for the natural draft tower is approximately 45.8 kg/hr (101 lb/hr); the maximum allowable emission rate is 13.6 kg/hr (30 lb/hr). The New Jersey primary and secondary ambient air quality standards would not be exceeded.

(d) System Costs and Plant Performance

The total estimated investment cost for the natural draft cooling tower system is $61 million (excluding property acquisition costs). This includes a 1976 material and installation cost of $27.3 million, an escalation cost (based on system operation starting in 1984) of $12.2 million, and an indirect cost of $21.5 million (Table 5.1-6). The total comparable annual system cost for the natural draft tower alternative, including adjustment for differential net capability and net annual generation, was estimated to be $20.4 million. The components of this cost figure are shown in Table 5.1-7.

The performance of the existing once-through cooling water system was used as a base for the above annual cost adjustments. The operation of the natural draft tower system would cause a loss in net annual generation on the order of about 100,000 MWh/yr and a loss in plant net capability at average summer conditions of 21.3 MW.

5.1.2 Discharge/Cooling Systems for FRNGS

Relatively few alternatives are available to mitigate the FRNGS discharge effects. The station design includes a natural draft cooling tower (see Section 1.3 and Appendix A3), which is designed for "best available technology" (BAT) with its cold-side blowdown in accordance with 40 C.F.R. Part 423.

A range of alternative discharge/cooling systems were considered during the early planning and development stage of the FRNGS (Appendix E2). These alternatives included various closed-cycle systems plus a "once-through" Canal Intake/Ocean Discharge Cooling System (alone and in combination with OCNGS).

Given the same circulating water flow, which is dictated essentially by plant design (the required thermal output, heat load, turbine design, pumping rate, etc.), the discharge characteristics of the alternative closed-cycle systems would be approximately the same with respect to blowdown temperature and water quality characteristics. For the purpose of this analysis, therefore, the closed-cycle alternatives considered during the planning and development stage of FRNGS are not material.

The canal intake/ocean discharge system alternative would remove the FRNGS discharge from the OCNGS discharge canal and Oyster Creek. However, this system was rejected due to investment and operating cost, practical constructability, and environmental impact and licensing constraints.

Two alternatives are currently considered feasible for the FRNGS: the natural draft tower with a small helper cooling tower for the main blowdown line; and the natural draft tower with a blowdown line to Barnegat Bay. The remainder of this section describes these systems. Appendix E2 discusses all of the discharge/cooling system alternatives studied to date for the FRNGS.

<u>Natural Draft Tower with a Small Helper Tower</u>

Mechanical draft helper towers are sized to cool the blowdown flow from the main cooling tower on the coldest day of the year. Such towers normally have several sectionalized cells each with its own fan. This design, in combination with multiple-speed, reversible fans, provides a reasonable amount of operational fexibility within meterological limits. Tower operation is normally varied in steps in an attempt to match cooling tower discharge with ambient receiving water temperatures.

The major disadvantage inherent in small helper towers is marginal reliability during winter operation. Because helper towers have a much lower normal flow and heat duty than their main cooling system, icing is common during severe weather conditions. Although reversing the fans or diverting a greater proportion of the normal flow to the outboard distribution trough can help reduce freezing, helper towers normally must be shut down at least part of the winter in this climatological region. Since maximum delta Ts normally occur during the winter, this could result in the helper tower being inoperable during that period when its operation is most desirable.

A conceptual drawing of the layout of the helper tower system is shown in Figure 5.1-10. The main advantage resulting from the addition of a small rectangular helper tower to the main blowdown line of the FRNGS natural draft cooling tower would be a marginal reduction in the heat released from the station to the OCNGS discharge canal. During normal and emergency shutdown of the FRNGS, the helper tower would serve to cool the nuclear services cooling water which would bypass the natural draft cooling tower as discussed in Appendix A3. However, due to the small blowdown flow from FRNGS (in comparison with the total combined flow from dilution pump operation and the OCNGS discharge), the reduction in delta Ts resulting from the operation of a helper tower as measured at the U.S. Route 9 bridge during normal operation or shutdown would be slight.

The construction of a mechanical helper tower near the other facilities at the FRNGS would have a minimal environmental impact on the area.

The operation of a helper tower with the natural draft cooling tower at FRNGS would have a negligible environmental effect in comparison to the operation of the natural draft tower alone. Because of its small size and rather remote location, the mechanical draft tower would have only minimal atmospheric effects. Near field salt deposition rates will be increased. Other than a small reduction in the hydrothermal effect of the FRNGS blowdown in the OCNGS discharge canal during certain periods of the year, the helper tower would have a negligible effect on water quality characteristics in the discharge canal or Oyster Creek. Similarly, the noise, esthetic, and terrestrial and avian ecology effects due to the operation of the mechanical draft helper tower would be nearly the same as those for the operation of the natural draft tower alone. Due to the slight reduction in the heat released from the FRNGS with the operation of the helper tower, there would be a marginal reduction in the aquatic ecological effect of the station's effluent in the discharge canal. This reduction in heat would have a negligible effect on the diluted flow from OCNGS and FRNGS by the time it reaches Oyster Creek, and therefore, the reduction in aquatic ecological impact in Oyster Creek would be minimal.

The discharge/cooling system alternatives described in this section (and Appendix E2) were evaluated on the basis of total comparative annual system costs. Using this method, the most cost-effective system over the life of the plant can be selected. However, because the various cooling system alternatives for the FRNGS have been studied over a period of eight years (beginning in 1971), the costs were normalized to the recent alternative system costs developed in the Alterntive Cooling Water System Study for the OCNGS (Appendix E1). The costs presented in this analysis are minimum cost figures since the difference in thermal output between the stations (1930 thermal megawatts for OCNGS and 3410 thermal megawatts for FRNGS) has not been factored into the alternative systems' current dollar costs.

The total comparative annual system cost resulting from the addition of a mechanical draft helper tower to the main blowdown line of the FRNGS natural draft cooling tower would be at least $1.2 million. This cost includes the following levelized expenses: annual ownership expense, operating expense, maintenance expense, and annual cost ajustments for differential station net output and net annual generation.

Due to the marginal environmental benefits to be derived from this system, the operational problems that could occur during severe weather conditions, and the additional costs this system would impose on the average residential customer, JCP&L does not consider the mechanical draft helper tower to be a cost effective alternative for the FRNGS.

Natural Draft Tower with Blowdown to Barnegat Bay

The FRNGS natural draft tower with discharge to Barnegat Bay would involve the construction of a large diameter concrete pipeline approximately 4.8 km (three mi) long to accommodate the required blowdown flow (32,200 gpm) from the FRNGS. A lift station on the east side of U.S. Route 9 and a concrete drop structure on the west shore of Barnegat Bay also would be required. The blowdown pipe would cross the OCNGS land on the periphery of its facilities, pass under U.S. Route 9 and cross about 2743 m (9000) ft of previous pasture land and a wetlands area near the Barnegat Bay Shore. A conceptual layout of this system is presented in Figure 5.1-11.

The major advantage to be derived from installing a pipeline to carry the FRNGS blowdown flow to Barnegat Bay would be a reduction in the heat load transferred to the discharge canal and consequently to Oyster Creek. However, as previously noted, when the OCNGS and its dilution pumps are operating, the FRNGS blowdown flow is only a minor component of the total combined flow. Therefore, the diversion of this flow from Oyster Creek would be significant only when OCNGS is not operating. In this situation, dilution pumping would no longer be necessary to meet the thermal criteria in Oyster Creek.

Under normal operating conditions (FRNGS and OCNGS in operation), the total blowdown flow from the FRNGS cooling tower would be diverted to Barnegat Bay via the pipeline. In contrast to the previous alternative, however, there would be no reduction in the total combined heat duty ultimately transferred to Barnegat Bay. In addition, the existing OCNGS dilution pumps would still be required for the OCNGS discharge.

Several problems would be likely during the construction and operation of this system. Since a portion of the construction would be performed below mean sea level (in order to cross under the road and railway), dewatering would be required. A drain line also would be necessary for maintenance. In addition, fouling of the concrete pipe with marine growths during operation could present a major maintenace problem. Finally, it is possible that some dredging would be required in the bay in order to maintain the required low discharge velocities from the drop structure.

The construction of a blowdown pipeline from the natural draft tower at FRNGS to the west shore of Barnegat Bay could have a significant environmental impact. From the tower basin to Barnegat Bay, the pipeline would occupy 25 to 30 acres during construction. Included in this land is a wetlands area which is potentially valuable as a wildlife and waterfowl habitat. In addition, suspended solids concentrations in Oyster Creek and Barnegat Bay could be increased significantly during excavation dredging and dredge spoil disposal operations.

The environmental impact resulting from the operation of a natural draft tower at FRNGS with a blowdown line to the bay would be essentially the same as the impact of the tower alone. There would be little or no change in the atmospheric, water quality, noise, visual, and terrestrial and avian ecological effects due to the operation of this system. Because the blowdown from the FRNGS would be released directly to the bay, the system would have no hydrothermal effect on the discharge canal or Oyster Creek.

However, a heat dissipation zone could be required in Barnegat Bay for the FRNGS discharge. The result is that a slight reduction in the thermal impact on organisms inhabiting the discharge canal and Oyster Creek would occur; and, theoretically, the thermal impact of the new discharge on Barnegat Bay would not be significant because the heated water would be dissipated more quickly due to the discharge structure and normal wave action in the bay. However, the overall aquatic ecological benefits of this system are expected to be minimal. On the other hand, the potential benefit of the mitigation of cold-shock mortalities by FRNGS discharge in the discharge canal when OCNGS shuts down during the winter would be lost by rerouting the discharge. In addition, if maintenance dredging were required to maintain low discharge velocities in the bay, aquatic populations would be impacted by an additional stress which would most likely not be necessary with the operation of the natural draft cooling tower alone.

The total comparative annual system cost resulting from the addition of a blowdown pipe to the FRNGS natural draft cooling tower would be at least $2.1 million. This cost figure includes all of the levelized expenses previously discussed.

Considering the fact that this alternative provides no significant hydrothermal benefit over the use of the natural draft tower alone, and, in fact, would have a significant detrimental effect on the terrestrial ecology and water quality in the area during construction and maintenance operations, the overall environmental impact of this alternative could be negative. Weighing this fact against the cost of the pipeline sytem indicates that this alternative is not cost effective for the FRNGS.

Summary

Due to the marginal environmental benefits that would result from the addition of a pipeline or helper tower to the natural draft cooling tower at the FRNGS, and, considering the fact that the natural draft tower design already is BAT for the station, neither of the alternatives discussed above are considered to be cost effective.

TABLE 5.1-1

SUMMARY OF PREFERRED AND RECOMMENDED SYSTEM SELECTION PROCESS

	Differential Comparable Annual Cost (million dollars)	Differential Plant Net Output[1] (MW)	Elimination Rationale Alternative Systems[2]	Elimination Rationale for Preferred Systems
Discharge Canal to the Bay	8.6	-1.6	Preferred	Insufficient Mitigation of Aquatic Impact
Discharge Pipelines to the Bay	10.9	-3.9	NCA	
Helper Cooling Towers with Minimum 50° F Cold Water Temperature	16.1	-11.5	OEI-Fogging/ Icing, Salt Deposition	
Natural Draft Cooling Tower (CT)	19.9	-21.3	Preferred	Recommended
Round Mechanical Draft CT	20.3	-20.4	Preferred	Exceeding of Noise Criteria
Fan-Assisted Natural Draft CT	20.8	-23.3	Preferred	Lack of Operating Experience and Noise Control Experience
Rectangular Mechanical Draft CT	21.2	-20.7	OEI-Fogging/ Icing, Salt Deposition	
Helper CT with Minimum 43.8° F Cold Water Temperature	22.3	-15.1	OEI-Fogging/ Icing, Salt Deposition	
Spray Cooling Module Canal	21.3	-21.4	OEI-Fogging/ Icing, Salt Deposition	
500 Acre Cooling Pond	28.2	-19.9	OEI-Fogging/ Icing, Terrestrial and Aquatic Ecology	
Wet/Dry Salt Water CT	32.5	-29.8	OEI-Salt Deposition	
Ocean Intake and Discharge with Multipressure Condenser	36.9	-13.3	NCA	
Wet/Dry Fresh Water CT	39.8	-36.6	SCR	
1000 Acre Cooling Pond	40.5	-6.4	OEI-Fogging/ Icing, Terrestrial and Aquatic Ecology	
Dry Cooling Tower	44.0	-50.3	SCR	
Ocean Intake and Discharge with Existing Condenser	102.2	+3.8	NCA	

(1) Computed as (Existing System Net Output - Alternative System Net Output) for Average Summer Conditions

(2) NCA: No Compensating Advantage Rationale
OEI: Overriding Environmental Impact Rationale
SCR: Significant Commercial Risk Rationale

TABLE 5.1-2

DISCHARGE PARAMETERS UNDER AVERAGE CONDITIONS

CANAL-TO-BAY SYSTEM

Month	Oyster Creek NGS Discharge Flow Into Canal GPM	Forked River NGS Discharge Flow Into Oyster Creek GPM	Required* Dilution Flow Into Oyster Creek GPM	Combined Flow To Barnegat Bay From Canal & Oyster Creek GPM	Combined Initial Temperature Rise To Barnegat Bay From Canal Deg F
January	460,000	26,400	520,000	1,006,400	9.8
February	460,000	26,200	520,000	1,006,200	9.7
March	460,000	25,600	520,000	1,005,600	9.6
April	460,000	25,000	520,000	1,005,000	9.4
May	460,000	24,600	520,000	1,004,600	9.2
June	460,000	24,100	520,000	1,004,100	9.2
July	460,000	23,800	520,000	1,003,800	9.2
August	460,000	23,800	520,000	1,003,800	9.2
September	460,000	24,200	520,000	1,004,200	9.3
October	460,000	24,700	520,000	1,004,700	9.4
November	460,000	25,100	520,000	1,005,100	9.6
December	460,000	26,200	520,000	1,006,200	9.7

*System Requires 520,000 GPM at All Times

TABLE 5.1-3

DISCHARGE PARAMETERS UNDER EXTREME CONDITIONS

CANAL-TO-BAY SYSTEM

Month	Oyster Creek NGS Discharge Flow Into Canal GPM	Forked River NGS Discharge Flow Into Oyster Creek GPM	Required* Dilution Flow Into Oyster Creek GPM	Combined Flow To Barnegat Bay From Canal & Oyster Creek GPM	Combined Initial Temperature Rise To Barnegat Bay From Canal Deg. F
January	460,000	24,400	520,000	1,004,400	10.2
February	460,000	24,300	520,000	1,004,300	10.1
March	460,000	24,200	520,000	1,004,200	9.9
April	460,000	23,800	520,000	1,003,800	9.7
May	460,000	23,100	520,000	1,003,100	9.6
June	460,000	22,100	520,000	1,002,100	9.5
July	460,000	22,100	520,000	1,002,100	9.4
August	460,000	22,100	520,000	1,002,100	9.4
September	460,000	22,300	520,000	1,002,300	9.6
October	460,000	23,500	520,000	1,003,500	9.7
November	460,000	23,800	520,000	1,003,800	9.9
December	460,000	24,400	520,000	1,004,400	10.1

*System Requires 520,000 GPM at All Times

TABLE 5.1-4

CANAL-TO-BAY ALTERNATIVE

TEMPERATURE RISE IN OYSTER CREEK FROM

FORKED RIVER NUCLEAR GENERATING STATION DISCHARGE AND TWO DILUTION PUMP FLOW

Month	Extreme Conditions	Average Conditions
January	2.4	1.8
February	2.2	1.5
March	1.9	1.3
April	1.5	0.9
May	1.2	0.7
June	1.1	0.5
July	0.9	0.5
August	1.0	0.5
September	1.2	0.7
October	1.5	1.0
November	1.9	1.3
December	2.2	1.5

TABLE 5.1-5
JERSEY CENTRAL POWER & LIGHT COMPANY
OYSTER CREEK NUCLEAR GENERATING STATION
TIME AND FEE REQUIREMENTS TO OBTAIN NECESSARY PERMITS FOR ALTERNATE DISCHARGE/COOLING SYSTEMS

	PREFERRED COOLING TOWER SYSTEMS		CANAL-TO-BAY SYSTEM	
ACTIVITY	TIME (MONTHS)(4)	FEES ($)	TIME (MONTHS)(4)	FEES ($)
NRC-EIS Process	24	N. A.	24	N. A.
NPDES Permit	6	N. A.	6	$100.
Section 401 Certification	6	N. A.	6	N. A.
Corps of Engrs Sect 404 Permit	N.A.(1)	N. A.	3-6(2)	$100.
Corps of Engrs Sect 10 Permit	N.A.	N. A.	3-6(2)	$100.
N J CAFRA Permit	4	N. A.	4	
Riparian Permit	N.A.	N. A.	3-4(3)	N. A.
Wetlands Permit	N.A.	N. A.	3-4(3)	N. A.
Stream Encroachment Permit	N.A.	N. A.	3-4(3)	N. A.
Soil Erosion & Sediment Control Certification	1	Fees set by Soil Conservation District based on cost	1	Fees set by Soil Conservation District based on cost
N J Wastewater Permit	6	N. A.	6	N. A.

Notes:

(1) Not Applicable

(2) Conditional until all state and other federal permits and certifications are issued.

(3) Conditional until N J CAFRA permit is issued.

(4) Statutory times; contingency time not included.

TABLE 5.1-6
OYSTER CREEK NUCLEAR GENERATING STATION
ALTERNATIVE DISCHARGE/COOLING SYSTEM STUDY
TOTAL ESTIMATED INVESTMENT COST
(MILLIONS OF DOLLARS)

SYSTEM	DIRECT[1]	INDIRECT[2]	ESCALATION	TOTAL[3]
DISCHARGE CANAL TO BAY	14.1	12.5	7.4	34
DISCHARGE PIPES TO BAY	22.0	17.8	12.2	52
HELPER COOLING TOWERS (3)	22.0	17.3	9.8	49
HELPER COOLING TOWERS (5)	30.8	24.4	13.8	69
OCEAN INTAKE & DISCHARGE	200.0	189.2	45.0	434
OCEAN INTAKE & DISCHARGE (MULTI PRESSURE CONDENSER)	60.0	58.1	25.9	144
MECH. DRAFT RECTANG. COOLING TOWERS	27.3	21.9	12.4	62
MECH. DRAFT ROUND COOLING TOWERS	24.9	19.9	11.2	56
NATURAL DRAFT COOLING TOWERS	26.7	21.7	12.2	61
FAN ASSISTED COOLING TOWERS	25.6	20.5	11.5	58
WET/DRY SALT WATER COOLING TOWERS	41.6	35.1	19.1	96
WET/DRY FRESH WATER COOLING TOWERS	44.2	37.4	20.3	102
DRY COOLING TOWERS	50.9	42.4	23.6	117
SPRAY MODULES	28.8	23.7	16.8	69
1000 ACRE POND	74.2	63.1	36.0	173
500 ACRE POND	45.2	38.2	21.7	105

[1]DIRECT 1976 MATERIAL AND INSTALLATION COST
[2]INDIRECT CONSTRUCTION COST, UTILITIES EXPENSES, INTEREST DURING CONSTRUCTION, LAND COST AND CONTINGENCY
[3]NUMBERS MAY NOT TOTAL DUE TO ROUNDING

*THE COSTS PRESENTED IN THIS TABLE HAVE BEEN UPDATED SINCE THE PREPARATION OF APPENDIX E1.

TABLE 5.1-7
OYSTER CREEK NUCLEAR GENERATING STATION
ALTERNATIVE DISCHARGE/COOLING SYSTEM STUDY
COMPARABLE ANNUAL SYSTEM COSTS
(MILLIONS OF DOLLARS)

SYSTEM	FIXED[1]	WATER & MAINTENANCE[2]	GENERATING[3] PENALTY	CAPABILITY[4] PENALTY	TOTAL[5]
DISCHARGE CANAL TO BAY	7.5	0.6	0.9	0.1	9
DISCHARGE PIPES TO BAY	11.6	0.8	(-)1.1	0.0	11
HELPER COOLING TOWERS (3)	10.9	0.8	4.4	0.5	17
HELPER COOLING TOWERS (5)	15.3	1.1	5.6	0.7	23
OCEAN INTAKE & DISCHARGE	96.6	4.9	1.2	0.0	103
OCEAN INTAKE & DISCHARGE (MULTI PRESSURE CONDENSER)	32.0	1.8	3.0	0.5	140
MECH. DRAFT RECTANG. COOLING TOWERS	13.7	1.1	6.0	1.0	22
MECH. DRAFT ROUND COOLING TOWERS	12.4	1.1	6.3	1.0	21
NATURAL DRAFT COOLING TOWERS	13.5	0.9	5.1	0.9	20
FAN ASSISTED COOLING TOWERS	12.8	1.1	6.3	1.1	21
WET/DRY SALT WATER COOLING TOWERS	21.3	1.3	8.5	1.8	33
WET/DRY FRESH WATER COOLING TOWERS	22.7	2.1	12.3	3.2	40
DRY COOLING TOWERS	26.0	1.4	14.0	3.1	45
SPRAY MODULES	15.4	1.4	4.2	0.9	22
1000 ACRE POND	38.6	2.0	0.2	0.3	41
500 ACRE POND	23.4	1.3	3.2	0.8	29

[1] LEVELIZED ANNUAL FIXED CHARGES ON INVESTMENT COST

[2] WATER & MAINTENANCE TREATMENT COST

[3] ADJUSTMENT FOR DIFFERENTIAL NET ANNUAL GENERATION

[4] ADJUSTMENT FOR DIFFERENTIAL NET PLANT CAPABILITY

[5] NUMBERS MAY NOT TOTAL DUE TO ROUNDING

*THE COSTS PRESENTED IN THIS TABLE HAVE BEEN UPDATED SINCE THE PREPARATION OF APPENDIX E1.

TABLE 5.1-8

ANNUAL FREQUENCY OF ELEVATED PLUMES FROM NATURAL DRAFT TOWER
OYSTER CREEK NUCLEAR GENERATING STATION

Plume Lengths (ft)	Hours per Year for Given Direction from Towers															
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
0 - 500	207	89	83	156	218	250	102	97	92	55	53	48	53	39	52	98
500 - 1,000	204	109	104	123	247	268	187	147	85	70	57	72	63	54	21	85
1,000 - 1,500	131	89	83	97	142	128	86	84	100	62	51	48	53	50	24	61
1,500 - 2,000	62	62	37	55	70	72	35	44	61	57	35	37	41	43	20	38
2,000 - 2,500	31	33	37	38	48	45	20	21	27	26	25	26	36	14	13	20
2,500 - 3,000	18	12	17	19	23	11	14	13	9	17	16	11	8	8	5	12
3,000 - 3,500	3	7	7	2	12	9	9	11	6	5	11	18	2	5	0	8
3,500 - 4,000	18	1	4	7	7	8	4	7	1	6	5	2	3	6	3	11
4,000 - 4,500	13	2	0	4	5	1	1	7	2	1	3	3	7	6	4	1
4,500 - 5,000	9	5	3	2	7	2	3	1	2	2	1	1	5	10	1	4
5,000 - 5,500	5	4	4	3	4	0	1	2	1	1	1	6	3	2	1	3
5,500 - 6,000	5	5	2	3	2	1	0	3	3	1	2	1	1	6	1	1
6,000 - 6,500	3	2	4	1	3	1	0	2	3	1	1	2	2	2	0	5
6,500 - 7,000	1	1	1	0	0	1	0	1	0	0	0	0	0	0	3	1
7,000 - 7,500	1	0	0	2	1	0	0	2	0	0	0	1	0	0	2	0
7,500 - 8,000	2	0	0	1	1	0	0	0	0	1	0	0	0	2	0	1
8,000 - 8,500	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	1
8,500 - 9,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9,000 - 9,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9,500 - 10,000	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
10,000 - 10,500	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
10,500 - 11,000	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
11,000 - 11,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11,500 - 12,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12,000 - 12,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12,500 - 13,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13,000 - 13,500	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
13,500 - 14,000	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 5.1-9
PREDICTED MAXIMUM PEAK SHORT-TERM NEAR GROUND AIRBORNE CONCENTRATION (ug/m^3) OF SALT RESULTING FROM OPERATION OF ONE NATURAL DRAFT COOLING TOWER AT THE OYSTER CREEK NUCLEAR GENERATING STATION

Month	Hours of Persistance	Direction[a]	Distance (miles)	Near Ground Airborne Concentration (ug/m^3)
January	10	W	0.16	6.6
February	5	SW	0.16	3.6
March	5	E	0.16	5.5
April	5	NNW	0.16	3.1
May	7	WSW	0.16	6.6
June	12	ENE	0.16	1.6
July	14	ENE	0.16	1.4
August	5	S	2.5	0.9
September	5	ENE	0.16	1.5
October	5	ESE	0.16	2.3
November	7	WSW	0.16	5.3
December	6	SE	0.16	4.3

(a) Indicates direction where salt is deposited - winds come from opposite direction

Source: Pickard, Lowe and Garrick, Inc., October 1977.

TABLE 5.1-10
DISCHARGE PARAMETERS UNDER AVERAGE CONDITIONS
NATURAL DRAFT TOWER

Month	Oyster Creek NGS Discharge Flow GPM	Forked River NGS Discharge Flow GPM	Required* Dilution Flow GPM	Combined Flow to Oyster Creek GPM	Combined Temperature Rise in Oyster Creek Deg F
January	16,000	26,400	520,000	562,400	2.3
February	16,000	26,200	260,000	302,200	3.7
March	15,900	25,600	260,000	301,500	3.0
April	15,400	25,000	260,000	300,400	2.1
May	14,800	24,600	260,000	299,400	1.5
June	14,500	24,100	260,000	298,600	1.1
July	14,400	23,800	260,000	298,200	1.1
August	14,400	23,800	260,000	298,200	1.1
September	14,600	24,200	260,000	298,800	1.6
October	15,000	24,700	260,000	299,700	2.3
November	15,500	25,100	260,000	300,600	3.2
December	16,000	26,200	260,000	302,200	3.7

*Based on number of dilution pumps required to Meet Thermal Criteria in Oyster Creek

TABLE 5.1-11
DISCHARGE PARAMETERS UNDER EXTREME CONDITIONS
NATURAL DRAFT TOWER

Month	Oyster Creek NGS Discharge Flow GPM	Forked River NGS Discharge Flow GPM	Required* Dilution Flow GPM	Combined Flow to Oyster Creek GPM	Combined Temperature Rise in Oyster Creek Deg F
January	14,700	24,400	520,000	559,100	3.5
February	14,600	24,300	520,000	558,900	3.3
March	14,500	24,200	520,000	558,700	2.7
April	14,400	23,800	520,000	558,200	2.2
May	14,100	23,100	260,000	297,200	3.3
June	13,500	22,100	520,000	555,600	1.5
July	13,500	22,100	520,000	555,600	1.3
August	13,500	22,100	520,000	555,600	1.3
September	13,600	22,300	260,000	295,900	3.3
October	14,300	23,500	260,000	297,800	3.9
November	14,400	23,800	520,000	558,200	2.7
December	14,700	24,400	520,000	559,100	3.2

* Based on number of dilution pumps required to Meet Thermal Criteria in Oyster Creek

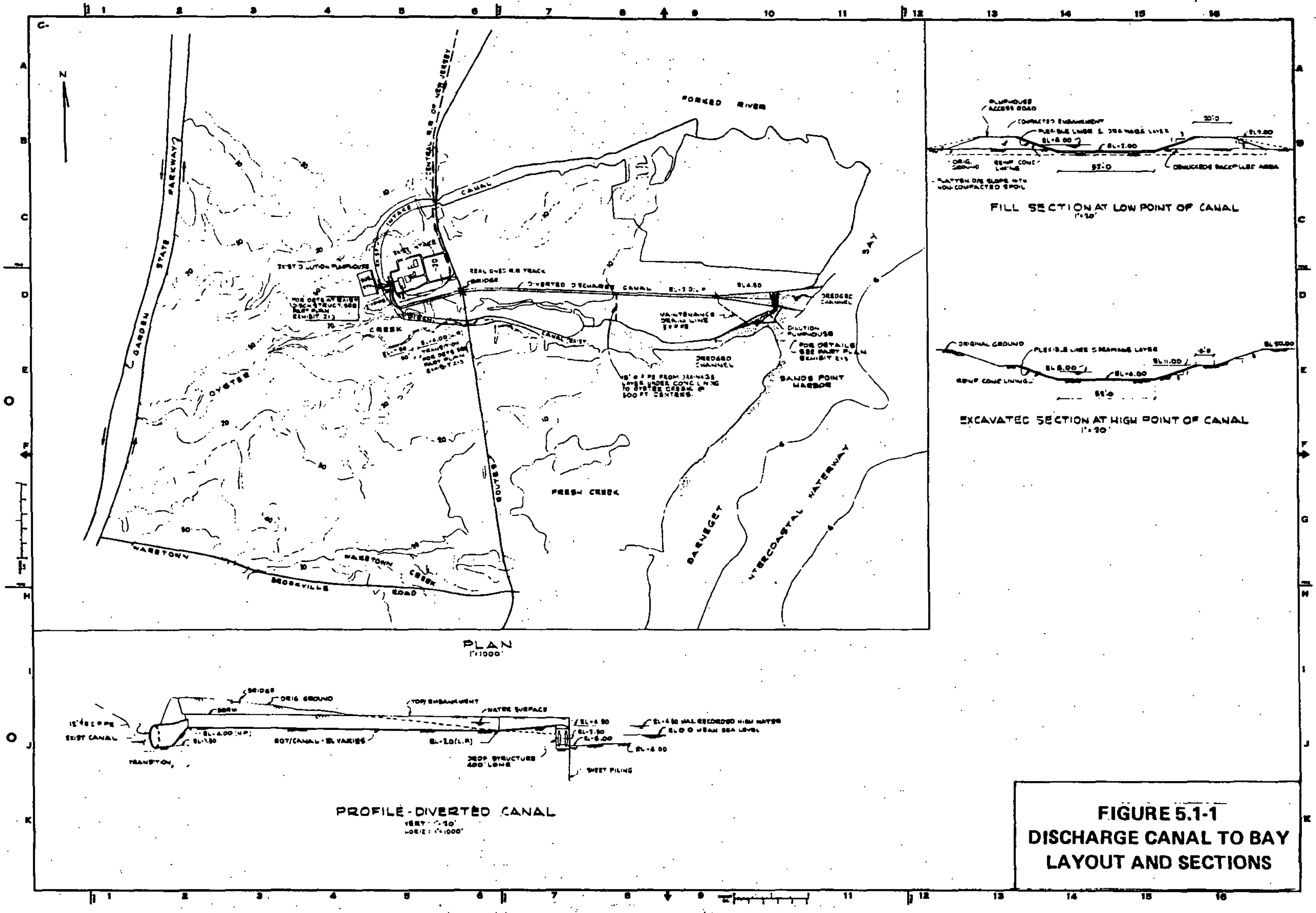


FIGURE 5.1-1
DISCHARGE CANAL TO BAY
LAYOUT AND SECTIONS

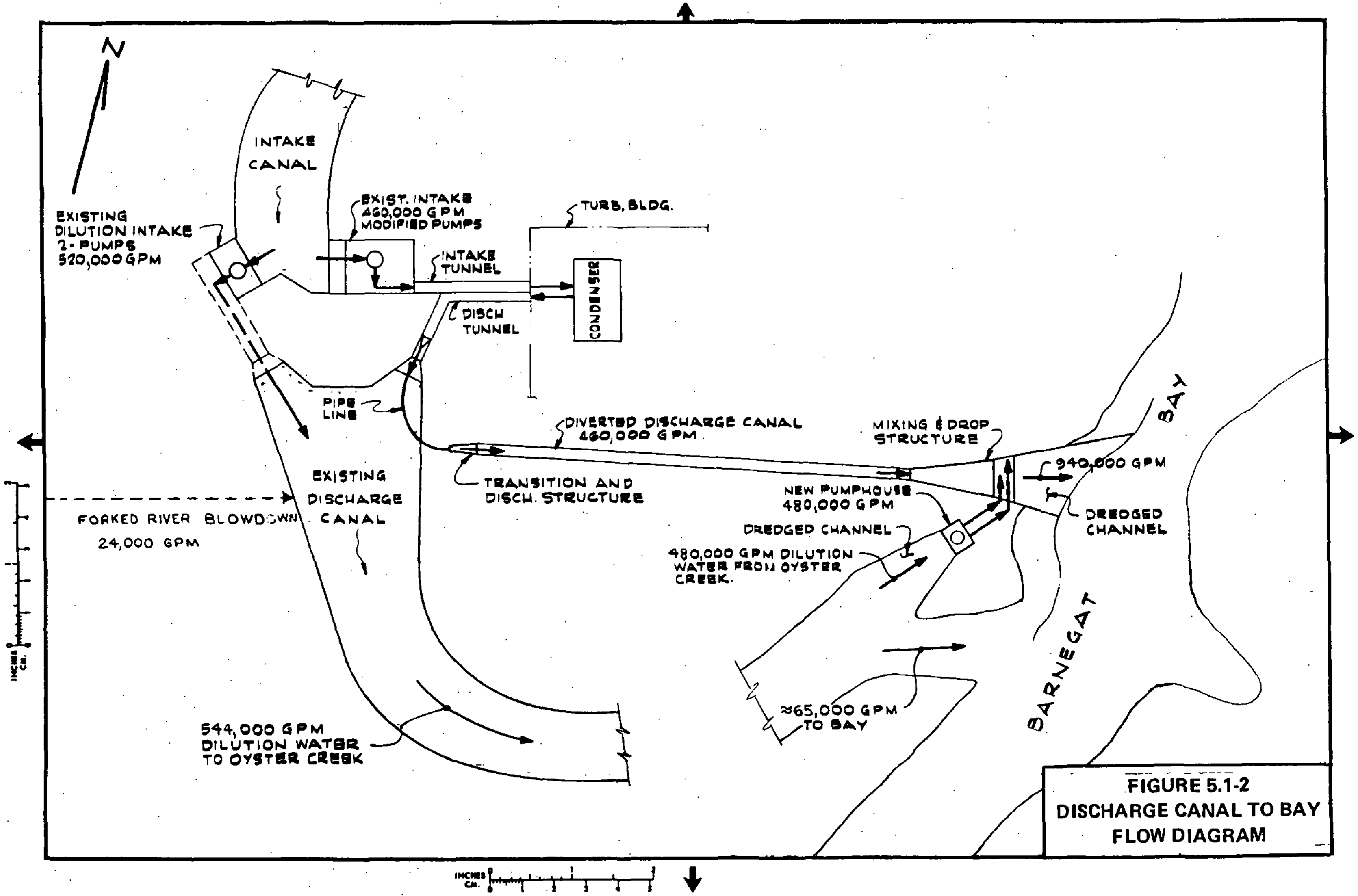


FIGURE 5.1-2
DISCHARGE CANAL TO BAY
FLOW DIAGRAM

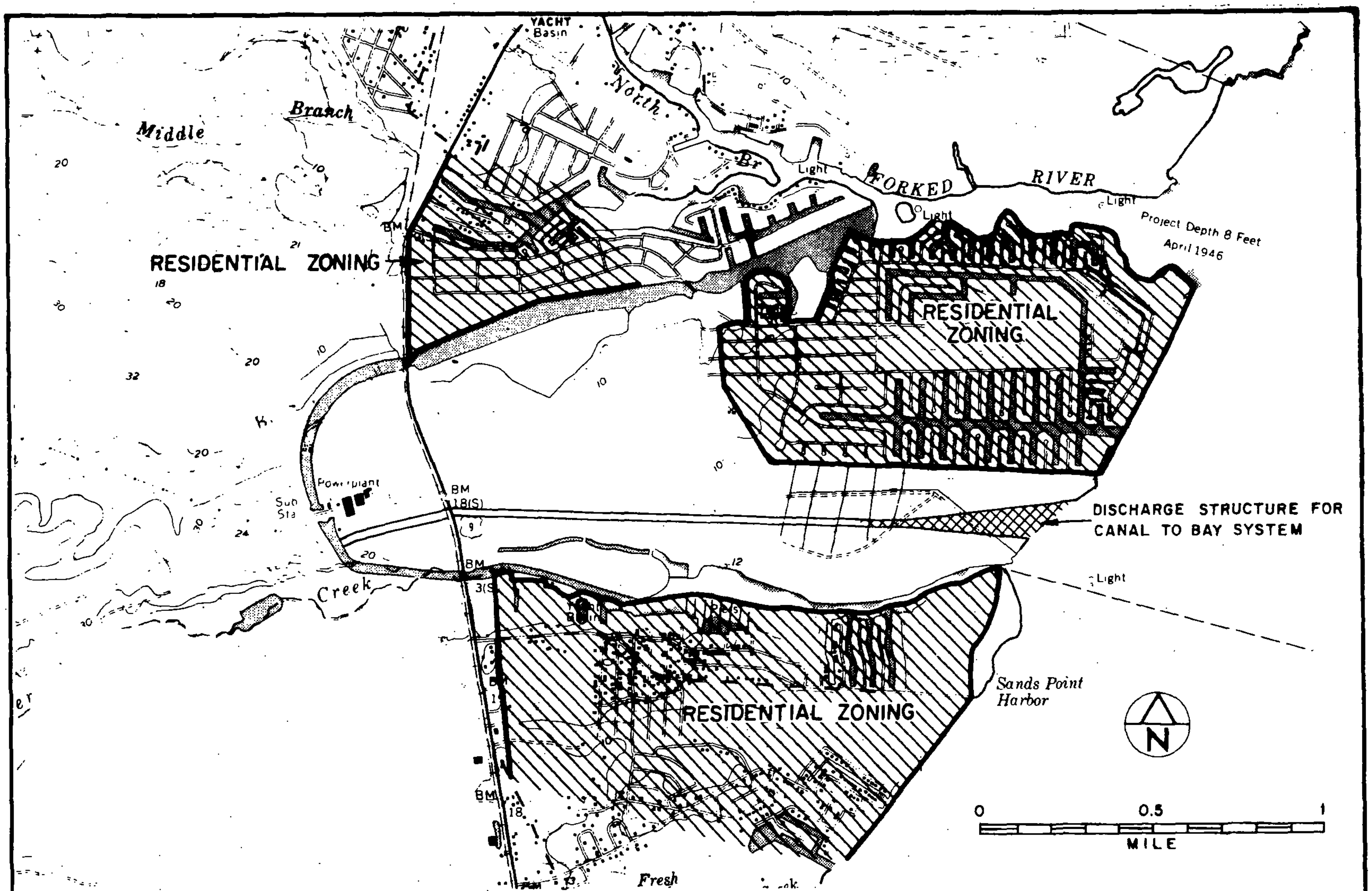


FIGURE 5.1-3
LOCATION OF CANAL-TO-BAY ALTERNATIVE
WITH RESPECT TO NEAREST RESIDENTIAL AREAS

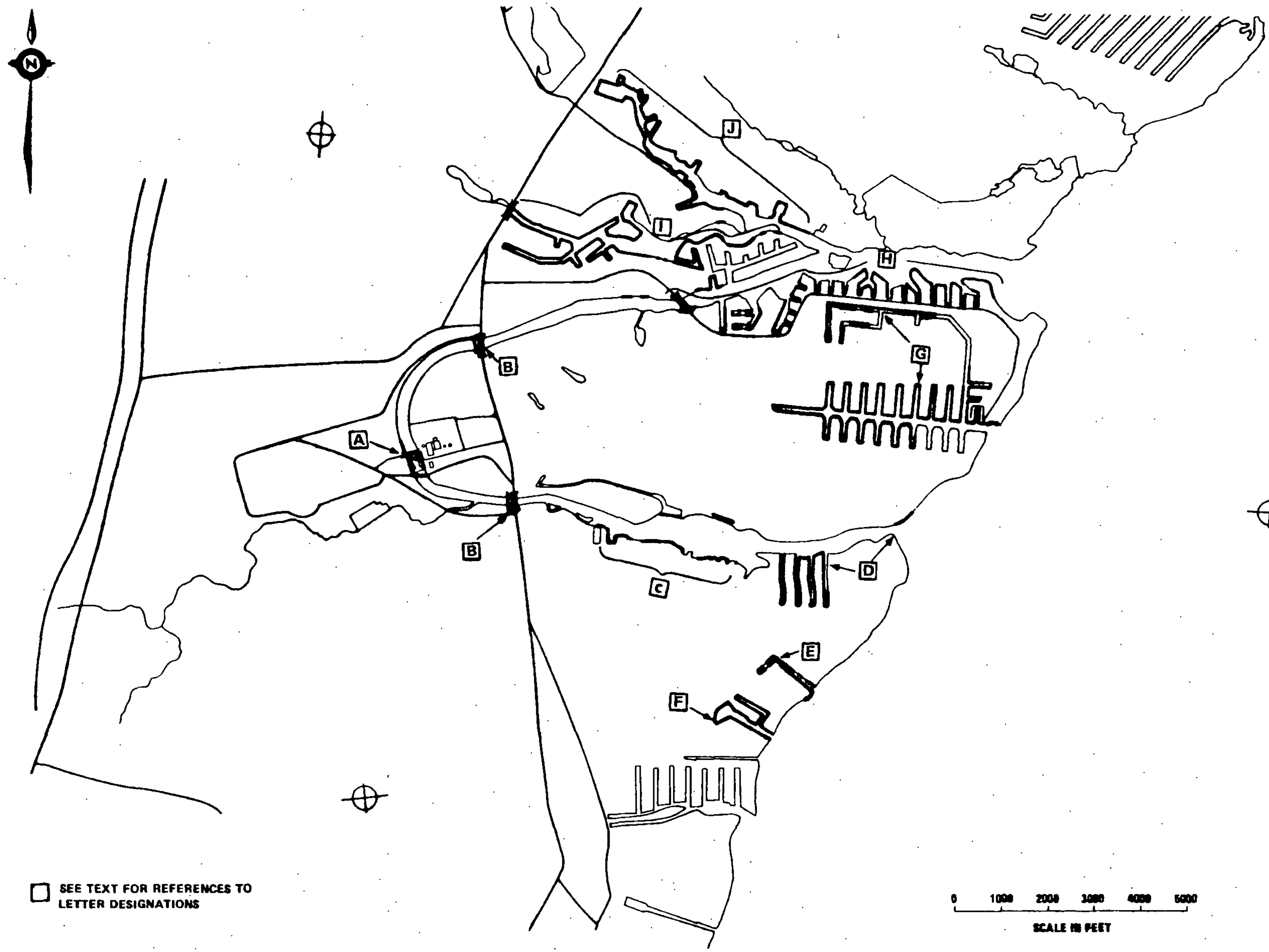


FIGURE 5.1-4
AREAS OF WOOD BULKHEADING, DOCKAGE AND PIERS
IN THE VICINITY OF THE DOCKS

HYPERBOLIC NATURAL DRAFT COUNTER-FLOW TOWER

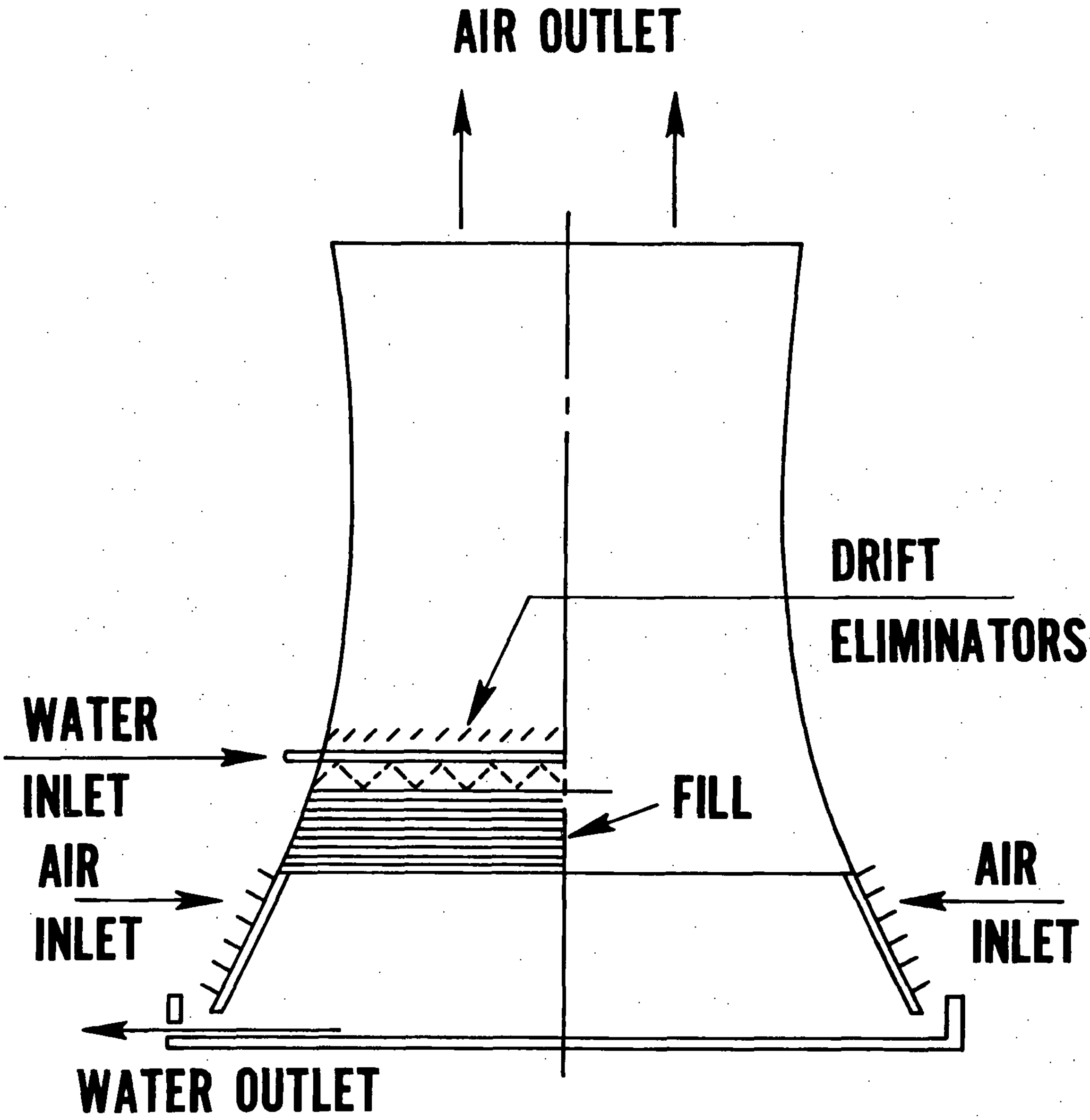


FIGURE 5.1-5

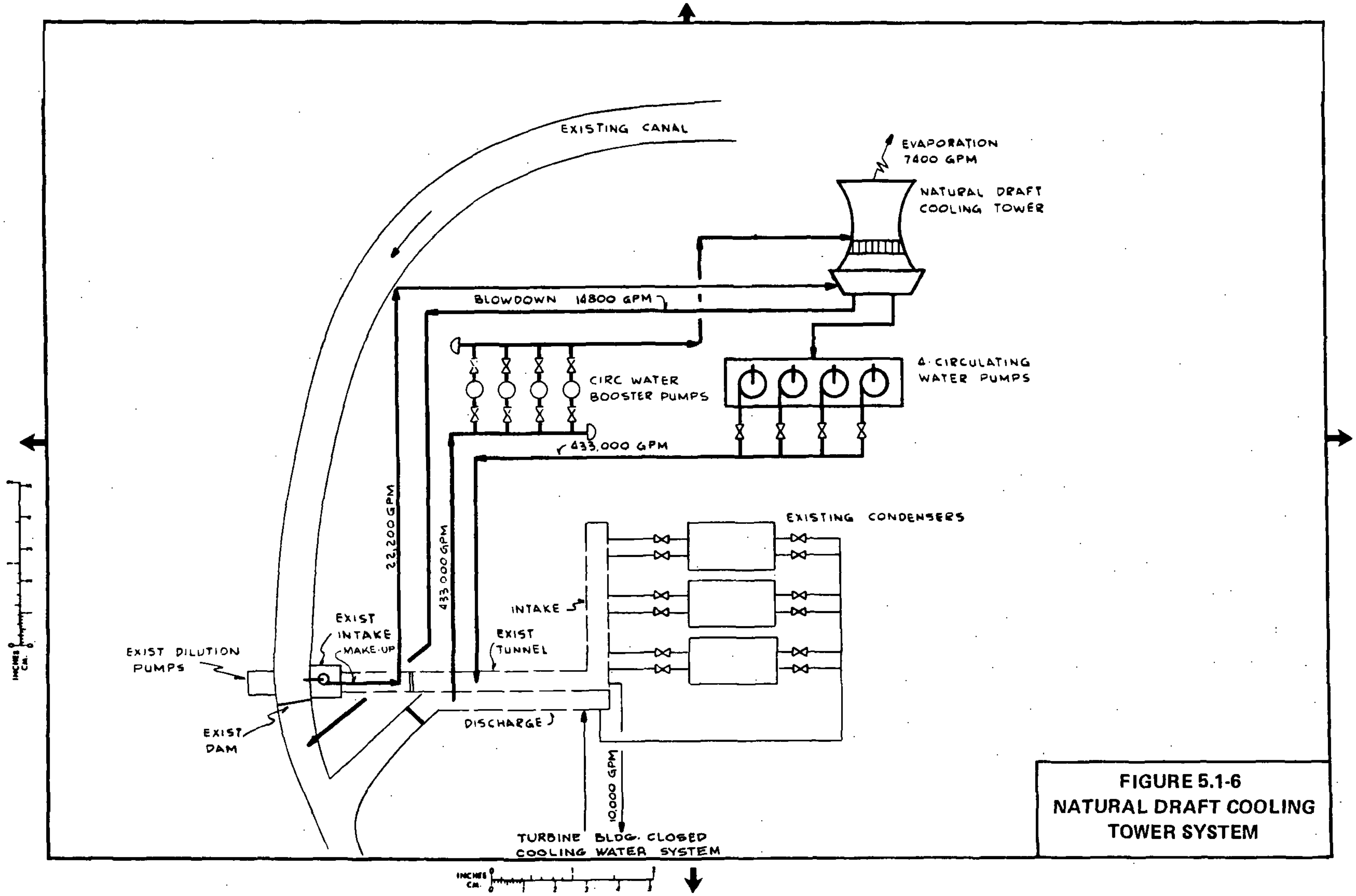


FIGURE 5.1-6
NATURAL DRAFT COOLING TOWER SYSTEM

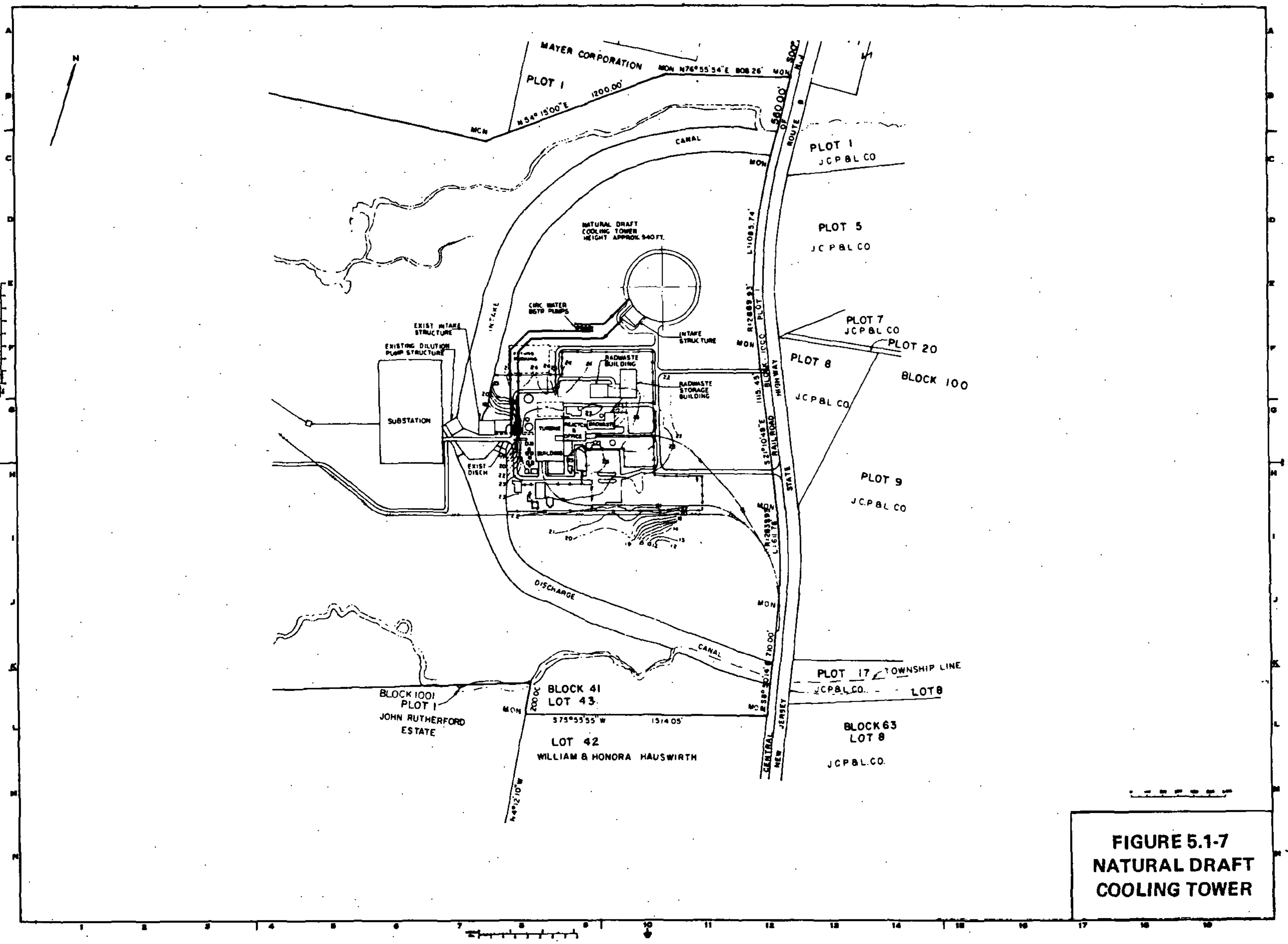
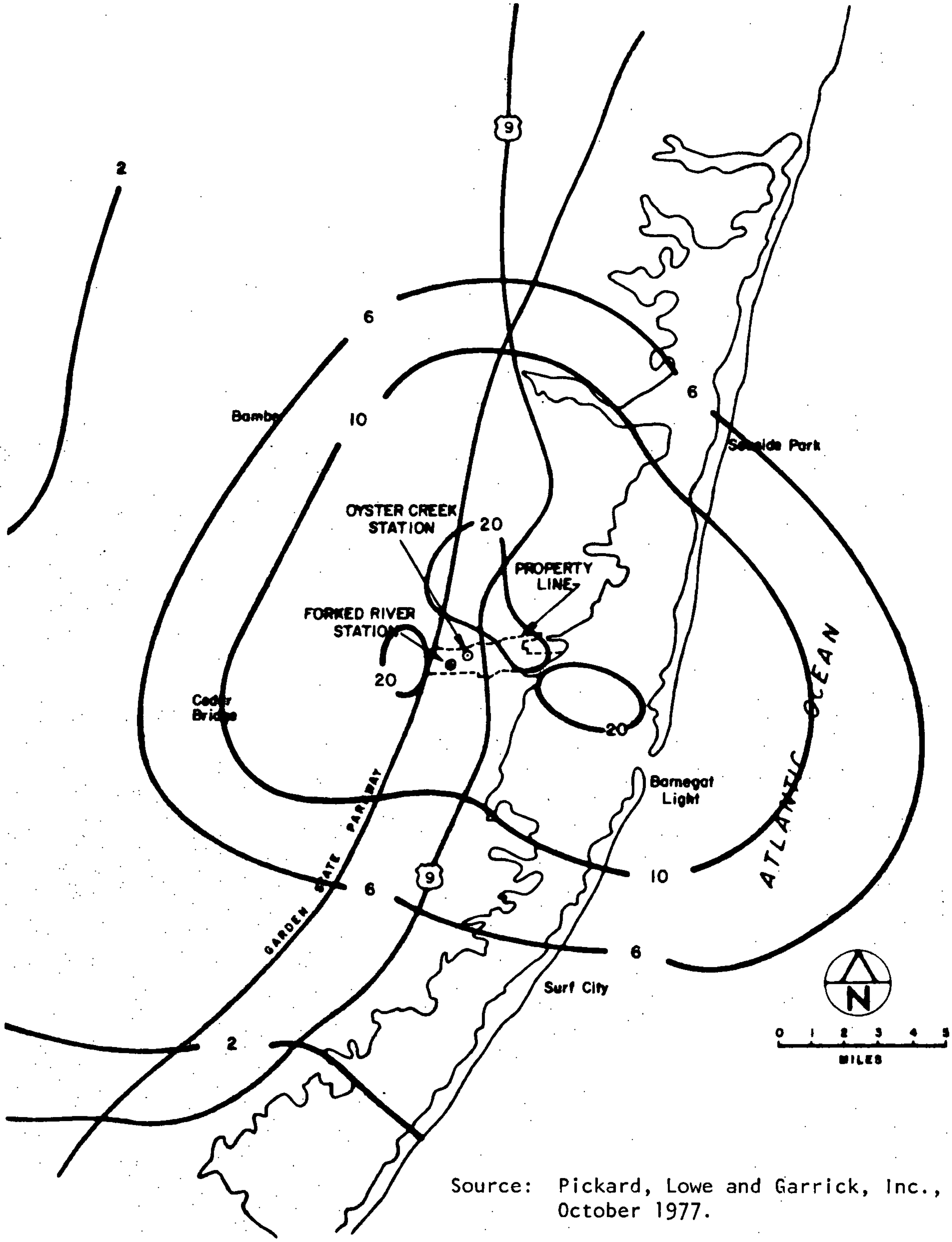
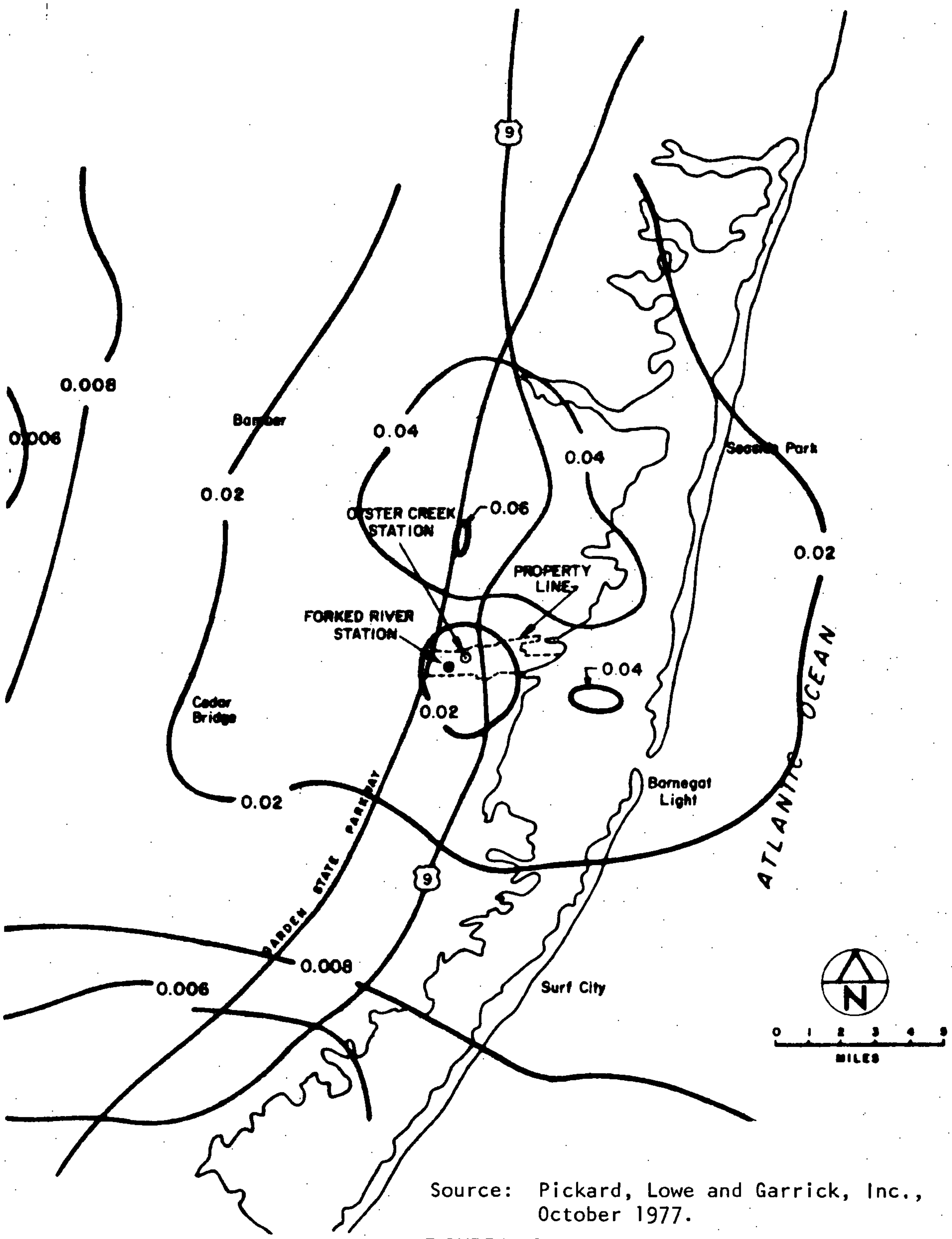


FIGURE 5.1-7
NATURAL DRAFT
COOLING TOWER



Source: Pickard, Lowe and Garrick, Inc., October 1977.

FIGURE 5.1-8
ANNUAL AVERAGE SALT DEPOSITION RATE
(Kg/Km2-Month) FROM ONE NATURAL DRAFT
TOWER AT THE OYSTER CREEK
SITE (0 - 15 MILES)



Source: Pickard, Lowe and Garrick, Inc., October 1977.

FIGURE 5.1-9
AVERAGE SUMMER AIRBORNE SALT CONCENTRATIONS (ug/m3) FROM ONE NATURAL DRAFT TOWER AT THE OYSTER CREEK SITE (0 - 15 MILES)

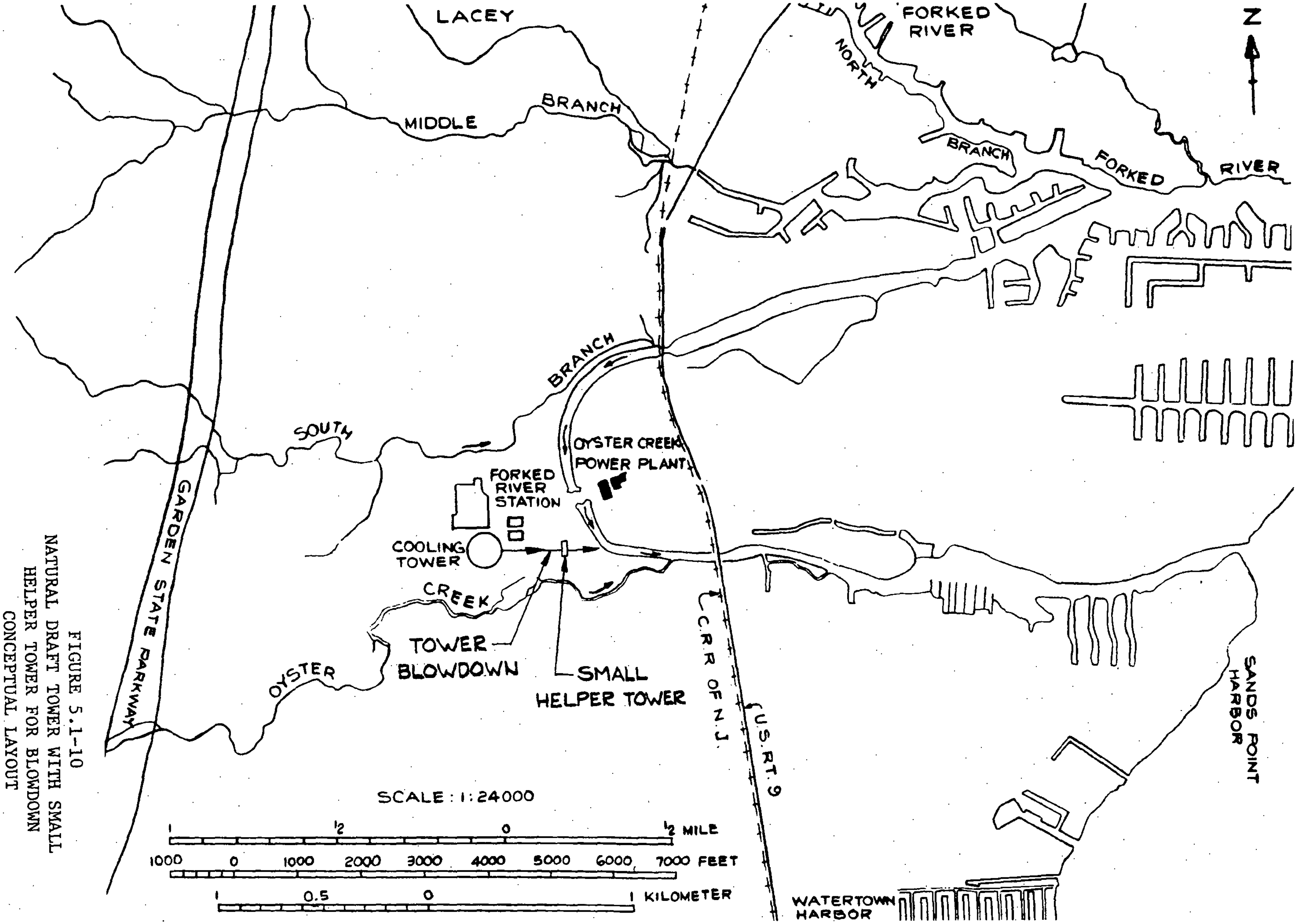


FIGURE 5.1-10
NATURAL DRAFT TOWER WITH SMALL
HELPER TOWER FOR BLOWDOWN
CONCEPTUAL LAYOUT

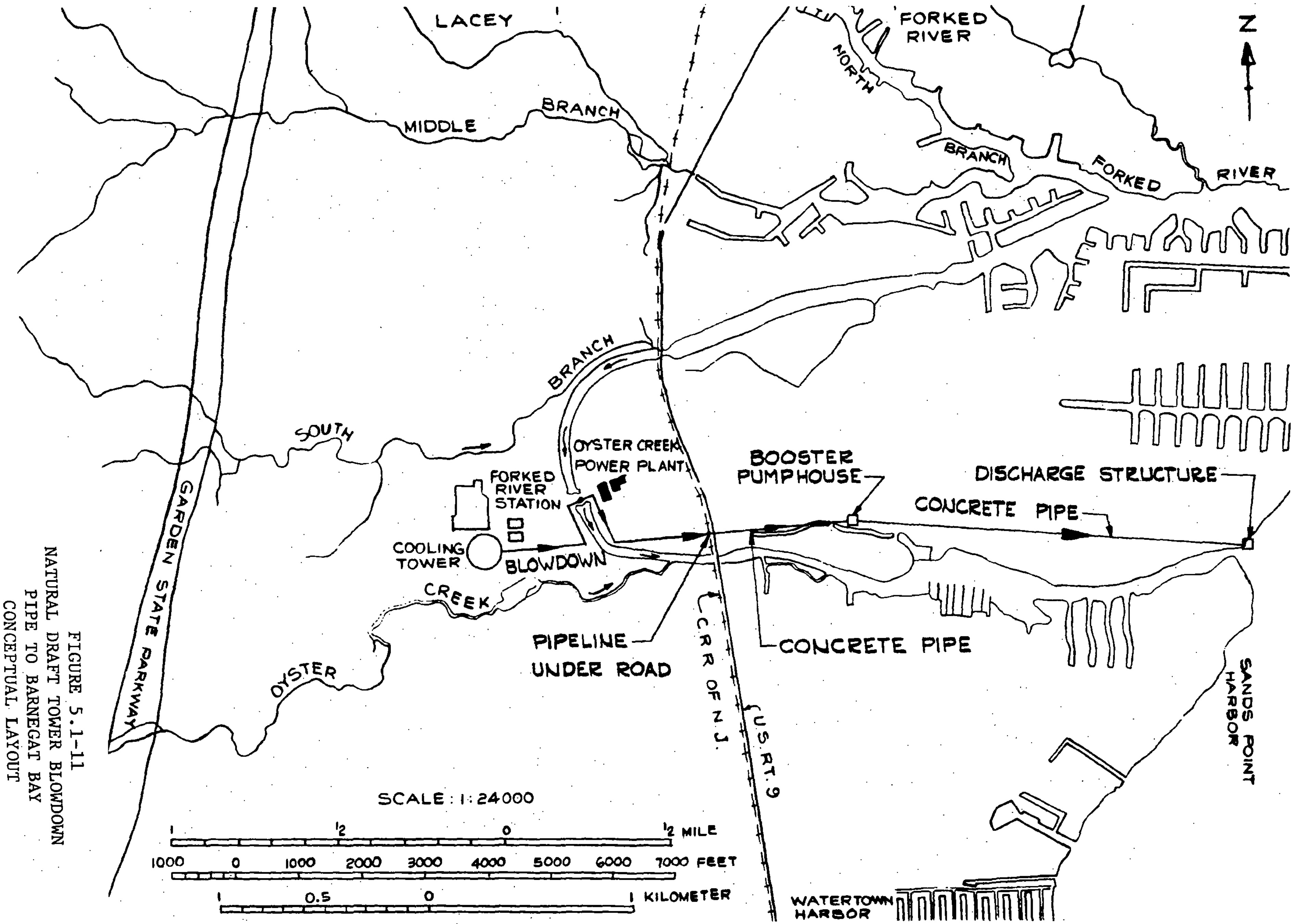


FIGURE 5.1-11
NATURAL DRAFT TOWER BLOWDOWN
PIPE TO BARNEGAT BAY
CONCEPTUAL LAYOUT

5.2 Intake Structure Alternatives

Under Section 316(b), standards may be established for the design, location, and capacity of cooling water intake structures to minimize their adverse environmental impact. No time limit for compliance is provided.

Considering their operational characteristics and effects, several different steps to reduce the environmental effects of cooling water intake structures have been recognized. Generally, these are reviewed in EPA's Development Document for cooling water intake structures. First, to reduce impingement and entrainment, an intake structure can be relocated away from areas in which species may be abundant. Considering the situation of OCNGS and FRNGS at the end of a long intake canal connected to Barnegat Bay, relocation is not feasible, and therefore, was not considered in this study.

Changes to the existing structure to reduce impingement mortalities is another possibility. JCP&L believes such changes to OCNGS may be effective, and is now studying their operational and environmental feasibility.

Changes to the existing structure to reduce entrainment may be possible with the application of either recently transferred technology developed in other industries or new, innovative intake designs. One of these is under investigation by JCP&L in studies now in progress in the OCNGS intake canal.

Finally, the entire structure may be enlarged or replaced. Several new designs for intake structures have been proposed which have the potential for reducing both impingement, impingement mortalities, and entrainment. One such design is under consideration for FRNGS, where the intake has not yet been built. No such change has been considered for OCNGS since replacement of the existing structure would be very expensive and time consuming (possibly placing the station out of operation for some time and requiring the purchase of power from other utilities). Should it be determined, however, that some change from the existing system, is necessary and alternatives already studied by JCP&L are inadequate or not feasible, JCP&L will begin an investigation of more radical possible modifications for discussion with EPA and NJDEP.

5.2.1 Intake Systems for OCNGS

Three alternatives to the present OCNGS intake are discussed below. They are Ristroph screens with 9.5 mm (3/8 in.) mesh, Ristroph screens with fine mesh or wedge wire, and circular wedge wire well type screens. The Ristroph system should significantly reduce rates of mortality due to impingement. As discussed in Appendix A, JCP&L presently is testing one such screen at OCNGS. The other two modifications also may reduce entrainment rates. Two of the three alternatives would require modifications of the intake system but would permit continued use of the existing intake structures and pumps. The third would require total replacement of the intake with one of a radically different design. Other alternatives are possible, but not specifically discussed here, since they would involve expansion of the intake (increasing capacity and reducing intake velocity) and possibly modification of the existing intake screen system. Further study would be necessary before these devices could be evaluated. An evaluation of the costs and benefits of the alternatives discussed is presented here and briefly in Section 6.2.

The alternative of a closed-cycle cooling system as a device to minimize both entrainment and impingement, by reducing intake flows, has not been discussed here. It is JCP&L's position that EPA does not possess the authority under Section 316(b) to require closed-cycle cooling in order to mitigate intake effects. However, information pertaining to closed-cycle cooling, its costs and benefits, is discussed in Sections 5.1 and 6.1.

Ristroph Screens with 3/8 In. Mesh

(a) Design, Operation and Capacity

This alternative is designed to decrease the mortality of impinged organisms by reducing the length of time organisms remain impinged and providing a mechanism by which organisms can be transported to the OCNGS discharge. The existing OCNGS traveling water screens with 9.5 mm (3/8 in.) mesh would be modified by adding a watertight "fish lip" at the bottom of each basket so that the basket will retain water approximately 51 mm (two in.) deep as the screen is rotated (Figure 5.2-1). Debris and fish troughs and high and low pressure sprays would be installed in the screen housings. In addition, the screens would be operated continuously so as to minimize the time that any individual organism is impinged on the screens. Based on data from Surry Station of Virginia Electric Power Company (VEPCO) where a similar system is in use, this could reduce substantially the mortality and stress to impinged organisms (Section 4.2). The Salem Station of Public Service Electric and Gas Company (PSE&G) has a similar system installed but a complete evaluation of impingement survivorship has not been completed as yet. A prototype of the Ristroph system has been installed in one of the six traveling screens at OCNGS and is undergoing operational and environmental testing (Appendix A2).

In principle, as the screen is rotated impinged fish and other organisms fall from the screen into the water filled fish lip, thus enabling them to remain alive until washed from the screens. When the screen basket rotates over the head-shaft and begins its downward travel, a gentle water spray (10-20 psig) flushes the fish and other organisms from the screen basket into a trough which transports them to the OCNGS discharge canal. The screen continues its descent and is washed by a high pressure spray (70-100 psig) which cleans the accumulated debris from the screen basket into a second trough which also transports the debris into the discharge canal.

The proposed OCNGS screens would be designed to pass 80,000 gpm of water each with a low water depth of 5 m (16.5 ft) at an average flow through velocity of 2.53 fps (the 9.5 mm (3/8 in.) mesh size has a 61 percent open area for water flow). Average flow through velocity at a normal water level of 5.5 m (18 ft) is 2.32 fps. The proposed screens would utilize a two speed motor for rotation, resulting in continuous screen travel of 2.5 fpm for normal loadings and ten fpm for heavier screen loadings. These screen speeds would result in fish retention times of eight to ten minutes, and two to 2.5 minutes, respectively.

(b) Capital Cost and Operation & Maintenance Costs

The estimated cost in 1977 dollars for replacement of the remaining five screens at OCNGS of the Ristroph design would be $260,000 for material. Installation can be simplified by having the screens delivered to the site assembled so that the old ones can be lifted out and the new ones set in place thus minimizing the field work required. Total project cost would be approximately $378,000. The levelized annual cost of this system is shown in Table 5.2-1.

It is expected that operation and maintenance (O&M) costs of the Ristroph type screen would be higher than the conventional screen principally because of the requirement for continuous rotation which accelerates wear on the moving parts and consumes more energy than the intermittent operation of conventional traveling screens. The experience of VEPCO bears this out as their O&M costs for Ristroph screens have run about twice that of conventional screens. The screens that would be installed at Oyster Creek have some features that also should tend to limit maintenance costs to approximately double those experienced with the existing system (Table 5.2-1). These features include: a lower screen rotational speed; fabricated footwheels with abrasive resistant wear rims, supported by abrasive and corrosive resistant journal bearings; "sealed for life" anti-friction headshaft support roller bearings; and, headshaft sprockets fabricated with abrasion resistant wear rims.

Operational power costs for the existing screen are approximately $1000 per month (1977 dollars). Continuous operation of the screens would increase this cost to approximately $3700 per month (1977 dollars). Fixed costs also would increase for the Ristroph screens, since they are both more expensive than the existing screens and continuous operation would reduce their useful life by approximately 40 percent (screen replacement every four to five years versus seven years with the existing system).

(c) Environmental Effects

Impingement and entrainment of aquatic organisms and any resultant mortality by the existing and alternative intake systems must be considered in the overall evaluation of OCNGS and FRNGS. The Ristroph screens with 9.5 mm (3/8 in.) mesh are presently undergoing an onsite evaluation. One of the six existing OCNGS vertical traveling screens has been converted to the Ristroph design. The results of this evaluation will be used to determine the cost effectiveness of this modification and provide the basis for the complete installation of these screens.

The predicted impact of this intake alternative has been evaluated in Appendix E1 and Chapter 4. Appendix E1 compares impingement mortality estimates for OCNGS with and without the Ristroph screens, and for various OCNGS closed-cycle cooling systems in conjunction with the existing vertical traveling screens. Based on the assumption that Ristroph screens will reduce the overall species mortality rate to 15 percent, this analysis concluded that Ristroph screens would reduce impingement mortality to within the same order of magnitude associated with the closed-cycle cooling alternatives.

Chapter 4 presents estimates of species loss for a 20 month period due to impingement on the existing OCNGS traveling screens. For eight of the species considered, loss estimates assuming the use of Ristroph screens are also presented. A tabulation of OCNGS impingement and impingement mortality for the existing and Ristroph screens is shown in Table 5.2-2. Average immediate mortality for the eight species common to Surry Station and OCNGS is about 44 percent at OCNGS and 13 percent at Surry. Assuming a 50 percent reduction of immediate mortality at OCNGS for the

Ristroph screens, estimates were developed for immediate mortality rates of the remaining species. Based on these computations, average immediate mortaliy for fishes at OCNGS is presently 69 percent but should be reduced to 16 percent with Ristroph screens. Likewise, average immediate mortality for invertebrates is presently 8 percent but should be reduced to 4 percent with Ristroph screens. Overall, impingement mortality is presently estimated to be 20 percent. This rate should be reduced to 7 percent with Ristroph screens.

A dollar value has not been developed for the estimates of the reduction in immediate mortality associated with the use of Ristroph screens at OCNGS during the 20 month period discussed above. However, for the 12 month period from March 1976 to February 1977, the estimated reduction in impingement mortality associated with a 95 percent reduction in OCNGS cooling water flow was determined to have a levelized annual economic benefit of approximately $1800 to $3600 (see Appendix E1). A similar benefit would accrue from the use of Ristroph screens, based on the similarity of immediate mortality estimates for Ristroph screens and the closed-cycle cooling alternatives discussed in Appendix E1.

<u>Ristroph Screen with Fine Mesh or Wedge Wire</u>

(a) Design, Operation and Capacity

A second possible modification to the existing intake system would involve replacing the 9.5 mm (3/8 in.) screen mesh with either a finer mesh screen or narrow opening wedge wire. Wedge wire is a "wedge" shaped wire, typically arranged to provide narrow slot-openings, which, in circular configurations, has found use in low volume intakes for oil wells and water supplies (Figure 5.2-2). Wedge wire screens possess several relatively unique hydraulic properties which have prompted recent investigations to determine their suitability for power plant intakes. With either fine mesh screen or wedge wire the finer openings would have the possible advantage of reducing organism entrainment in the circulating water system.

Based upon studies conducted by several screen vendors and utilities, and given relatively low (0.5 fps) screen approach velocities, a 1.5 mm (0.06 in.) wedge wire or fine mesh screen will exclude soft-bodied organisms (fish larvae and plankton) greater than 18 mm (0.70 in.) long and hard-bodied organisms (invertebrates) greater than 1.5 mm (0.06 in.) (Bason, personal communication). The size of organisms excluded by the screen is dependent on, among other things, intake velocity; at lower velocities, smaller organisms will be excluded.

A 2.5 mm (0.1 in.) screen would produce an open flow area of about 37 percent. With fine wedge wire of 1.5 mm (0.06 in.) slot openings, the open flow area would be 57 percent whereas a comparable size opening fine mesh screen would result in a much lower open flow area. When the high hydraulic efficiency of wedge wire is taken into consideration, its effective pressure drop across the screen would be essentially the same as that of 9.5 mm (3/8 in.) mesh. The 1.5 mm (3/8 in.) wedge wire screens would thus achieve a greater reduction in entrainment but without the flow penalties which would result from the use of finer mesh screen. Preliminary information indicates that the biological exclusion results associated with velocities of 0.5 fps would not be applicable at through screen velocities of two to 2.5 fps. No exclusion data are presently available on higher approach velocities.

A comparison of fine mesh and wedge wire indicates that for installation at OCNGS, the wedge wire appears to be preferable for hydraulic considerations but because the velocities will be greater than 0.5 fps, a reduction in entrainment of microorganisms is not assured.

JCP&L has begun a study of wedge wire screens and their specific suitability for use in the OCNGS canal (Chapter 1). Of particular concern is that engineering problem associated with the method of screen attachment and high approach velocity may preclude the use of either of the above alternatives on the present intake without an extensive research and development effort for wedge wire and a significant increase in the intake size for the fine mesh alternative. The results of the studies now being conducted will be submitted to the EPA and NJDEP in the future.

(b) Capital Cost and Operation & Maintenance Costs

The material cost for refitting the existing intake screen system with wedge wire, assuming a 1.5 mm (0.06 in.) slot spacing, would be approximately $105,000 (1977 dollars). Installation could be accomplished by purchasing one extra set of baskets, having them fitted with the wedge wire and then installing them on a screen, fitting those removed baskets with wedge wire and installing them on the next screen, etc., until installation is complete on all screens. Estimated cost fot the completed installation is $608,000 (1977 dollars). The levelized annual cost of this system is shown in Table 5.2-1.

Although an economic study has yet to be performed, the operation and maintenance costs for this alternative would be expected to be approximately double the costs incurred for the existing screen system. The reasons are basically the same as those described for the Ristroph screen alternative with 9.5 mm (3/8 in.) mesh.

There are potentially other operating problems associated with the wedge wire screens. These stem principally from a lack of experience with this type of material. Some of these problems are heavy material weight, rapid clogging, biofouling and collapse from weight buildup. The weight of wedge wire panels available today is significantly greater than 9.5 mm (3/8 in.) mesh and may require replacement of chains, sprockets and strengthening of baskets. Rapid clogging of the screens would increase the weight problem potentially leading to screen collapse. However, continuous operation of the screens could minimize this problem. The problem of biofouling may be serious depending on the screen material selected. Fouling organisms may find the area just downstream of the orifice formed by two adjacent wedge wires a relatively quiet place to settle and grow, eventually reducing available flow area and increasing the pressure drop across the screen. If this condition occurs rapidly it would necessitate frequent mechanical cleaning of the screen fabric, greatly increasing maintenance costs. These problems will be addressed in JCP&L's current study. Further rate specific information will be forthcoming on these problems from the OCNGS intake canal test facility.

(c) Environmental Effects

Studies are being conducted by several investigators on the operational and environmental characteristics of fine mesh and wedge wire screens for use on traveling screens (TVA, 1976; Con Ed, 1977; Hanson et al., 1978). Estimates of the magnitude of entrainment reduction utilizing either of these screen materials on the existing OCNGS intake is not possible at this time. If the OCNGS intake were enlarged and though-slot velocities of 0.5 fps were achieved, estimates of entrainment reduction could be computed. Reducing cooling water flow by 95 percent is estimated to have a levelized annual economic benefit of approximately $1700. JCP&L is now conducting in situ testing of wedge wire screen to determine the effectiveness of one and two mm (0.04 and 0.08 in.) screen for entrainment exclusion and will report on these results in the future.

<u>Circular Wedge Wire Well Screen Design (submerged screen)</u>

(a) Design, Operation and Capacity

This alternative would involve a complete redesign of the intake structure to provide for circular wedge wire well type screens instead of traveling screens (Figure 5.2-3). This system would have the potential advantage of minimizing both impingement and entrainment, and possibly maintenance and operating costs. Design of this system would presume a 460,000 gpm water flow with a maximum through screen velocity of 0.5 fps. Screening material would most likely be stainless steel bars with widths of 19 mm (0.75 in.) and slot openings of 1.5 mm (0.06 in.), resulting in a 57 percent open area. The required surface area would then be 650.3 m^2 (7000 ft^2) for this configuration.

Use of the wedge wire well screen design would face significant engineering problems and is currently undergoing a feasibility study. The size of the screens would be constrained by the depth of the existing canal (3.0 m, ten feet) and the requirement that, for effective operation, approximately three ft of water must be maintained above and below the screen. The maximum possible screen diameter for the present canal configuration would be 1.2 m (four ft). For a 0.91 m (three ft) diameter,226 m (734 lineal ft) of screen would be needed to handle the required water flow for OCNGS; a 1.2 m (four ft) screen would use 62 T-shaped modules with nine lineal ft of screen per module. In the OCNGS intake canal, these modules would extend from the present station intake nearly 70 percent of the way along the canal to U.S. Route 9. Additional screen capacity would be required to ensure cooling flow continuity in order to satisfy nuclear safety requirements. At present, this is estimated at 100 percent, but would be subject to modification after safety review by the USNRC.

The above described design is only speculative, and could be substantially modified as a consequence of the wedge wire feasibility studies now being conducted by JCP&L and of more complete design engineering. A careful study would have to be made to determine the proper configuration and location of the screens and manifolds leading to the pump intakes. Depending on the results of that study, it also is possible that considerable dredging would be required in order to locate this type of intake in the intake canal.

A further difficulty with the wedge wire screens is their unknown potential for biofouling and clogging in an environment such as the OCNGS intake canal. Only one power plant is known to use wedge wire screens, and that is located on a freshwater body where biofouling is of little concern. Studies conducted to date on biofouling have not provided results from which the potential in the intake canal can be predicted. JCP&L's studies on wedge wire are being conducted in the intake canal and should provide this data. Additionally, one wedge wire vendor is working on an alternative screen material which may be resistant to biofouling. The results of that research are as yet inconclusive.

(b) Capital Cost and Operation & Maintenance Costs

Without undertaking a considerable engineering effort, the total capital cost of this alternative is difficult to predict. However, cost of the screening material ranges from $150-175 per sq ft for a total screening cost range of from $1 million to $1.2 million. In addition to this cost must be added the modifying the present structure allowing the screens to be changed to circular wedge wire well screens and located in the intake canal. This cost is estimated to be between $100 million and $140 million (see Table 5.2-1 for the annual levelized costs associated with this alternative). Operating and maintenance costs for this type of screen should be low since there are no moving parts. The screens would be cleaned by backflushing, using up to 100 psi air. However, one vendor claims that most debris would wash off by action of the current enroute to the OCNGS dilution pumps, thus minimizing backflushing requirements.

(c) Environmental Effects

Based on information from studies in the Chesapeake and Delaware Canal (Hanson et al., 1978) circular wedge wire well screens are effective in eliminating impingement and reducing entrainment. Many investigators are now evaluating their merits. JCP&L and GPUSC has embarked on a testing program using a barge with two screens in the OCNGS intake canal. However, because of the engineering constraints this type of screen is not considered practical for OCNGS.

Other Intake Alternatives

Several intake systems other than the above offer potential environmental benefits of reduced impingement and entrainment relative to the existing system. Single-entry double-exit traveling screens, angled traveling screens, horizontal traveling screens, and lower diversions in conjunction with traveling screens all have potential applicability to the present system. All would necessitate complete intake retrofits and would be very expensive. No estimates are presently available for the costs or benefits of these systems.

Summary

Reviewing the alternatives for the intake modifications, the Ristroph modification will improve survival. The addition of wedge wire fabric on the screen should be the most effective alternative from a hydraulic point of view, although the effect on entrainment reduction is unknown. Other intake modifications are possible to reduce impingement and entrainment impacts but require total redesign of the existing system. In view of the conclusion that the present intake impact is not significantly affecting the aquatic community of Barnegat Bay and the projected high cost of modifying or replacing the intake structure, such redesigns are not warranted unless their costs are extremely low and the benefits great.

5.2.2 Intake Systems for FRNGS

Presently Planned FRNGS Intake

The presently planned FRNGS intake system utilizes two Ristroph design traveling water screens behind vertical trash bars. The screen fabric will be 9.5 mm (3/8 in.) mesh. The Ristroph design screens provide for reduced impingement mortality by minimizing the time an organism is impinged and enabling transport back to the water body away from the intake. The intake structure will contain three nuclear services pumps. These pumps provide cooling water to the Nuclear Services Cooling Water System which supplies water to the secondary services and component cooling water heat exchangers. Discharge from these heat exchangers is to the cooling tower basin where it provides make up to the circulating water system. During normal operation only two of the three pumps will be in service.

Ristroph Screens with Wedge Wire Panels

As an alternate to the presently planned design for the FRNGS intake structure, the 9.5 mm (3/8 in.) mesh screen fabric could be replaced with either a fine mesh fabric (2.5 mm, 0.1 in.) or wedge wire panels with slot openings of 1.5 mm (0.06 in.) to reduce the number of entrained organisms. The fine mesh screen greatly reduces flow area and is not a practical option unless the structure design is modified to provide additional flow area in order to keep velocities through the screens at approximately 0.5 fps.

Substitution of wedge wire panels with slot widths of 1.5 mm (0.6 in.) results in a flow area only slightly less than the 9.5 mm (3/8 in.) mesh (57 percent versus 61 percent). This reduction in flow area is offset by the much greater hydraulic efficiency of the wedge wire versus the 9.5 mm (3/8 in.) mesh which minimizes the pressure loss across the screen. Attachment of the wedge wire fabric to the baskets must be carefully done to avoid stresses that can result in basket distortion due to the high strength of the wedge wire fabric.

The cost of the wedge wire screening material is approximately $25 per sq ft. Other installation costs, since these are new screens, could be the same as for the conventional 9.5 mm (3/8 in.) mesh and are included in the price of the original screens. O & M costs will be similar to the 9.5 mm (3/8 in.) mesh Ristroph screens (presently planned design).

Based on studies by other investigators (TVA, 1976) wedge wire on the Ristroph screen may reduce both impingement mortality and entrainment. The magnitude and size range of organisms excluded from entrainment will depend upon the through-slot velocity. Studies now underway in the OCNGS intake canal will help provide this information.

Circular Wedge Wire Well Screens

This alternative, if implemented, would involve a complete redesign of the FRNGS intake structure. In this design the traveling screens would be replaced by cylindrical screens and manifold piping leading to the nuclear service pump intakes. This type of system has no moving parts which should minimize maintenance problems caused by wear.

The tentative design of the circular wedge wire system presumes a 45,800 gpm water flow with a maximum velocity of 0.5 fps. The design, from Burns & Roe, includes 15 to 25 screens in line. Each screen is 1.3 m (4.2 ft) long and has an outside diameter of 0.9 m (3 ft). The exact number of screens will depend on the wedge wire slot width. As discussed elsewhere in this document, feasibility studies are currently being conducted on the use of wedge wire in an estuarine environment. These studies will also aid in the determination of the optimum slot width. Cleaning would be accomplished using up to 100 psig air with provision for screen removal for manual cleaning if required. Most debris would wash off the screens by action of the current passing by the intake structure enroute to the OCNGS intake structure and dilution pumps.

At this time, it is not possible to estimate the total capital cost of this alternative since information on the number of screen modules required, the optimum screening material to be utilized, or even the engineering feasibility of this alternative has not been sufficiently detailed.

Operation and maintenance costs will most likely be minimal compared to the traveling screen alternatives since there are no moving parts. Maintenance costs would only be a problem if clogging is sever and manual cleaning of the screens is required frequently.

Based on studies from a generating station relatively near the FRNGS (Hanson et al., 1977), circular wedge wire screens are effective in eliminating impingement and minimizing entrainment. The environmental benefits at the FRNGS would be similar with the use of this alternative if the operating and other ambient conditions of the two stations are similar.

Summary

Reviewing the alternatives for the Forked River Intake Structure it is found that the presently planned alternative of 9.5 mm (3/8 in.) mesh Ristroph design traveling screens has NRC and, currently, EPA approval. There is concern, however, that, by the time Forked River begins commercial operation, the 9.5 mm (3/8 in.) mesh Ristroph design may no longer represent "best available technology." This could result in expensive modifications to convert to an alternative design, such as circular wedge wire screens.

The circular wedge wire screen alternative is more expensive than the others but could offer a savings in operation and maintenance costs if biofouling is easily controlled. Testing of the screens in the OCNGS intake canal will provide this information. The tests, being conducted by JCP&L and GPUSC, will determine which intake design is most cost effective in minimizing intake derived mortalities based on environmental, capital, operating and maintenance considerations. It should be noted, however, that a change to circular wedge wire screens from the Ristroph design would result in a delay in the availability of intake water for use during final construction phases and testing, and therefore, could result in a delay of the station completion date.

References

Con Ed. 1977. Preliminary investigations into the use of a continuously operating fine mesh traveling screen to reduce ichthyoplankton entrainment at Indian Point Generating Station. Ecological Analysts, Middletown, NY.

Hanson, B.N., W.H. Bason, B.E. Beity and K.E. Charles. 1977. A practical raw water intake screen which substantially reduces the entrainment and impingement of early life stages of fish. Presented at the Fourth National Workshop on Entrainment and Impingement, Chicago, Ill.

TVA. 1976. A state-of-the-art report on intake technologies. Report EPA-600/7-76-020. U.S. Environmental Protection Agency, Washington, DC.

TABLE 5.2-1

LEVELIZED CAPITAL AND OPERATION & MAINTENANCE COSTS, AND ESTIMATED MAINTENANCE HOURS FOR ALTERNATIVE INTAKE SYSTEMS AT OCNGS

	Capital Cost[1] ($)	Maintenance Man-hours/Mo.	O & M Costs $/Yr.
1. Existing System	Base	100	Base
2. Ristroph Backfit	$82,146	200	172,516[2]
3. Ristroph with Wedge Wire	$157,060	200	172,516[2]
4. Wedge Wire Well Type	$25.8-$36.2 million	Not Available	Not Available

1. Levelized annual cost figures based on a discount rate of 11.22 percent, a fixed charge rate of 22.5 percent and a 21 year operating life.

2. Levelized annual cost based on an operating life of 21 years and an escalation rate of 7 percent.

TABLE 5.2-2
SPECIES IMPINGEMENT AND IMMEDIATE MORTALITY AT OCNGS-1975 TO 1977

SPECIES	20 Months OCNGS IMPINGEMENT number	IMMEDIATE OCNGS MORTALITY percent	IMMEDIATE OCNGS MORTALITY WITH RISTROPH percent
Alosa aestivalis	55,616	42	10(a)
Brevoortia tyrannus	112,748	28	5(a)
Anchoa mitchilli	1,958,752	77	18(a)
Menidia menidia	96,323	41	6(a)
Pomatomus salatrix	18,021	54	15(a)
Cynoscion regalis	39,087	61	41(a)
Leiostomus xanthurus	109,632	44	3(a)
Paralichtyus dentatus	6,646	8	3(a)
Syngnathus fuscus	47,286	25	13(b)
Prionotus evolans	60,625	27	14(b)
Etropus microstomus	65,795	28	14(b)
Pseudopleuronectes americanus	22,526	23	12(b)
Sphoeroides maculatus	4,829	7	4(b)
Palaemonetes valgaries	403,173	6	3(a)
Crangon septemspinosa	3,942,421	10	5(a)
Callinectes sapidus	5,857,944	7	4(a)
Total Vertebrates	2,597,886	67	16
Total Invertebrates	10,203,538	8	4
Total	12,801,424	20	7

(a) assumed Ristroph mortality based upon Surry Station (see Section 4)

(b) assumed Ristroph mortality of 50% of existing OCNGS mortality for species with no Surry data.

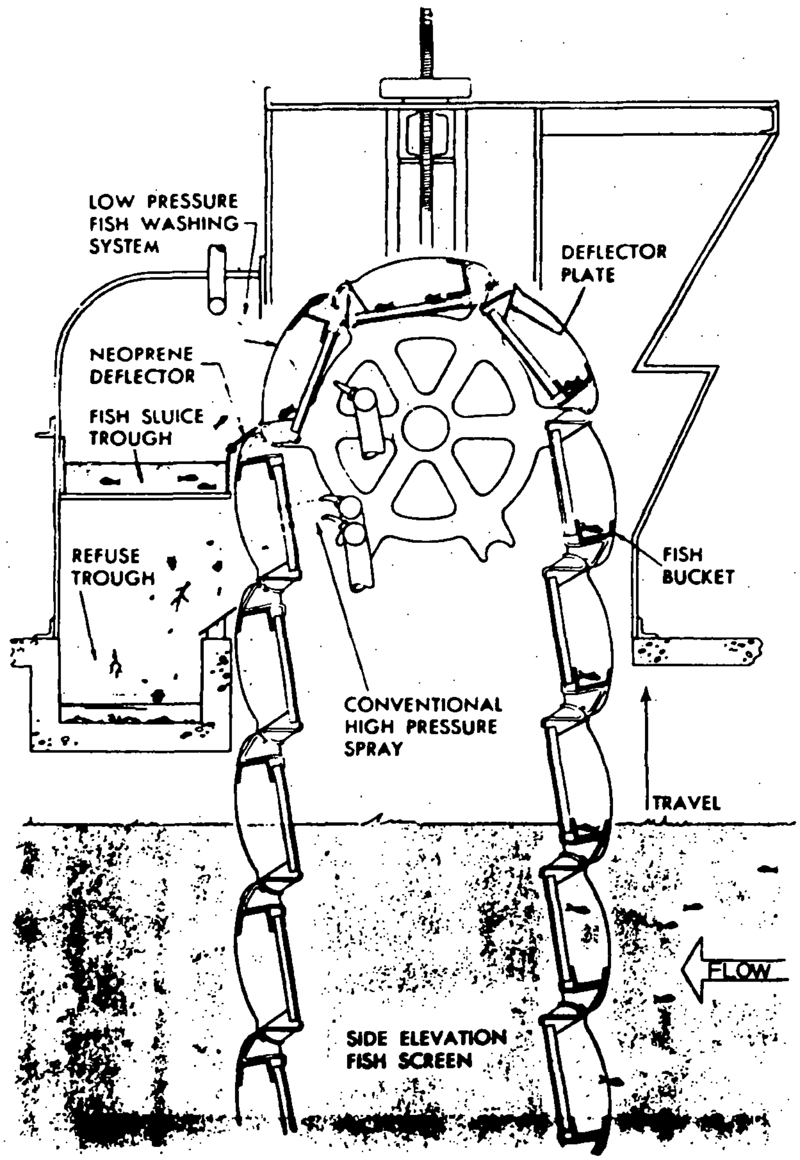


FIGURE 5.2-1
RISTROPH TRAVELING SCREEN WITH DOUBLE-TROUGH
FISH RECOVERY SYSTEM

DETAILS OF WEDGE WIRE WELL SCREEN

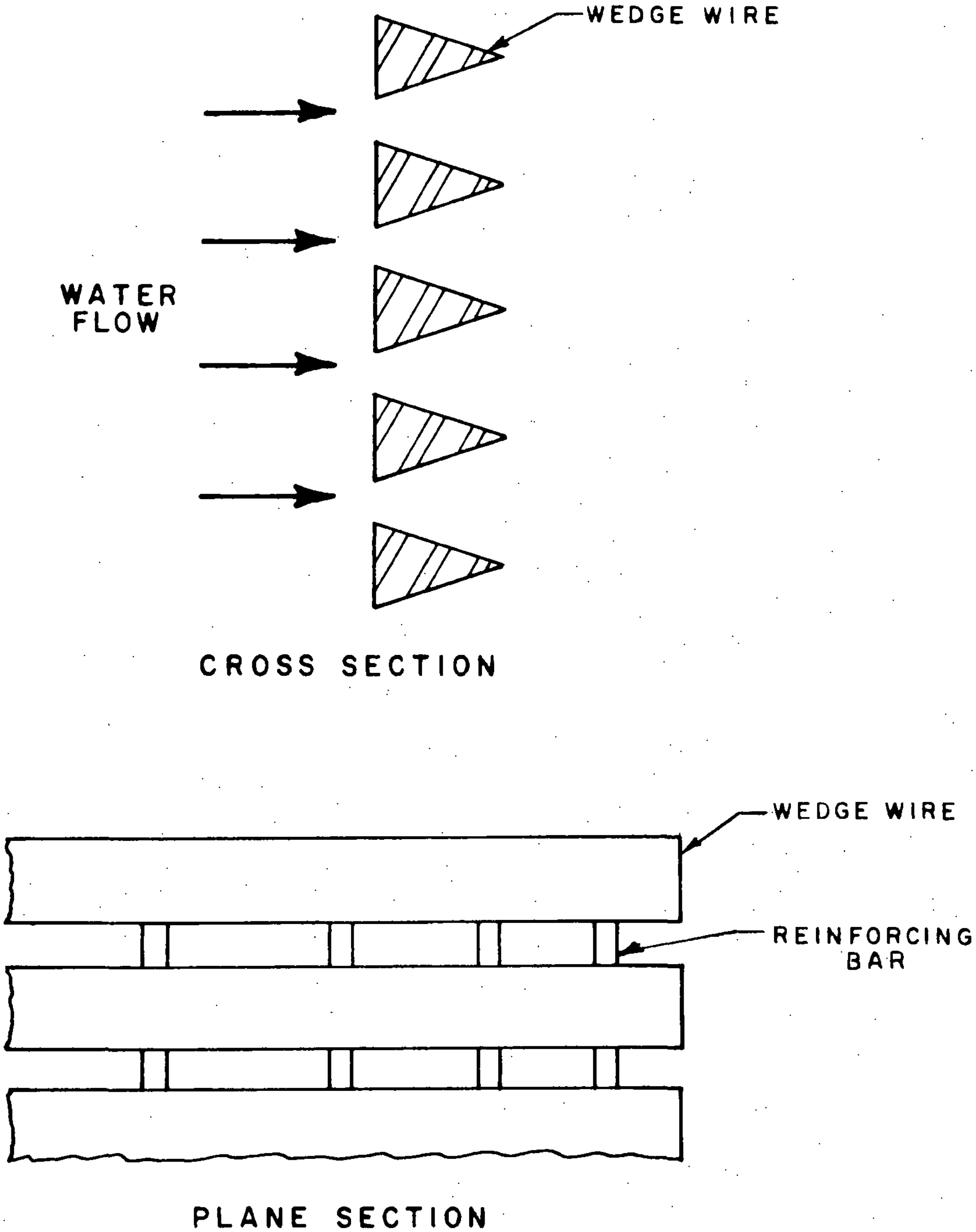
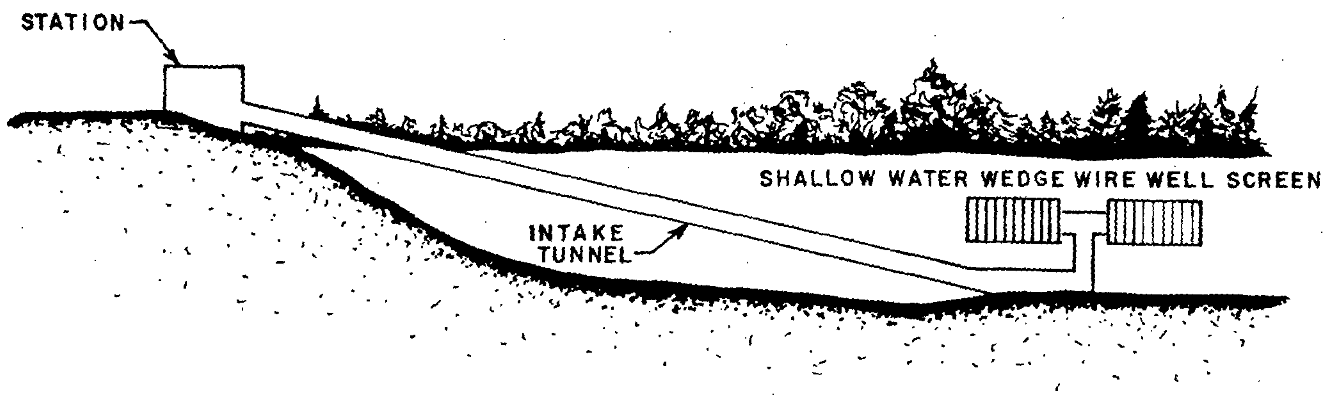
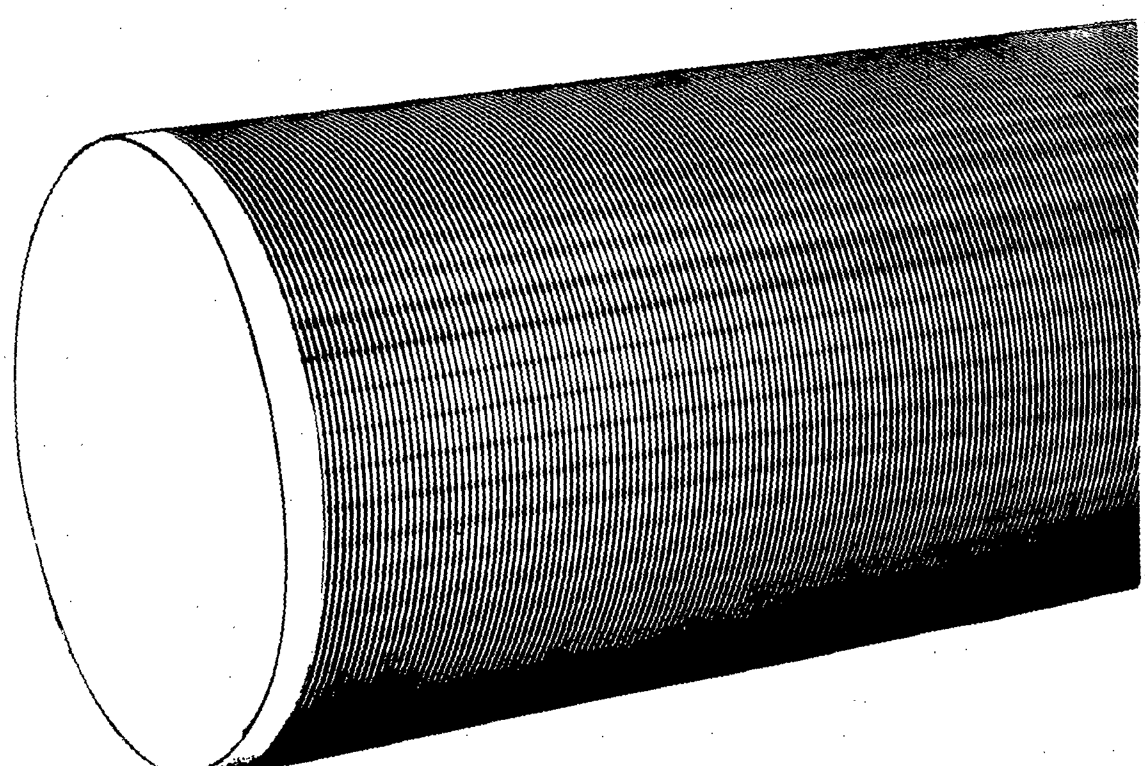


FIGURE 5.2-2





DETAILED VIEW OF WELL SCREEN

FIGURE 5.2-3

Chapter 6

CHAPTER 6: ECONOMIC ANALYSIS

CHAPTER 6: ECONOMIC ANALYSIS

This chapter is a presentation of the basic concepts used in the development of an economic analysis to assess the attractiveness of various alternative systems proposed for OCNGS and FRNGS. Section 6.1 provides the general methodology for determining the cost/benefit of an alternative system. Section 6.2 provides a more specific presentation of the cost/benefit analysis for OCNGS alternative systems. Because FRNGS already is designed to operate with closed-cycle cooling (BAT under Section 301(b)(2)(A)) and because the intake features recommended by the Section 316(b) Development Document, and other potential intake structure alternatives are now under study (as discussed in Section 5.2), no cost/benefit analysis of alternatives for FRNGS is included here. Appendix F contains a detailed description of how the major environmental effects associated with the operation of an alternative were identified and evaluated in monetary terms.

6.1 General Methodology for Determining the Cost/Benefit of an Alternative System

In order to evaluate the desirability of modifying the OCNGS to incorporate one of the various alternative intake and discharge/cooling systems analyzed, it was necessary to develop a methodology for equitably comparing the alternatives. To do this, an economic analysis was conducted in two parts: first, the capital and operating costs of each alternative were estimated; and second, the major environmental effects produced by the operation of each system were identified and translated into a predicted dollar value. (i.e. the environmental costs and benefits). An aggregate measure of the economic attractiveness of each system was obtained by summing the estimated capital, operating, and environmental costs and subtracting this total from the predicted environmental benefits. This allowed a ranking for each system of the alternatives considered for the OCNGS.

The design of the FRNGS discharge/cooling system already incorporates the "best available technology" under Section 301(b)(2)(A), closed-cycle cooling with cold-side blowdown. A wide range of cooling system alternatives was considered by JCP&L and GPUSC in selecting this design, but none of the alternatives would have achieved either a lower discharge rate or discharge temperature. As a consequence, the engineering and environmental analysis of FRNGS alternatives in Section 5.1.2 did not consider fundamental alternatives to the existing design. However, two "add-on" alternatives were analyzed: a small helper tower to cool the closed-cycle system blowdown, and a discharge pipe from the closed-cycle system to the bay.

Analysis of the possible add-on systems failed to reveal any noteable benefit to be obtained from their application to FRNGS. Indeed, there were several adverse impacts which would be associated with them. And, they would be relatively costly to construct and operate. Because of the clear lack of substantial benefit to be obtained, JCP&L concluded that further study was not justified and did not attempt to quantify either the costs or the marginal benefits which would result from implementation of the helper systems. Information on the costs of the systems and their potential effects can be obtained from Section 5.1.2.

Similarly, the intake system presently proposed for the FRNGS meets the design criteria currently accepted by the NRC and EPA. The proposed system utilizes Ristroph traveling water screens with 9.5 mm (3/8 in.) mesh fabric behind vertical trash bars. However, recognizing that this design may not be accepted by the EPA as best available technology at the station's in-service date of 1983, a number of possible intake alternatives were considered. While a detailed cost/benefit analysis of these alternatives was not undertaken given the present acceptability of the proposed design, some basic costs were developed and were presented in Section 5.2.2. Investigation into the benefits that may be derived from, and the compatability of, at least one of these alternatives, the wedge-wire well screens, will be conducted at the OCNGS intake canal. A decision to modify the proposed design to incorporate one of the alternatives or some variation thereof cannot be made until present investigations are complete.

6.2 Presentation of Cost/Benefit Analysis for OCNGS Alternative Systems

OCNGS Discharge/Cooling System Alternatives

In the development of a cost/benefit analysis for the various discharge/cooling system alternatives at the OCNGS, four types of major environmental effects associated with the operation of each alternative were identified and evaluated. These included reductions in damage to aquatic population, increases in ground-level fogging and icing, corrosion induced by salt deposition and increases in background noise levels. To incorporate these effects into the economic analysis, the following methodologies were used to translate the environmental impact of each type into monetary values.

Effects on aquatic organisms: Some alternatives will result in a reduction in species mortality levels from that of the present system through decreased impingement and entrainment as a result of reductions in intake water volume. However, in the case of at least one species, the blue crab, entrainment mortalities are expected to increase with the cooling tower alternatives. This is expected to occur even though the total number of organisms entrained is reduced since there is 100 percent mortality of the entrained biomass. A benefit also may be observed in a reduction of mortality consequent to the discharge effects, principally cold shock. To place a dollar value on these environmental effects, estimates of the annual changes in species mortalities were developed and translated into annual weight gains or losses in species stocks for all species with recognized commercial and/or recreational value. These estimated annual weight changes were then evaluated using weighted averages of commercial and recreational values per pound to estimate an annual aquatic benefit dollar value. The commercial values used in this analysis were based on estimates of ex-vessel prices, and the recreational values were derived from the ratio of an estimate of the consumers' surplus per recreation day of saltwater fishing to an estimate of the per diem weight of recreational harvests. Appendix F gives a more detailed analysis of how these values were obtained. From these values an aggregate aquatic cost/benefit was then determined.

Ground level fogging and icing: Some of the alternatives will result in increased ground level fogging and icing around the OCNGS site and thereby impact on vehicular traffic on portions of U.S. Route 9. Based on estimates of incremental hours of fogging and icing, estimates of changes in the number of accidents and the amount of time lost in delays due to speed reductions were developed. Changes in the number of fatalities, injuries, and damaged vehicles associated with changes in the number of accidents were also estimated and a dollar value was developed using estimates of consequent costs.

Materials damage from salt deposition: Some of the alternatives will result in additional environmental costs due to increased salt deposition in an estimated 30 mile square impact area around the OCNGS site. Although the salt deposition can produce economic damages to both material surfaces and vegetation, no distinct quantifiable impact on vegetation was identified. The analysis therefore focused exclusively on the damages to material surfaces. A population-weighted average deposition rate applicable to the entire impact area was developed and used to estimate the average annual increases in maintenance costs of steel and zinc metal systems based on increases in the rates of relative corrosion from salt deposition and estimates of the stock of exposed steel and zinc surfaces in the impact area. Damages to copper metals used in electrical components were estimated as a proportion of total damages to steel and zinc. Similarly, estimates of the average annual costs of maintenance of residential home sidings based on increased frequency of repainting due to salt deposition were developed and adjusted for projections of the stock of housing units in the area over the useful life of the discharge/cooling system.

Evaluation of increases in noise levels: Some of the alternatives are projected to increase nighttime noise levels beyond the company property lines to levels in excess of New Jersey noise standards for properties not zoned for commerical or industrial use. For those alternatives where mechanical noise attenuation is not feasible, resolution of this problem would require additional land aquisition to extend the property lines sufficiently to bring the augumented background noise levels at the perimeter below the standards. The boundaries of the required noise buffer zones were established and the projected cost of property acquisitions was developed based upon the market value of the acquired lots assuming a purchase year of 1982. Since property acquisition would involve the acquisition of residential dwellings, relocation costs, (including moving expenses and the costs of searching for new residences), were estimated and applied to the number of dwellings affected. The cost of land acquisition was not included in the cost of system development. The inconveniences which may be experienced by persons displaced from this area are, of course, not amenable to quantification.

All estimates of benefits and costs are expressed in terms of levelized annual values which establish a stream of constant annual benefits and costs which have the same present values as the actual benefit/cost streams projected for the period of operation of the system. The levelized annual values were calculated assuming a discount rate of 11.22 percent, a fixed charge rate of 22.25 percent and an operating period of 21 years (1984 through 2004).

The capital costs used in the analysis are defined to include a levelized capital cost to install the alternative system and the annual capital cost of any loss in plant capacity due to generation required to operate the new system, and of plant deratings resulting from increased turbine back pressure. The operating costs are defined to include the annual fuel cost, annual maintenance cost and annual water costs associated with the systems operation.

In determining the aggregate levelized annual benefits and costs from the installation and operation of the alternative discharge/cooling systems, single dollar values of the total capital and operating costs projected to be incurred were developed. However, due to the variable nature of the total environmental benefits and costs which may be incurred, ranges of these estimates were developed depicting best, most likely and worst cases. The best case combines high environmental benefit estimates with low environmental cost estimates; the worst case combines low environmental benefit estimates and high environmental cost estimates; and the most likely case generally represents an average of the best and worst case estimates.

Finally, it should be recognized that not all environmental costs and benefits are amenable to economic valuation. This may be a result either of insufficient data, or a lack of a definable economic index. For example, a canal-to-bay discharge alternative for the OCNGS would eliminate a section of freshwater marsh area. However, because little is known of its present and future development or productivity the cost of eliminating it cannot be estimated by any meaningful standard. In the same respect, it also is not possible to assign any kind of realistic economic valuation to the benefits from compliance with water quality standards, or a reduction in resident shipworm population in Oyster Creek. Thus, the net costs or benefits discussed should serve only as a focal point for assessing the relative effectiveness of the alternatives proposed and the nonquantifiable costs and benefits also should be considered.

Table 6.2-1 presents a summary of the aggregate levelized annual benefits and costs from the installation and operation of various alternative discharge/cooling systems at the OCNGS. The "preferred" alternatives presented in this summary include one open-cycle system (a canal-to-bay discharge identified in Appendix E1 as one of the "preferred" alternatives); and three closed-cycle systems (a natural draft tower, fan-assisted natural draft towers and round mechanical draft towers). The aggregate values presented represent additional costs per year which must be incurred over the cost of continued operation of the present once-through cooling system employed at the OCNGS. A review of this summary indicates that the total environmental benefits of any of the alternatives are greatly overshadowed by the total environmental, capital, and operating costs associated with that alternative. The canal-to-bay alternative has the most favorable cost-effectiveness value of all the alternatives considered with the costs exceeding benefits by $9.1 million. Among only the closed-cycle alternatives, the natural draft tower would be preferred when considered from a most likely case basis, with costs exceeding benefits by a value of $20.5 million.

OCNGS Intake System Alternatives

In the development of a cost/benefit analysis for the various intake system alternatives at the OCNGS, the environmental benefit derived from reductions in damage to aquatic population was translated into monetary values using a methodology similar to that described in the discharge/cooling system section on effects on aquatic organisms. Again, the estimates of benefits and costs are expressed in terms of levelized annual values over an assumed system operating life of 21 years.

Estimates of the values of the aquatic benefits derived from the various alternatives along with estimates of the capital and operating and maintenance costs associated with the installation and operation of these alternatives were presented in Section 5.2. Table 6.2-2 presents a summary of the levelized annual benefits and costs for the presently available intake alternatives. The circular wedge wire well screens were not included in this summary since the estimated levelized annual capital cost of this alternative ($25.8 to $36.2 million) clearly indicated that this alternative would not be economically feasible and further investigation into estimated benefits and operating and maintenance costs was not justified.

In reviewing Table 6.2-2 it can been seen that the environmental benefits derived would be greatly outweighed by the costs incurred for either of the Ristroph alternatives. However, as previously indicated, investigations into modifying the existing intake system are continuing. In spite of the relatively small direct benefits and the negative aggregate benefits to be derived from the installation of Ristroph screens at OCNGS, if the studies presently being conducted indicate that this alternative system is operationally feasible, JCP&L intends to minimize the aquatic environmental impact of OCNGS by installing Ristroph screens.

TABLE 6.2.-1

SUMMARY OF THE AGGREGATE LEVELIZED ANNUAL BENEFITS AND COSTS FROM INSTALLATION & OPERATION OF ALTERNATIVE COOLING SYSTEMS AT OCNGS

	Total Benefits	Total Costs		Total
	Environmental	Environmental	Captital and Operating	Benefits Less Costs
	-(Thousands of Dollars)-			
	(1)	(2)	(3)	(1)-(2)-(3) (4)
Canal-to-Bay Discharge				
Best Case	0	0	9,131	-9,131
Most Likely Case	0	0	9,131	-9,131
Worst Case	0	0	9,131	-9,131
Natual Draft Tower				
Best Case	20	110	20,368	-20,458
Most Likely Case	12	142	20,368	-20,498
Worst Case	4	175	20,368	-20,539
Fan-Assisted Natural Draft Towers				
Best Case	20	1,208	21,303	-22,491
Most Likely Case	12	1,262	21,303	-22,553
Worst Case	4	1,317	21,303	-22,616
Round Mechanical Draft Towers				
Best Case	20	1,211	20,807	-21,998
Most Likely Case	12	1,267	20,807	-22,062
Worst Case	4	1,324	20,807	-22,127

Note: The best case combines high environmental benefit estimates with low environmental cost estimates; the worst case combines low environmental benefit estimates and high environmental cost estimates; and the most likely case represents an average of the best and worst case estimates.

TABLE 6.2-2

SUMMARY OF THE LEVELIZED ANNUAL BENEFITS AND COSTS FROM INSTALLATION & OPERATION OF ALTERNATIVE INTAKE SYSTEMS* AT OCNGS

	Benefits Environmental	Costs Captital & Operating & Maintenace	Benefits Less Costs
Ristroph - 3/8 in. Mesh	$1800 to $3600	$254,662	-$252,862 to -$251,062
Ristroph - Wedge Wire	$1700	$329,576	-$327,876

*NOTE: Circular wedge wire well screens had an estimated levelized annual capital cost of $25.8 to $36.2 million. Because of the magnitude of the capital cost alone, no detailed estimates were made on the benefits or operating and maintenance costs of this system since these values would be insignificant when compared to the annual levelized cpaital costs.