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MILLSTONE NUCLEAR POWER STATION

UNITS 1, 2 AND 3

ENVIRONMENTAL ASSESSMENT

OF THE

CONDENSER COOLING WATER INTAKE STRUCTURES

(316 (b) DEMONSTRATION)

VOLUME I

+

VOLUME II

Submitted to

The

State of Connecticut

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MILLSTONE NUCLEAR POWER STATION
316 (b) DEMONSTRATION

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SUMMARY OF FINDINGS

INTRODUCTION

The Millstone Nuclear Power Station NPDES Permit issued by the Connecticut State Department of Environmental Protection requires continued ecological monitoring and special studies with results reported on or before September 30, 1976 for the purposes of consideration under Section 316(b) of the Federal Water Pollution Control Act. This report satisfies that requirement and demonstrates that the location, design, construction and capacity of the Millstone Units 1, 2 and 3 cooling water intake structures reflect the best technology available for minimizing adverse environmental impact. The demonstration is based upon results of hydrological and ecological monitoring and studies conducted before and during Unit 1 operation and upon extrapolations of observed impacts to three unit operation.

SITE AND PLANT DESCRIPTIONS

Millstone Nuclear Power Station is located in Waterford, Connecticut, on the north shore of Long Island Sound and the east shore of Niantic Bay (Figure 2.1-1). The site includes two operating units and a third under construction. Unit 1 is a 652-MWe boiling water reactor and has operated since November 1970. Unit 2, an 830-MWe pressurized water reactor (PWR), began operating in October 1975. The third unit is a 1,150-MWe PWR scheduled for commercial operation in May, 1982.

All three units employ a "once through" circulating water system. Intake structures typical of shoreline installations with trash racks and traveling screens will draw cooling water from Long Island Sound. The rated circulating flows for Units 1, 2 and 3 are 935, 1,220 and 2,000 cfs respectively. Including service water flow the power plants will utilize 4,342 cfs of cooling water ultimately discharged to Long Island Sound through an abandoned quarry. This flow represents about four percent of local tidal flow.

The intake structures also include design philosophies to minimize impingement such as shoreline continuity, cutoff walls extending below normal low water and minimal approach velocities. The Unit 3 design incorporates a fish handling system intended to reduce mortality subsequent to impingement.

Even though the intakes include these design features, various approaches for deterring fish and invertebrates have been researched. These include underwater lighting, acoustic stimuli, surface and bottom barriers and electric stimuli. Presently, further experimentation is planned for the surface and bottom barriers and underwater lighting.

MARINE ECOLOGY STUDIES

Biological monitoring was initiated at Millstone on a continuing basis in 1968. The investigations have been continually expanded and/or modified to provide sufficient scope with respect to the areas of concern and methodology available. Presented in this report are methods and results of studies pertinent to the demonstration and requirements of the NPDES Permit. Results of ecological monitoring at Millstone indicate that to date operation of Unit 1 has not significantly impacted the marine community in Long Island Sound around Millstone Point.

ASSESSMENT OF THREE UNIT OPERATION

Introduction

The assessment presents predictions of the effect of three unit operation on the Long Island Sound marine community around Millstone Point. Considered are impacts associated with impingement of organisms on power plant traveling screens and entrainment of organisms in condenser cooling water systems. The predictions are extrapolations based upon results of the ecological studies which in some instances represent a period encompassing two years prior to power plant operation and five years of one unit operation. The assessment utilizes mathematical models for the prediction of impact to winter flounder (*Pseudopleuronectes americanus*) and Atlantic menhaden (*Brevoortia tyrannus*). Rationale is provided for use of certain assessment approaches and for selection of winter flounder, Atlantic menhaden, and American lobster for detailed consideration.

Characterization of Effected Communities

Ecological monitoring and study results are used to characterize those populations impinged and entrained. Of the organisms impinged on the Unit 1 traveling screens from 1972 through 1975 and on the Unit 2 screens between September, 1975 and December 31, 1975, fish are represented by 76 species and invertebrates by twelve. Based upon a list of 90 percent of all fish taken from the traveling screens, the intakes impinge organisms of the rocky, shore-zone and benthic communities in which the intakes are located. Of the 90 percent, 28 percent are winter flounder. The other 62 percent consist of shore-zone or rocky area dwellers such as sticklebacks (*Gasterosteus aculeatus*), grubbies (*Myoxocephalus aenaeus*), silversides (*Menidia* spp.), cunner (*Tautogolabrus adspersus*), tautog (*Tautoga onitis*) and tomcod (*Microgadus tomcod*). Distributional analyses of shore-zone seine, otter trawl and gill net data indicate that the present shore line intakes minimize adverse impact from impingement relative to other potential locations onshore or offshore. Shore-zone seine catch effort values at a sampling station adjacent to the present intake locations are among the lowest of all stations sampled. Offshore gill net catches were dominated by two pelagic commercial species, Atlantic herring (*Clupea harengus*) and Atlantic menhaden (*B. tyrannus*) which presently represent only a relatively small percentage of the organisms impinged. Winter flounder are represented equally at most otter trawl stations except Niantic River where they concentrate during spawning. Further consideration is given to this species because of its recreational importance, its apparent abundance and widespread distribution around Millstone Point and higher relative impingement rate. Impingement observed to date is incorporated into a biological model to predict combined effect of entrainment and impingement on the Niantic River winter flounder spawning population.

The mortality of an estimated 50 million juvenile menhaden and blueback herring at the Unit 1 intake in late summer 1971 is evaluated through development of a population dynamics model.

Of the invertebrates impinged, the squid, (Loligo sp.) accounts for 33 percent. Four species of crab and the American lobster (Homarus americanus) constitute most of the other invertebrates taken. Survival of arthropods following impingement was extremely high. In 1975, blue crab (Callinectes sapidus) averaged 97 percent survival. All live specimens are returned to Long Island Sound. Lobster survival was also good averaging 79 percent in 1975 but the regional economic significance of this species required that additional consideration be given in this report relative to impacts from impingement by three operating units.

The entrained phytoplankton and zooplankton (excluding ichthyoplankton) populations are not found to be unique to the Millstone area. A similar phytoplankton community seems to be present over large areas of Long Island and Block Island Sounds. Entrained zooplankton is dominated by a group of common estuarine and marine copepods. Species composition and seasonal abundance were similar for entrainment and offshore studies at Millstone and for several other studies across Long Island Sound. For these reasons, a more general approach to the assessment of entrainment is taken for phytoplankton and zooplankton focusing on reproductive capacities and percent of local tidal flow entrained.

Ichthyoplankton demonstrates much year-to-year and regional differences especially the variable summer and migrant populations such as mackerel (Scomber scombrus), menhaden and bay anchovy (Anchoa mitchilli). These species are more abundant offshore. The more localized bottom and inshore species such as winter flounder, cunner and tautog are selected in this report for entrainment assessment with emphasis on the winter flounder.

Plankton Entrainment

In assessing the impact to plankton communities, a comparison is made between the amount of seawater required for cooling purposes and the tidal exchange. Combined three unit operation will utilize 4342 cfs of cooling water. The mean tidal flow in Twotree Island Channel is estimated at over 120,000 cfs and the tidal exchange in Niantic Bay averages over 100,000 cfs. By either comparison, the power plant intake flow represents about 4 percent of the local tidal flow. Because of the ubiquitous nature of phytoplankton and zooplankton in the Millstone area, the relative percent of local populations entrained should be roughly equivalent to the percent of tidal flow entrained.

The estimated amount in numbers or biomass of phytoplankton, zooplankton and ichthyoplankton to be entrained over an annual cycle is calculated. Point estimates (day or night, single or average over replicates) derived from entrainment studies were multiplied by the number of full days in the interval proceeding the point estimate. This product is multiplied by the daily cooling water volume (1.066×10^7 m^3/day) of the three units. For phytoplankton and zooplankton the numbers lost to entrainment are also judged by using a trophic level approach and by considering reproductive capacity. For ichthyoplankton the numbers are extrapolated to equivalent adults or factored into the mathematical models.

The impact of three unit entrainment on the phytoplankton community around Millstone is judged to be minor. Over a year of operation a total of 1.5×10^{18} phytoplankton cells are estimated to be entrained. Dominant species are Skeletonema costatum, Asterionella japonica, Thalassiosira nordenskioeldii and Thalassionema nitzschoides. Although 100% mortality of phytoplankton cells has been assumed, entrainment studies show the cells are available to the ecosystem subsequent to passage out of the quarry. Using a trophic approach, the amount of phytoplankton entrained annually would be equivalent to less than 10,000 pounds of carnivorous fish. Since the cells are not consumed by the Millstone units, however, this energy and material remains available to support the ecosystem in the vicinity. Allowing for continuous dilution with unaffected Long Island Sound water which has been shown to contain similar abundance and species composition of phytoplankton and considering the short generation time of phytoplankton, the effect of entrainment is expected to be insignificant compared to natural fluctuations.

Similar assessment approaches are used for zooplankton. Based upon results of entrainment sampling at Unit 1 in 1971 and 1975 the number of zooplankters estimated to be entrained by 3 units ranges between 2.5 to 6.7×10^{12} per year. Most of these are holoplanktonic calanoid copepods such as Acartia tonsa, Acartia clausi, Temora longicornis and Pseudocalanus minutus. Assuming a 10% conversion efficiency between zooplankton and primary carnivores, the equivalent dry weight of zooplankton entrained in 1975 might be equal to the wet weight biomass of 7474 pounds of fish over a year. Information from the literature is also provided to demonstrate the favorable reproductive characteristics of the dominant zooplankters found around Millstone. These factors include short generation time, high fecundity, high survivorship and variation of population sex ratios.

The zooplankton species composition and abundance is typical of a large area compared to the Greater Millstone Bight. Further, considering that the Millstone Units would be entraining only about 4% of the tidal exchange and since zooplankton have favorable reproductive characteristics, the effect of entrainment on zooplankton in the Millstone vicinity will probably be small and difficult to detect over natural seasonal and year-to-year fluctuations.

Ichthyoplankton entrainment extrapolations are made for total larvae, winter flounder, cunner and tautog. The maximum number of fish larvae affected by three unit operation based upon historical data would be about 2.2 X 10^9 annually. Equivalent adult calculations were applied to the number of cunner and tautog larvae entrained annually. Using 1975 entrainment data and establishing a range from day and night samples, an estimated 12 to 31 million cunner larvae and 21 to 31 million tautog larvae would be entrained by three units. These numbers are the equivalent of 2723 to 6872 reproductive cunner adults and 475 to 655 tautog adults. The number of adult tautog is compared to the annual sport catch of 150,000 to 300,000 in Gardiners Island Sound and Peconic Bays on the opposite shore of Long Island Sound.

The number of winter flounder and menhaden estimated entrained by three units is evaluated in terms of mathematical model predictions.

Winter Flounder Assessments

The winter flounder assessment utilizes the combined hydrodynamic, concentration and population submodels developed under the direction of Dr. Saul Saila at the University of Rhode Island, as well as impingement data, in a simulation of impact to the Niantic River spawning population. The selection of winter flounder as most appropriate for such detailed evaluation has been substantiated by ecological monitoring results. This species was most abundant in the otter trawls on a year round basis and constituted the highest relative percent (28) of the total fish impinged at Units 1 and 2. Adults are found concentrated each year in the Niantic River for spawning. Hatched larvae are subject to entrainment mortality as a result of prevailing current patterns and an extended larval period of up to 2-1/2 months.

The hydrodynamic and concentration models are used to simulate a hatch of larvae in the Niantic River and other possible breeding areas, and the movement of the larvae under the action of tidal currents around the river, the waters of Millstone Point and into Long Island Sound. A comparison of the final number in the waters near Millstone Point at the end of the larval period, with and without the plants in operation is used to estimate the entrainment mortality rate.

Results of a simulated river hatch show that after twenty tidal cycles only 30 percent of the total organisms remain in the Millstone Bight. A direct comparison of those remaining both with and without power station operation projected out to 150 tidal cycles indicates a plant mortality or a reduction in flounder entering year-class one of less than 1%.

Another significant finding of the simulated hatches was the favorable larval retention characteristic of the river compared to Niantic Bay or Jordan Cove. After 150 tidal cycles, enough larvae are retained in the river to account for the apparent larval survival of this species. Niantic Bay and Jordan Cove are flushed more rapidly.

Verification of the hydrodynamic and concentration submodels was accomplished through extensive hydrographic field surveys, dye releases and entrainment sampling. Results show excellent correspondence of field measurements and model predictions.

The model prediction of a 1% reduction in flounder entering year-class one is employed along with impingement rates (extrapolated from one unit to multiple units) in a compartmental population model of the Niantic River winter flounder population in order to simulate the impact of entrainment, impingement and the combination of entrainment and impingement over the life of the power station (35 years). After 35 years of three unit operation, the simulated population would be reduced by about 6 percent from entrainment alone. The population reduction from impingement after 35 years is 12 percent. Simulated with a 65 year recovery period after the termination of power station operation, the population recovers to within 2 percent equilibrium. The combined effects of entrainment and impingement associated with three unit operation when simulated for 35 years suggests an 18 percent reduction compared to the equilibrium population. The simulated population recovers to within three percent of the equilibrium population after 65 years from termination of power station operation.

The estimates of the change in the simulated winter flounder population when compared to tag-recapture population estimates of the Niantic River winter flounder population are well within the annual variability of this population.

Finally, it is pointed out that various conservative assumptions used in model formulation make the predictions upper bounds to the probable impact to the Niantic River winter flounder population.

Menhaden Population Dynamics - Power Plant Impact

This study estimates the effect on Atlantic menhaden based on the abnormal mortality that occurred at the Unit 1 intake in 1971 and also considers the effect from routine entrainment and impingement. Results suggest the effect of Millstone Station on menhaden is so minor that it probably will be undetectable. The worst case estimate of mortality rate for three unit operation is 0.00087 of the NY - NJ subpopulation based on input data from the 1971 incident. This mortality rate projected each year for fifty years results in a reduction in population size by 1.1 percent compared to the unaffected population.

The study consists of a review of the literature on the population ecology of Atlantic menhaden and a review of the published mathematical models for menhaden population dynamics. The University of Rhode Island (URI) reviewed the literature on methodology for the estimate of mortality in early life stages of fishes such as menhaden. URI developed a method for estimating the mortality to zero age class fish. The information on menhaden population dynamics is synthesized and used to develop a life cycle model which is used to make predictions of the effect of Millstone station on this species.

The model developed is an extension of those reviewed in Section 5.5. It assumes the population age structure is partitioned into ages one year to ten years. The model is a self-regenerating dynamic pool model using the Leslie model. The dimensionality is increased by partitioning the population into the subpopulations north of Chesapeake Bay, Chesapeake Bay area, and south to Florida.

The effect of entrainment of menhaden larvae on the population is determined from density estimates of menhaden larvae entrained at Unit 1 extrapolated to three units on the basis of flow. Predicted entrainment at all three units is 4×10^7 for 1973, 3.5×10^7 for 1974 and 2×10^6 for January through April of 1975. The highest estimate is converted to a mortality by considering the proportion of larvae in the NY - NJ subpopulation from the simulation model which could have been entrained. The mortality would be 0.000015 of the NY - NJ subpopulation.

Based upon similar impingement extrapolation from observations at Unit 1 since 1972, the mortality from this effect is calculated as the proportion of age one fish in the NY - NJ subpopulation from the simulation model which are estimated to be impinged or 0.0000005.

The worst case estimate is derived from an extrapolation of the 50 million juveniles killed at Unit 1 in 1971. If all these fish are assumed to be juvenile menhaden at age three months, the proportion of the three month old menhaden in the NY - NJ subpopulation from the simulation model representing this loss would be 0.00087. Since the mortality associated with routine entrainment and impingement is so small, for the purposes of simulation the largest mortality (0.087 percent) was assumed to occur each year. This is highly conservative. No incident of similar size has been observed since.

Various scenarios were then simulated using the 0.00087 mortality rate with density dependent and density independent formulations. These simulations indicated that even such incredible events, when repeated annually, would not significantly effect the menhaden population in the regions considered.

Lobster Assessment

The effect on American lobster from Millstone station operation was evaluated by comparing the numbers estimated to be impinged by three units (based on extrapolation from Unit 1 data) to estimates of the local population and to commercial catches in the New London County area of Long Island Sound. Entrainment was not considered since so few lobster larvae have been observed in entrainment samples.

An estimated 979 lobsters would be lost to the local population from impingement at Units 1, 2 and 3. This assumes survival at Units 2 and 3 is at least equivalent to the 79 percent observed at Unit 1. Actually, it is anticipated that the fish handling facility at Unit 3 will eliminate lobster mortality. Compared to the local population estimated by tag-recapture, the number of lobsters lost represents about 14 percent. This change is well within observed natural variability.

Compared to the pounds of commercial catch between 1972 and 1975 reported for New London County by the Connecticut State Department of Environmental Protection, the pounds of lobster lost each year by impingement at Millstone would be on the average less than 1 percent.

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SECTION 1

INTRODUCTION

The Connecticut State Department of Environmental Protection authorized by the United States Environmental Protection Agency issued an N.P.D.E.S. permit to Northeast Nuclear Energy Company for Millstone Nuclear Power Station Units 1, 2 and 3. Conditions of the permit require continued ecological monitoring and special studies with results reported on or before September 30, 1976 for the purposes of consideration under Section 316(b) of the Federal Water Pollution Control Act. This report satisfies that requirement and demonstrates that the location, design, construction and capacity of the Millstone Units 1, 2 and 3 cooling water intake structures reflect the best technology available for minimizing adverse environmental impact.

The demonstration presents general hydrological and ecological characteristics of Long Island Sound around Millstone Point, gives design features of each condenser cooling water intake structure and details the hydrological and ecological study results used in an assessment of the environmental impact of three unit operation.

SECTION 2

SITE DESCRIPTION

2.1 Station Location

The Millstone Nuclear Power Station is located in the town of Waterford, Connecticut, on the north shore of Long Island Sound and the east shore of Niantic Bay, 3.2 miles WSW of the New London town limits and 40 miles SE of Hartford, Connecticut. The site contains approximately 500 acres and is shown on the area map given in Figure 2.1-1.

The main station area, as shown in Figure 2.1-2 is located on a peninsula jutting into Long Island Sound, bounded on the east by Jordan Cove and on the west by Niantic Bay. The site has been in continuous industrial use for approximately two centuries, first as a quarry, more recently for light industry and research, and now for power generation.

The town of Niantic, consisting of a small commercial complex and attendant residential developments, is located 1.5 miles NW of Millstone Point. Other residential areas, many of which are seasonally occupied, stretch from Crescent Beach to Black Point on the west side of Niantic Bay, north along the shore of the Niantic River and east around Jordan Cove.

New London is the nearest urban center and includes mixed residential, commercial and industrial land uses. The surrounding area is dotted with institutional and government property.

2.2 Hydrography

Information relative to the hydrological characteristics of Long Island Sound adjacent to Millstone Point are available from surveys conducted in 1965 (E.R. Appendix B, Section III-B) and later in 1973 and 1974 (Summary Report, 1975). Bathymetric and tidal velocity measurements made in 1965 were utilized in calculating volume flow past the site. Measurements of tidal level, speed and direction were taken in 1973 and 1974 as part of an hydrodynamic model verification effort and were used to refine estimates of tidal periodicity and range (Section 4.2.5).

2.2.1 Tides, Tidal Currents and Volume Flow

Tides in Long Island Sound and in the Niantic Bay area are mixed diurnal-semidiurnal, with a dominant semidiurnal tide. Mean periodicity of the semidiurnal or lunar tide is 12 hours-25 minutes. Mean tidal range recorded during the August to September 1973 hydrographic survey at White Point was 2.70 feet.

Long Island Sound, a long, narrow body of water, acts as a tidal resonator. The tides at the closed western end of the Sound have a larger amplitude than the tides at the open eastern end - approximately 7 feet as opposed to 2 feet. For example, the mean tidal range at the Mystic River in Connecticut is 2.3 feet, while at Port Chester, New York, the mean tidal range is 7.2 feet (U.S. Department of Commerce, 1974). Increasing tidal amplitude from east to west is reflected in a detectable difference across Niantic Bay. The tidal range is greater at Black Point on the western side of Niantic Bay than at White Point on the eastern side by 0.18 foot. There is also a tidal phase lag with White Point leading Black Point by about 11 minutes.

The resonator effect in Long Island Sound results in strong tidal currents developing in the vicinity of Millstone Point. Current speeds logged by continuously recording meters at various points near Millstone usually ranged between 0.5 and 2.0 feet per second (fps). Representative data are shown in Figure 2.2-1. Maximum tidal currents occur about 4 hours after high and low water (U.S. Department of Commerce, 1974). Slack water occurs approximately 1 hour after low and high water.

Flow patterns in the Sound around Millstone Point are shown diagramatically in Figures 2.2-2 and 4.2-2, 3, 4 and 5. The movement of water at flood tide is toward the west with less well defined circulation in upper Niantic Bay and in Jordan Cove. With the ebbing tide, currents flow generally eastward past Millstone Point. The mean tidal flow in Twotree Island Channel is estimated at over 120,000 cubic feet per second. Across a line drawn from Millstone Point to Black Point a mean tidal exchange for Niantic Bay is estimated at over 100,000 cfs. These flows across Twotree Island Channel and Niantic Bay were estimated from the current components derived from the verified tidal circulation patterns presented in Figures 4.2-2 through 4.2-5. At each tidal stage, the current components perpendicular to the two cross-section lines were first plotted as shown in Figures 2.2-3 through 2.2-6. Flows were then obtained by multiplying the current components with the corresponding cross-sectional areas as shown in Figures 2.2-7 and 2.2-8. Summarized below are the different flows for the four tidal stages. It should be noted that both the direction and magnitude of flow vary a great deal depending upon the stage of the tide.

Tide Stage	Flow Duration	Flow Across Twotree Island Channel-cfs To West	Flow Across Twotree Island Channel-cfs To East	Flow Across Niantic Bay - cfs Into Niantic Bay	Flow Across Niantic Bay - cfs Out of Niantic Bay
Strength of Flood		136,710	0	146,435	92,893
High Slack		16,000	12,550	68,291	56,016
Strength of Ebb		0	140,616	123,050	188,928
Low Slack		7,098	9,171	48,409	30,562

This vigorous tidal circulation combined with a moderate negative current velocity gradient from surface toward bottom results in extensive mixing in the area and effective flushing.

Niantic River Tidal Flow

Niantic River estuary is also an important water body relative to the Millstone Nuclear Power Station. During late winter the river serves a large spawning population of Winter Flounder (Pseudopleuronectes americanus). Hatched flounder larvae are flushed into Niantic Bay and are therefore subject to power plant entrainment.

The River is a partially mixed estuary as opposed to the classical two-layered system. Freshwater inflow from Latimer Brook provides a small contribution to the total circulation which is tidally driven.

The River is connected to Niantic Bay by a restricted channel. This channel causes high and low water to occur in the Niantic River mouth about 50 minutes after occurring at Millstone Point. The tidal range is also 0.1 foot less in the Niantic River. Mean strength of flood and ebb velocities through the channel are approximately 1.5 fps.

Based upon tidal prism estimates, tidal flushing in the southern quarter of Niantic River is good but in the northern three quaters, tidal flushing is less pronounced. Flux at the mouth of Niantic River is estimated to reach a maximum of 7000 cfs and the lag between high water in the bay and the river is 72 minutes.

Wind Effects

Effects of wind stress on current patterns in Long Island Sound around Millstone Point are generally small when compared to tidal effects. Wind induced surface currents were estimated from wind records collected during the hydrographic surveys. An average wind speed of 10 fps could induce surface currents of about 0.2 fps in the direction of the wind. This translates to less than 10% of the maximum tidal currents. Throughout most of the year average wind speeds are less than 10 fps (Table 2.2-1). During storm conditions the wind may play a greater role in the upper circulation of Niantic Bay. Maximum observed surface currents during the winter hydrographic survey 1974 were about 3 fps. Wind induced surface currents estimated from the greatest mean wind speed (28.6 fps) were about 15% of maximum tidal velocities.

2.2.2 Water Quality

A substantial water quality data base is available for Long Island Sound around Millstone Point. Water temperatures have been continuously recorded at five land-based monitors since 1966. A one-year intensive water chemistry survey was conducted during 1974. Thirty parameters were analyzed from monthly samples taken at nine stations and other selected parameters were analyzed on a quarterly basis in sediments. Routine water quality measurements have been conducted on a regular basis as part of the ecological monitoring program initiated in 1968. Other sources include reports from the EPA, Dehlinger et al. (1973), Hardy (1971), Kollmeyer (1972) and Riley (1959).

Water Temperatures

Land-based continuous recording temperature monitors log near surface water temperatures at Millstone Point Cove, White Point, Millstone Environmental Laboratory, Niantic Bay Yacht Club and Mijoy Dock (Figure 2.2-9). Temperature sensors were added at Millstone Unit 1 intake and discharge and at the quarry cut in 1971.

Surface water temperatures were consolidated by averaging weekly maximum and minimum values between years 1966 and 1975 (Figures 2.2-10 and 2.2-11). Based on these presentations the maximum average water temperature for Niantic Bay area was 77°F and the minimum average was 26°F. The maximum temperature recorded among all onshore locations excluding the quarry stations was 81.5°F at Mijoy Dock during August, 1973. The maximum value recorded at the Unit I intake was 77°F in August, 1973 (Figure 2.2-11).

A marked trend in water temperatures at Millstone has been an increase in the average minimum temperature while maximum values have changed little. This warming has also been reported for the North Atlantic area (Ruddiman, et al. 1970) and is coincident with the occurrence of various organisms commonly associated with more southerly waters.

Salinity

Variations in surface salinity can be attributed to the amount of tidal action and freshwater runoff from tributaries. Salinity gradients occur along Long Island Sound because of the combined influx of high salinity water from Block Island Sound at the eastern end and freshwater input from the Connecticut River and other tributaries along Connecticut's coast. Salinities are found to decrease from about 30.0 ppt in Block Island Sound to 25 ppt at New York (Hardy, 1971).

Salinity data gathered around Millstone Point as part of ecological monitoring since 1969 indicate average values in the range of 28-30 ppt (Figure 2.2-12). Seasonal maxima occur from September to November peaking at greater than 31 ppt. Seasonal minima usually occur between March and May, generally at 27-28 ppt.

Niantic River salinities also exhibit seasonal fluctuations dependent upon tidal conditions and stream flow from Latimer Brook. Salinities range from over 29 ppt in late summer coincident with low freshwater runoff to values less than 24 ppt during winter or spring when filling of Lake Konomoc Reservoir results in overflows to Latimer Brook (Kollmeyer, 1972). Gradients of salinity have been observed from mouth to head in the river as well as vertically in the water column. The gradients are usually small except during the few periods of extreme runoff when layering can occur in the upper arm of Niantic River.

The seasonal difference in Niantic Bay and Niantic River water masses can be demonstrated through temperature-salinity (T-S) diagrams (Figures 2.2-13, 2.2-14). Niantic Bay is distinguished by higher salinity (30.0 ppt) and lower temperature characteristic of salt water entering through the race from Block Island Sound.

Dissolved Oxygen

Dissolved oxygen measurements taken at various locations around Millstone since 1969 are presented in Figure 2.2-15. Concentrations usually are lowest in September of each year and have been observed to reach values less than 4 ppm. Maximum dissolved oxygen levels are recorded in late spring and can exceed 12 ppm.

Hardy (1971) measuring dissolved oxygen in surface waters of eastern Long Island Sound also found well oxygenated waters in spring. At the Niantic River values of 12.7 to 13.3 ppm were observed at this time. In August, 8.0 and 8.3 ppm were found in the Niantic River.

pH

Figure 2.2-16 gives the time history of pH levels measured routinely during ecological monitoring since 1969 at selected stations around Millstone Point. The pH values are generally maintained between 7.0 and 8.0.

Water and Sediment Chemistry

Results of the one year intensive water quality survey conducted in 1974 are summarized in Tables 2.2-2 and 2.2-3.

The major seawater constituents in eastern Long Island Sound remain relatively constant, but are subject to minor fluctuations when ocean water is diluted, in varying degrees, by freshwater. These fluctuations are reflected in the changing salinities shown in Figure 2.2-12.

The total alkalinity and calcium concentration remained relatively constant throughout 1974. The chloride and magnesium concentrations fluctuate more than expected in a given month. The results indicate a problem with the analytical techniques. Potassium concentration is higher than would be expected.

The concentrations of ammonia, nitrite, nitrate and organic nitrogen are subject to seasonal fluctuation and are the rate limiting nutrient for phytoplankton growth. The fluctuations in concentration of these parameters reflect the changes in the phytoplankton growth cycle.

Both total and orthophosphate concentration build up to maxima in late February. Phosphate decreased to a nondetectable level in March, parallel to the nitrate depletion at that time. Low phosphate concentrations are generally maintained throughout the remainder of the year except for a slight increase in September. The amount of biodegradable organic materials in the water appears to be constant, but at a low concentration.

No fluctuations in Biochemical Oxygen Demand (BOD) with increased organic carbon concentration is apparent, suggesting fluctuations in the concentrations of organic carbon in the water are due to non-biodegradable material.

Trace metals concentrations are generally low, and suggest little input of heavy metals to these waters.

Quarterly samples of sediment were collected off the quarry cut and at Twotree Island Channel. The sediment analyses indicated that the concentrations of sediment constituents are less than, or equal to, concentrations in Chesapeake Bay, suggesting that the sediment near the Millstone discharge is characteristic of a nonpolluted sediment environment.

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2.3 Marine Ecology

The marine community in the area of Millstone Point is perhaps as varied as any marine community in northern temperate waters (Long Island Sound area). Since 1968, over 65 species of macroalgae; 50 species of phytoplankton; 40 species of zooplankton; 315 species of intertidal, epibenthic, and benthic invertebrates; and 105 species of fish have been collected in an area of approximately 10-square miles around Millstone Point. These 575 species are about 22 percent of the estimate of around 2,650 species in all of Chesapeake Bay (McErlean and Kerby, 1972) including bacteria, meiofauna, and other groups not specifically studied in the Millstone Point area.

The 575 species mentioned above constitute part of what can be called the indigenous marine community of the Millstone Point area, representing most of the key groups making up the essential food webs of the area and including all trophic levels from primary producer to top carnivore.

To understand the relationships between the populations in the community or between the various trophic levels, and the possible effects on these relationships by the operation of a nuclear power station in an ecosystem as complex as that in the greater Millstone bight, each population or trophic level must first be characterized. Following is a discussion of the major marine populations around Millstone Point. Some of the groups have been observed continually for over seven years, while others have been studied in detail for only two or three years. Included is a discussion of the life history aspects of the principal fish and invertebrate species in the vicinity of the Millstone Point Nuclear Station.

2.3.1 Intertidal Zone

The intertidal communities were selected as indicator communities when the Millstone Point Ecological Study began in mid-1968. Both rocky shore and sandy beach communities were investigated.

The dominant species along the natural rocky outcroppings and the man-made jetties in the Millstone Point area are the brown algae, _Fucus_ spp. and _Ascophyllum nodosum_. Three species of _Fucus_ occur around Millstone Point: _F. edentatus_, _F. evanescens_, and _F. spiralis_, an indication of the variety of ecological niches to be found in the rocky intertidal zone.

Usually both _Fucus_ and _Ascophyllum_ can be found in the same general intertidal zone, with _Fucus_ on the more exposed rocks and _Ascophyllum_ in the protected crevices.

Where there is a relatively heavy surf and waves are continually pounding the rocks, such as Bay Point, the only algal coverage will come from the clinging filamentous green algae like _Enteromorpha_ spp. and also the sea lettuce, _Ulva lactuca_.

Algal growth on the rocks at Bay Point was very sparse until 1974, when there was a considerable increase in both _Ulva lactuca_ and _Enteromorpha_ spp. This "bloom" decreased somewhat in 1975.

One noticeable effect of the thermal plume on the intertidal zone was seen along the southern tip of Fox Island, which is approximately 175 yards from the quarry cut and extends directly into the plume on an ebb tide. Up until the summer of 1971, the predominant algal covering was Fucus, with limited amounts of Ascophyllum. When the power station went into operation, Fucus and Ascophyllum were gradually replaced by Ulva and Enteromorpha, which covered the tip of Fox Island. The total area affected was small compared to the Fox Island study area, but the coverage by Ulva and Enteromorpha on the tip was so complete that it excluded the settling of the other plants and animals usually present.

When the power station was not operating for about nine months, Fucus and Ascophyllum rapidly began to reestablish themselves, indicating that the effects of the plume were not permanent.

Another species of green alga, Codium fragile, was found to have increased considerably at Fox Island, and by 1974 was identified from all of the rocky shore study sites.

Growth of Codium continued through 1975 and was particularly heavy along the southern portion of Fox Island and moderately so at Bay Point.

There has been a considerable increase in the number of algal species, especially the red algae, reported in the rocky intertidal zone since 1973. This may be due, in large part, to increased attention to the algal groups. There has also been, however, a similar increase in the algal species occurring on the exposure panels since 1971, and it is felt that while these species may have been in the area in limited quantities, changing conditions in Long Island Sound (since their occurrence is not limited solely to plant-influenced areas) have permitted them to occur in more noticeable abundance.

Barnacles are the most abundant invertebrate of the intertidal rocky shore. Most of the intertidal barnacles are Balanus balanoides; however, at Bay Point, the major barnacle species is B. crenatus, which is also quite abundant below the low water line at several sites where there are exposure panels.

In terms of biomass, mussels (Mytilus edulis) are the principal invertebrate occurring along the rocky intertidal zone.

There are a variety of invertebrates, other than barnacles and mussels, found on the rocks. Some occur occasionally; others, like the snail, Littorina littorea, are generally present. The character of the snail population has changed somewhat along the southern tip of Fox Island. The major species used to be L. littorea, as at the other sites. Within the past two years, however, there has been a significant increase in the number of oyster drills, Urosalpinx cinerea, found at Fox Island-South. This could be because the metabolites from the oysters growing in the quarry wash over Fox Island-South, virtually the only emergent land touched by the plume on the ebb tide. The drills are possibly being attracted to the oysters in the quarry area, and enough are present at Fox Island-South, which is near the quarry cut, to cause a noticeable shift in abundance.

Compared to the rocky shore, the sandy intertidal zone has few organisms, thus demonstrating the biological axiom - the more plants you have, the more animals you will have. There is virtually no attached plant life along the sandy intertidal zones. The substrate on the sloping beaches is primarily medium to coarse sand. The only species existing in this kind of environment, except perhaps for some of the minute forms living in the film of water in the interstices between the sand grains and not within the scope of the present studies, were the polychaete worms and amphipods.

The groups common to all of the sandy intertidal sampling sites were larger nematodes; immature Mytilus edulis (which do not survive to adulthood in the sandy areas); three polychaete families, Cirratulidae, Nereidae, and Orbiniidae; and two species of amphipods, Corophium insidiosum and Jassa falcata.

2.3.2 Benthic Zone

Riley (1956) indicated that benthic populations in shallow areas like Long Island Sound may be occupying the niche in the aquatic ecosystem usually ascribed to the zooplankton, i.e., primary consumer. This speculation was substantiated by Williams, et al., (1968) in shallow water in North Carolina.

Benthic communities, for the most part, are less mobile compared with plankton and fish and are unable to avoid undesirable change in their environment. Because of their diversity, they exhibit differential tolerances to various changes, natural and artificial. They could be, therefore, the most important indicator communities in the Millstone Point area.

There are two types of benthic communities to consider - the infauna, dominated by worms, mollusks, and amphipods; and the epifauna, such as amphipods, crabs, and lobsters.

Around Millstone Point, the benthic substrate is sand, with some emergent rocks. The majority of the benthic communities consist, therefore, of fauna rather than flora.

For the six benthic sampling periods since June, 1974, through September, 1975, 173 identifiable taxonomic groups representing ten animal phyla (including lobsters) have been identified from the eight subtidal sand stations. The greatest number of groups (69) were arthropods. Mollusks were represented by 46 taxa, and there were 39 species of annelids from 27 families.

The largest average faunal assemblages at any one sampling period (34) and the largest number of species or groups (44 in December, 1974) occurred in the Little Rock area of Niantic Bay, 25 feet deep at mean low water. The second largest average number of groups per sampling period (31) came from the site in front of the effluent at 20 feet mean low water, where 40 groups were collected in June, 1974.

The fewest average groups per sampling period (23), for those stations sampled since June, 1974, occurred at the intake area at 15 feet mean low water and in Twotree Island Channel at 25 feet mean low water. The station in the center of Niantic Bay produced only 15 groups per sampling period, but that was from only three sampling periods beginning in March, 1975.

As with the intertidal zone, where there are more plants, there are more animals. Consequently, the greatest number of benthic groups occurred at the rocky stations, although these groups are not necessarily representative of the general benthic area around Millstone Point. For the six sampling periods from June, 1974, through September, 1975, there were 49 algal species and 172 invertebrate species identified from the two subtidal rock stations.

At the Effluent station, 20 feet deep at mean low water, there was a mean of 21 algal species and 50 invertebrate species present per sampling period. Algal populations were dominated by two closely related red algae, Chondrus crispus and Phyllophora brodiaei, and a third red alga, Cystoclonium cirrhosum.

The dominant invertebrate species included the gastropod mollusks, Mitrella lunata and Lacuna vincta; and the bivalve Mytilus edulis; the polychaete worm, Sabellaria vulgaris; and the amphipod Corophium spp.

The Giants Neck subtidal rock station was also located in 20 feet of water. The algal species, fewer in number than at the Effluent, were dominated by Phyllophora brodiaei, which usually accounted for more than 50 percent of the algal biomass at that site.

There were also fewer invertebrates at the Giants Neck Station than at the Effluent. The snail, Mitrella lunata, was the most consistently collected invertebrate. Also consistent in the samples, but not as abundant, was the polychaete Sabellaria vulgaris.

The most important commercial fishery in the immediate Millstone Point area is for the epibenthic invertebrate, the American lobster (Homarus americanus). In 1973, a tag-and-recapture program to estimate the number of lobsters in the area was begun. Estimates made on a monthly basis from May, 1974, through May, 1976, ranged from around 500 in May, 1974, to almost 34,000 in April, 1975.

Increased tagging efforts begun in September, 1975, resulted in greater returns and more consistent estimates. Weekly estimates from mid-September, 1975, through May, 1976, ranged from a low of approximately 1,250 lobsters in September, 1975, to a high of approximately 23,800 lobsters around Millstone Point during the first week of December, 1975.

In general, the estimates indicate a population of lobsters (with a carapace length of greater than 55 millimeters) of less than 10,000. At this time, it is difficult to determine the number of legal size lobsters (carapace length of three and three-sixteenths inches, or approximately 81 millimeters) since most of the lobsters captured have been about 69 millimeters in carapace length.

An important benthic species not usually collected in the samples but present in the area in numbers to be least recreationally significant is the blue crab (Callinectes sapidus). To date, 4,462 have been collected from the intake screens of Units 1 and 2 since 1972, with almost half of them (2,023, or 45 percent) occurring in 1972. With both units operating for at least part of 1975, only 681 (15 percent) were collected on the screens in 1975.

2.3.3 Phytoplankton

Diatoms dominated the phytoplankton community in the Millstone Point area, accounting for 88 of the total of 128 species found by Carpenter (1971), Carpenter, et al., (1971) and Fontneau, (1976).

Stephanopyxis costata (Skeletonema costatum) was the most important species. It appeared in almost all of the samples and was the dominant species from early winter through summer, together with unknown microflagellates and co-dominant with the diatoms Thalassiosira nordenskioldii and Asterionella japonica in late autumn and early spring.

Other important diatom species observed were Thalassiosira pseudonana (Cyclotella nana) dominant in autumn; Thallassionema nitzschioides and Ceratulina bergonii, dominant in June; and Rhizosolenia delicatula, abundant in May and June.

Two cryptomonad flagellates, Rhodomonas minuta and Rhodomonas amphioxeia, were numerically dominant through the autumn and early winter of 1971, although they were not previously recorded for Long Island Sound by Conover (1956) or for nearby Block Island Sound by Riley (1952). The preservation technique used by Riley and Conover destroys these small naked flagellates, and they probably would not have been observed in their samples.

While dinoflagellates were not abundant as a group (only 16 species), the dinoflagellate Katodinium rotundatum was an important species appearing in all samples from March through June 1971, and often was more abundant than some of the diatoms.

Of the most important diatom species, i.e., consistently present from year to year, according to Riley (1967), only Thalassionema nitzschioides, Paralia sulcata, Thallasiosira decipiens, Thalassiosira nordenskioldii, Rhizosolenia setigera, and Rhizosolenia delicatula were observed in the Millstone area.

The bloom of Skeletonema in the Millstone Point area during the early spring and its importance in the phytoplankton agree with observations in Niantic Bay by Marshall and Wheeler (1965), Long Island Sound by Conover (1956), and Block Island Sound by Riley (1952), although the bloom at Millstone Point has occurred slightly later in the spring.

The diatom Leptocylindrus danicus was observed only frequently in the Millstone Point area, but is listed by Riley and Conover (1967) as present throughout the year and a major dominant form in Long Island Sound.

2.3.4 Zooplankton

Most of the zooplankton community is made up of seven species of copepods with occasional abundances of other taxa. The two species that dominate the zooplankton numerically are the calanoid copepods Acartia tonsa and Acartia clausi.

A. tonsa was usually present when samples were taken; however, its peak abundances occurred from about mid-summer through the fall, decreasing sharply through the colder winter months. The increase in abundance started in the Niantic River, and populations remained high in the river throughout the summer. The largest numbers of A. tonsa occurring outside the river were at the stations further out in the Sound.

Peak abundances of A. clausi coincided directly with the decline and lowest numbers of A. tonsa. Peak abundances of A. clausi started and remained in the Niantic River.

Other zooplankters which occurred in relatively high numbers around Millstone Point were the calanoids Temora longicornis, Pseudocalanus elongatus, and Paracalanus parvus; and two species of cladocerans Podon sp. and Evadne sp. They were all generally more abundant in the spring and summer.

2.3.5 Fish

At least 86 species of fish, from all collections combined, have been identified in the Millstone Point area. Shore-zone fish seines collected 35 species; otter trawls, 62 species; gill nets, 40 species; ichthyoplankton, at least 44 species; and 66 species were collected on the traveling screens.

While the fewest species occur in the shore zone, the greatest numbers of adults are found there. Numerically, the shore zone is dominated by the Atlantic silverside (Menidia menidia). About 64 percent of all fish collected in the shore zone since 1969 have been Atlantic silversides. The striped killifish (Fundulus majalis), and the mummichog (F. heteroclitus), each accounted for about seven percent.

Although not taken in the quantities that silversides were, the important residents of the shore zone also included the tidewater silverside (Menidia beryllina); the fourspine stickleback (Apeltes quadracus); the sheepshead minnow (Cyprinodon variegatus); the threespine stickleback (Gasterosteus aculeatus); the sand launce (Ammodytes americanus); and the pipefish (Syngnathus fuscus).

Occasionally, schools of migratory juvenile menhaden (Brevoortia tyrannus), pass along the shore in late summer and fall.

The shore-zone collecting sites are of three general types. The exposed beaches at Seaside, Crescent Beach, and Bay Point generally had the fewest fish, and these were the foragers such as the silversides M. menidia and M. beryllina. The protected sites, such as Jordan Cove and Sandy Point in the river, are nursery areas for many of the species in the area, but also harbor resident populations of the striped killifish, mummichog, and the various sticklebacks.

Intermediate areas such as White Point and Giants Neck usually contained species from both areas.

The offshore epibenthic fish populations are dominated by the winter flounder (Pseudopleuronectes americanus), which accounted for 41 percent of all fish collected in the otter trawls. Scup (Stenotomus chrysops) are also quite abundant, comprising 19 percent of the total number of fish in the trawl samples. Other common species taken in the trawls include the windowpane (Scophthalmus aquosus); two species of skates, Raja spp.; and cunner (Tautogolabrus adspersus); accounting for ten, seven, and five percent, respectively, of all fish collected by trawl since April, 1973.

Because of the important sport fishery for winter flounder, increased emphasis was put on determining the number of adults in the spawning population around Millstone Point, most of which occur in the Niantic River.

Based on a relatively limited number of returns from a tagging study done in 1974, estimates of the population of winter flounder in the Niantic River ranged from approximately 4,800 to 250,000. It was apparent that the variability in the returns was too high, so intensive mark and recapture programs were undertaken during the expected spawning seasons in 1975 and 1976.

The results of the 1975 study indicated that the total population of winter flounder in the Niantic River during that study period exceeded 160,000. This was higher than expected, and it is possible that this did not necessarily represent the spawning population since few flounder with ripe gonads were collected during the period.

A repeat of the study in 1976 produced an estimated 104,000 fish during the period from March 1 through May 5. Again, there were few fish with ripe gonads, indicating that much of the spawning may have taken place prior to March 1, 1976.

Rough estimates of the total winter flounder population in the Millstone Point area, based on the number of fish per area towed during the otter trawl collections ranged from a high of approximately 1,400,000 in 1973 to a low of 995,000 in 1975.

The gill nets sampled a different portion of the fish community than either the shore-zone seines or otter trawls. The Atlantic herring (Clupea harengus) represented 57 percent of all fish caught in the gill nets since 1971, with the menhaden, B. tyrannus, second with 15 percent.

Herring are seasonal in the Millstone Point area with the largest catches occurring in the winter. Menhaden, on the other hand, were generally present on a year-round basis.

The presence of the thermal plume did not seem to have any unusual attraction for fish. Catches in nets set in the thermal plume on both ebb and flood tides did not catch any more fish than nets set at the other sites, and in most cases, the catches were less than at some sites.

The largest catch-per-set was in Jordan Cove, and the smallest was near Bartlett Reef. There was basically no difference in the catches-per-set among the other sites.

Of the 86 species of fish collected around the Millstone Point area, the eggs and larvae of at least 21 of them have been collected since 1973, indicating that a large portion of the fish use the area for spawning and as a nursery ground.

Eggs and larvae can be found in the water around Millstone Point during every month. Most of the spawning periods occur in the spring and summer. There are, however, some late fall and winter spawners like the cod (*Gadus morhua*) which spawns from early November into early April; and winter and early spring spawners like the haddock (*Melanogrammus aeglefinus*) and the winter flounder (*P. americanus*). The eggs of the winter flounder are demersal, and are not found in the plankton. Summer flounder (*Paralichthys dentatus*) eggs, on the other hand, can be found in the area from an October peak period through April, the longest period for any of the species.

A large part of the spawning in the area takes place in the Niantic River, as most of the eggs collected occurred at stations in the river. However, the collecting station further offshore had the greatest number of larvae per cubic meter, with the station furthest up the river having the least larvae per cubic meter. Most of those were winter flounder.

Engraulid larvae comprised the largest single percentage (30 percent) of the total larvae collected with winter flounder second (13 percent).

Clupeid larvae were fifth in terms of actual abundance, but were present in most collections making them the most abundant species relatively.

The greatest number of species collected in any one month during the study period (35) occurred in June, 1974, while the greatest number of larvae collected during any month occurred in July, 1973.

Of the species of fish collected through 1975 around Millstone Point, 66 of them were found in the intake baskets. The "catch per unit-effort" was quite small however. For example, a total of 2,917 winter flounder were counted in the intake trash baskets of Unit No. 1 in 352 days, or approximately eight winter flounder per day. Otter trawls, conducted biweekly at stations in 1975, resulted in 5,729 winter flounder, or approximately 18 per 15-minute tow.

A total of 14,294 fish was collected in the trash baskets of the Units No. 1 and 2 intake screens in 1975. Table 2.3-1 shows thenine most abundant species impinged in 1975. Winter flounder represented 20 percent, while the silver hake, second-most abundant species with 1,693 individuals, comprised 12 percent. The three spine stickleback was third with 1,450 individuals. The approximate 2,900 winter flounder impinged represents only about one and one-half percent of the 160,000 flounder estimated to be in the Niantic River during 1975.

A number of fish species occur only occasionally in the samples or on the intake screens but are nevertheless present in sufficient numbers to make them commerically or recreationally important. Two such species are the bluefish (Pomatomus saltatrix) and the striped bass (Morone saxatilis) both of which are caught seasonally by recreational fishermen using hook-and-line.

Most of the bluefish were taken in samples in the fall, when schools of migratory juveniles were in the near-shore area. Through December, 1975, there was a total of 159 bluefish captured by sampling and 112 impinged on the screens of Units 1 and 2.

Striped bass were taken only in gill net samples. A total of six was captured since 1971. Likewise, only 14 were impinged on the screens of Units 1 and 2 since 1972.

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2.3.6 <u>Pertinent Life Histories</u>

Following are brief descriptions of the life histories of the more abundant fish and shellfish occurring in the Millstone Point area. The species discussed here were selected because of their occurrence in the top 95 percent of at least one type of sampling (e.g., shore-zone seines, gill nets, otter trawls), their occurrence on the intake screens, or because they are known to be either commercially or recreationally important, e.g., the striped bass. Some species, such as the cusk (*Brosme brosme*), are important constituents of the ichthyoplankton, although the adult forms are rarely captured by sampling or impingement.

<u>Fish</u>:

Blueback Herring (*Alosa aestivalis*)

<u>Range</u>

Occurs along the American coast as far south as northern Florida and as far north as southern New England.

<u>Life cycle and habitat requirements</u>

This species grows in saltwater but migrates into fresh water to spawn. Little is known of their movements in the sea, except that they are schooling fishes.

Their breeding habits are similar to the alewife (*Alosa pseudoharengus*) but it does not spawn until the water is 70-75 F. The eggs sink, sticking to anything they chance to touch. At 72 F incubation takes approximately 50 hours. The young find their way back to the sea and the spent fish return shortly after spawning.

<u>Abundance</u>

This is an abundant form in the Connecticut waters as is evidenced by gill net catches.

<u>Food and other interspecies relationships</u>

The blueback herring is a plankton feeder, feeding chiefly on copepods, pelagic shrimp, sand launce and small fish fry.

Alewife (<u>Alosa</u> <u>pseudoharengus</u>)

Range

Gulf of St. Lawrence south to North Carolina.

Life cycle and habitat requirements

Alewives are found in both salt and fresh water. However, they are found in the latter only during the spawning season. Alewives spend much of their time at sea, either on or near the surface.

The spawning season of this fish is in April and May. The mature alewives swim up fresh water streams to spawn. The female alewife deposits as many as 100,000 eggs in lakes or sluggish streams. These eggs are heavy and adhesive, enabling them to anchor securely on the bottom. They hatch in about six days at about sixty degrees Fahrenheit.

The larvae remain in fresh water after hatching, remaining there until their first winter, by which time they have reached lengths up to four and one-half inches before moving downstream and out to sea.

Alewives grow at a rate of about two inches per year and reach sexual maturity by their third or fourth year, at which time they are between seven and eight inches in length. Alewives may reach a maximum size of up to fifteen inches. This fish spends most of its life at sea, except for spawning migrations into fresh water, which they start by the third or fourth year.

Alewives have been captured by both trawls and gill nets at the inshore and offshore stations. They have been taken by shore-zone seine, primarily in the Giant's Neck area. Alewives have also been found impinged on the rotating screens of Millstone Point generating station.

Abundance

In the period May, 1969, through December, 1975 alewives represented less than 1% of all fish taken with shore-zone seines. The majority of those caught (97%) were taken at Giants Neck in 1971. They also accounted for less than 1% of all fish taken in trawls from July, 1973, through December, 1975. While alewives have been recorded as being impinged in 1973, 1974, and 1975, it was not until 1975 that they accounted for as much as 1% of the total yearly impingement catch. From December, 1971, to December, 1975, alewives accounted for 2% of all fish taken with otter trawl sampling gear.

Food and other interspecies relationships

During their stay in fresh water, young alewives feed on diatoms and copepods. After they move to the sea as adults, they feed on shrimps, crabs, and small fish. The alewives are preyed upon by large predator fish.

Sand lance (Ammodytes americanus)

Range

Atlantic Coast of North America from Cape Hatteras to the Gulf of St. Lawrence, northern Newfoundland and northern Labrador, perhaps to Hudson Bay. This species was taken in shore seines at White Point.

Life cycle and habitat requirements

Sand lance are usually found along sandy shores and over the shoals of offshore fishing banks. They tend to swim in dense schools. They are often found buried in the sand above the low water mark at low tide, awaiting the return of the tide. Their sharp-pointed snout enables them to dig several inches into the sand with great speed.

It is not known whether they also follow this habit in deeper waters. If it is done for refuge it is not always successful, for porpoises have been seen rooting them out of sand (Smith, 1895 as cited by Bigelow and Schroeder, 1953).

The spawning has not been observed. However, the chief production of eggs occurs in autumn and early winter. The Gulf of Maine appears to be a site of considerable production with spawning beginning as early as November and progressively later to the northward. Apparently the sand lance breeds successfully throughout the northern part of its range. The actual spawning grounds are not known but it is surmised that the habits of the European species, which deposit their eggs on sandy bottoms in approximately 10 fathoms where they adhere to the sand grains, most likely applies to the American form as well.

Food and interspecies relationships

The sand lance feeds on many small marine animals though especially on copepods and on fish fry including their own. Worms have also been taken from the stomachs but it is believed that this species does not feed while burrowing.

Its importance, especially in the economy of the northern seas, is as food for larger fish including finback whales, porpoises, cod, haddock, silver hake, salmon, mackeral, striped bass and bluefish. They also form the primary source of food for the common tern (Ian Nesbitt, National Audubon Society, personal communication).

General

The numbers that have been taken in the Millstone area may not be indicative of the abundance of this species. Due to the rapidity in which they can burrow into the sand they may well be able to avoid the seining net.

It would seem that this species would be very sensitive to higher temperatures.

Striped anchovy (<u>Anchoa hepsetus</u>)

Range

Most common from the West Indies to Chesapeake Bay, a stray as far north as Nova Scotia.

Life cycle and habitat requirements

This fish occurs in shallow waters and prefers sandy beaches and shoal waters.

At Millstone, the striped anchovy spawns from June until September with June being the month of peak presence for the eggs of the striped anchovy.

The various anchovies are very difficult to distinguish in the larval stage. However, the anchovy family Engraulidae represents 33 percent of all larvae taken at Millstone in the period of May, 1973 to May, 1975. July and August are the months when anchovy larvae are most abundant at Millstone.

As an adult, the striped anchovy can reach lengths of up to six inches. It generally travels in large schools, and in winter withdraws to deeper water to avoid extremely cold water.

The striped anchovy has been taken in surface gill nets at Black Point, Jordan Cove, and the effluent. While the striped anchovy has not been specifically identified in either trawls or impingement catches, the anchovy family Engraulidae has been taken with both methods. The Engraulidae taken in trawls were captured at the shore stations and up in the Niantic River.

Abundance

The striped anchovy accounted for one percent of the total gill net catch at Millstone in the years 1971 to 1975. Engraulidae represent one percent of the total otter trawl catch for July, 1973, to December, 1975. In the years 1973 and 1975, anchovies accounted for less than one percent of all fish impinged; however, in the year 1974, they represented two percent of the total impingement.

Food and other interspecies relationships

The food of the striped anchovy consists mainly of small crustaceans such as shrimps and copepods. The striped anchovy plays a major part in the diet of larger predatory fish, especially in estuarine ecosystems.

Bay anchovy (<u>Anchoa mitchilli</u>)

<u>Range</u>

Coast of United States from Maine to Texas, chiefly west and south of Cape Cod.

<u>Life cycle and habitat requirements</u>

The bay anchovy is generally found in shallow waters. It will sometimes ascend freshwater streams. It is found most often on hard packed, clean sand.

At Millstone, the bay anchovy spawns from June until the end of September. June and, to a lesser extent, July are the months when the bay anchovy's eggs are most abundant in the waters around Millstone. Though the egg takes only 24 hours to hatch, it sinks to the bottom 12 hours after hatching due to a lack of natural flotation.

The various anchovies are very difficult to distinguish in the larval stage. However, the anchovy family Engraulidae represents 33 percent of all larvae taken at Millstone in the period of May, 1973, to May, 1975. July and August are the months when anchovy larvae are most abundant at Millstone.

The adult bay anchovy seldom grows to a length greater than four inches. It spends its life in large schools, frequenting sandy beaches. It will, however, move offshore in the winter to avoid extremely cold water.

The bay anchovy has been taken with shore-zone seines and gill nets at Millstone. The anchovies captured in gill nets were taken at the effluent station in a surface set gill net. While the bay anchovy has not been specifically identified in either trawls or impingement catches, the anchovy family Engraulidae has been taken with both methods. The Engraulidae taken in trawls were captured at the near shore stations and up in the Niantic River.

<u>Abundance</u>

The bay anchovy accounts for less than 0.1 percent of the total shore-zone seine catch. The anchovies captured by gill net were not taken until 1975 and reflected less than one percent of the total catch for the period 1971 to 1975. Engraulidae represent one percent of the total otter trawl catch for July, 1973, to December, 1975. In the years 1973 and 1975, anchovies accounted for less than one percent of all fish impinged; however, in the year 1974, they represented two percent of the total impingement.

<u>Food and other interspecies relationships</u>

The bay anchovy's diet consists primarily of mysids and copepods with adults preferring the former and the young anchovy the latter. The anchovy is important as it appears to enter into the food of larger fish extremely often. This is especially true in estuarine communities.

American eel (<u>Anguilla</u> <u>rostrata</u>)

Range

The Atlantic Coast from New Foundland to Florida, also the Gulf of Mexico.

Life cycle and habitat requirements

The American eel is found in both fresh and salt water. In general, it prefers a muddy bottom and still water. This is not always the case, however, because the eel is often found in swift streams and on rocky sections along the coast.

The American eel begins its spawning migration in the fall. Adult eels, both males and females, move downstream and out to sea. Their ovaries ripen as they reach their spawning ground, which is far out at sea in an area east of Florida and south of Bermuda.

Eels spawn in mid-winter, laying as many as 15 to 20 million eggs at one time. After spawning, the eels die. The eggs float in the intermediate water layer until hatched.

The hatched larvae grow until they are about 60 mm in length, at which time they go through metamorphosis. After this change, young eels resemble adult form.

By spring of their first year, the young elvers (as the metamorphosed larvae are called) are between two and one-half and three inches in length. At this time, May and June, they have completed their journey from their spawning ground to the coast of North America. Many of these elvers remain in the sea inhabiting sheltered bays and estuaries, but others enter into fresh water, often ascending great distances up freshwater streams. These elvers represent less than 1% of all larvae taken at Millstone.

The young elvers remain and grow to adults in these areas. Growth is a slow process; a two-year-old eel generally measures about 5 inches in length. While the American eel may grow up to four feet in length, the average size is between two and three feet.

At Millstone, the American eel has been found impinged on the rotating screen of the generating station. It has also been taken with shore-zone seines and trawls. While the eel has been taken in Niantic River and the shore stations, it is absent from the deepwater trawl stations.

Abundance

At Millstone Point during the period of May, 1969 through December, 1975, the American eel accounted for less than 1% of all fish taken by shore-zone seines. It also represented less than 1% of all fish taken with trawls from July, 1973, to December, 1975. In 1972, the American eel comprised 1% of all fish impinged; however, in the years 1973 through 1975, the American eel accounted for less than 1% of all fish impinged in each year.

Food and other interspecies relationships

The American eel is an omnivorous fish feeding on both living and dead matter. Its diet consists of crustaceas, worms, fish, mollusks, and eelgrass. It is reported to be very destructive of other fish, so much so that occasionally bounties have been offered on these eels.

Fourspine stickleback (Apeltes quadracus)

Range

From the southern side of the Gulf of St. Lawrence to Virginia.

Life cycle and habitat requirements

This fish is common in the salt marshes. It often runs up into fresh water, though it is primarily a saltwater fish. It is never found far from the coast or out at sea. It is often found in dense sea grass.

The fourspine stickleback spawns during the months of May and June. The mating practices of the sticklebacks are quite peculiar. The male first builds a nest of plant fragments which he cements with mucous threads. The male then picks up the eggs that the female has laid, which adhere together in clumps, and deposits them in the nest and guards them for the incubation period which lasts about six days.

The larvae of the fourspine are about 3.5 millimeters when hatched and reach a length of two and one-half inches when full grown.

The adult fourspine stickleback is, in general, a year-round resident of a given area, but there is some evidence that this fish may winter in slightly deeper waters in order to avoid extremely cold temperatures.

The fourspine stickleback has been taken at all shore-zone seine stations, but Jordan Cove shows a much higher concentration than any other station. The fish has also been taken trawls at Millstone. They are taken most often at the stations in the Niantic River, but have also been captured both at Millstone Point and Jordan Cove.

Abundance

In the period May, 1969, to December, 1975, the fourspine stickleback accounted for 1.7 percent of the total shore-zone seine catch. The fourspine also represented two percent of all fish taken at Millstone by otter trawl in the period July, 1973, to December, 1975.

Food and other interspecies relationships

This species feeds chiefly on small crustaceans, the majority of which are amphipods.

While the fourspine stickback undoubtedly contributes to the diet of larger predatory fish, their protruding spines may make them somewhat difficult to swallow. For this reason, they do not contribute as heavily to the predator's diet as do some of the other small fish.

Menhaden (<u>Brevoortia</u> <u>tyrannus</u>)

Range

Coastal waters along the Atlantic coast of America from Nova Scotia to eastern Florida. This species has been taken at all seining sites in the Niantic Bay area and great numbers, forming extremely dense schools, have been observed in late August and September.

Life cycle and habitat requirements

It is said but not yet proven that this species moves inshore on the flood tide and offshore on the ebb. The menhaden is a schooling species where one school may have as many as a thousand individuals. Though little is known about their breeding habits the chief production of eggs is south of this area and the adults spawn at sea. Spawning off southern New England begins in June and continues through August (according to Reintjes, 1969, they spawn from May to October). Menhaden are a warm water fish, apparently not appearing in the spring until the coastwise temperature has warmed to 50 F or more, or in abundance until the temperature is several degrees higher. According to Bean (1903, as cited by Bigelow and Schroeder, 1953) menhaden will not survive in an aquarium if the water chills below 50 F.

Eggs have been collected in Long Island Sound from May to October (Perlmutter, 1939; Wheatland, 1956; Richards, 1959 as cited by Reintjes, 1969).

Larvae move into estuaries where they transform into juveniles and where they remain up to 8 months before returning to the sea. This species has been taken at all seining sites during July and September.

Menhaden occur annually at points between Cape Cod and northern Florida with striking regularity. Most likely the dense schools observed in early fall in Niantic are part of the southern migration.

Abundance

The appearance of schools and the apparent seasonal movements along the coast accompany changes in water temperature.

Salinity does not seem to restrict distribution during most of the life cycle. Juveniles and adults tolerate salinities of less than 1 to as high as 36 ppt. Eggs and larvae are usually in salinities greater than 25 ppt but Wheatland (1956), Richards (1959), and Herman (1963) found eggs and small larvae in Long Island Sound and Narragansett Bay in salinities as low as 18 ppt (Reintjes, 1969).

This species tends to fluctuate tremendously in abundance from year to year (Bigelow and Schroeder, 1953).

The largest schools observed at Millstone were in the fall of 1971. June (1972) suggests that there is probably an optimum school size for fish of a given length, that is more favorable for survival.

Food and interspecies relationships

The menhaden feeds mainly on microscopic plants, especially diatoms, and the very small crustacea. It sifts the organisms out with comb-like gill rakers. The food eaten at any given locale parallels the general plankton content of the water excluding the largest and smallest forms.

This species is the prey of every predaceous animal, the worst enemy being the bluefish. Other predators include striped bass, cod, pollock, osprey, and herring gull.

The menhaden, over the years, has been one of the most important, commercially, of the fishes of the Atlantic coast, being used for the manufacture of oil, fertilizer, and fish meal (Bigelow and Schroeder, 1953). However, the number of bunker boats in Long Island Sound has decreased substantially in recent years.

Studies on young menhaden (Lewis and Hettler, 1968) indicate that 33 C (91.4 F) is the lethal temperature, and the length of time they can survive is dependent on the acclimation factors. That is, if the temperature is raised gradually over several days, they can survive longer than if the temperature was raised in a few hours.

Existing environmental stresses

This species experienced massive kills along the Connecticut coast of Long Island Sound during 1971. The actual cause of death is not known. This species appears to be very much attracted to warm waters but at the same time cannot withstand extended exposure as was witnessed by the massive kills in the quarry of the Millstone Nuclear Power Station during the summer of 1972.

Cusk (<u>Brosme brosme</u>)

General range

From Newfoundland to Cape Cod, rarely to southern New England and only occasionally to New Jersey.

Life cycle and habitat requirements

The cusk ranges from depths of 10 fathoms to extremes of 530 fathoms. It is most common, however, between 10 and 100 fathoms. The cusk is found chiefly on hard or rough ground and only occasionally on mud or clean sand.

Cusks spawn from early April until the end of July. In May and June, the cusk's egg reaches peak presence in the Millstone waters.

Cusk larvae are seldom taken at Millstone; and, in fact, from the period May, 1973, until May, 1975, they represent less than one percent of the total larvae catch.

As an adult, the cusk is more or less solitary; and after it takes to the bottom, it is almost exclusively a ground fish - seldom, if ever, rising to the upper waters.

The cusk has been recorded as one of the species which have been impinged on the rotating screen at Millstone.

Abundance

From the years 1973 to 1975, the cusk has comprised less than one percent of the total number of fish impinged on the rotating screens.

Food and other interspecies relationships

Little is known of the cusk's diet; but as he is a sluggish and weak swimmer, it is doubtful that other fish comprise a major part of this diet. His diet most probably consists of crabs, mollusks, and other crustaceans.

Atlantic Herring (Clupea harengus harengus)

Range

Found on both sides of the North Atlantic. It is found on the American coast as far north as Northern Labrador and west coast of Greenland and as far south as Cape Hatteras although only occasionally in winter and in small numbers. It is a common form in the waters off Cape Cod and Block Island. This species has only been taken rarely at Bay Point.

Life cycle and habitat requirements

The Atlantic herring is an open water fish, traveling in schools of hundreds or thousands, all approximately of the same size.

The activity of the herring is controlled largely by water temperature, moving more sluggishly in colder waters and becoming active again when the water temperature reaches 40-43 F.

There have been studies done on the breeding habits and growth of the herring (Moore, Huntsman, and Lea, 1914-15). Breeding is mostly along the eastern coast of Maine and in the Grand Manan region although it has occurred as far south as Block Island. Spawning takes place from spring to fall depending on the locality, on rocky, pebbly or gravelly bottoms and from 2-30 fathoms. The eggs sink to the bottom where they adhere to the sand, seaweed or other objects they chance to settle on. Incubation is governed by temperature and according to some European studies it may require as long as 40 days at 38-39 F, 15 days at 44-46 F, and 11 days at 50-51 F. Studies completed by the Bureau of Commercial Fisheries showed an incubation period of 10-12 days in Massachusetts waters (autumn). A study by MacFarland (1931) gave the upper lethal temperature of 68 F.

Abundance

The relative abundance of this species does vary considerably from year to year. Factors involved are abundance or scarcity of the microscopic plankton, favorable or unfavorable temperatures and salinities and general water quality.

Food and interspecies relationships

The herring is a plankton feeder. From the moment it is first hatched it feeds on larval snails and crustaceans, diatoms and peridinians. However, as they grow they depend more and more on copepods, amphipods, pelagic shrimp, and decapod crustacean larvae. It is felt that the local appearances and disappearances of large schools of herring are directly connected to the abundance or lack of euphausiid shrimp. Herring however can and do feed on molluscan larvae, fish eggs, Sagittae, pteropods, and annelids.

This species is easy prey to cod, pollock, haddock, silver hake, striped bass, mackerel, tuna, and dogfish.

Preexisting environmental stresses

The herring is a very "tender" fish. It is easily stranded on beaches during storms and appears very sensitive to pollution. Mass destructions have been recorded over the years.

Sheepshead minnow (Cyprinodon variegatus)

Range

Atlantic Coast of the United States from Cape Cod to Florida.

Life cycle and habitat requirements

The sheepshead minnow is a shallow water fish found in inlets, harbors, and salt marshes, often in brackish water.

Spawning takes place in shallow water from April until September. The eggs which stick together in clumps and sink to the bottom, are not deposited in one batch, but rather in a few at a time over the course of the spawning season. The eggs hatch after an incubation period of between four and five days.

Sheepshead minnow larvae are approximately 4 mm in length at the time of hatching. The fry mature when one year old, at which time they have grown to a length of 12 mm. The sheepshead minnows can grow up to a length of three inches.

The adult sheepshead, contrary to general rule, is longer than its female counterpart. The sheepshead generally travels in schools and moves inshore and offshore with the tide.

The sheepshead minnow have been taken with the shore-zone seines and have also been impinged on the rotating screens of the Millstone Point generating station.

Abundance

In the period May, 1969, through December, 1975, sheepshead minnow have accounted for less than 1% of all fish taken by shore-zone seine. They also represent less than 1% of all fish impinged at Millstone Point in each year, 1972 to 1975.

Food and other interspecies relationships

While the sheepshead minnow is omnivorous in its feeding habits; its diet is primarily vegetation. When it does attack other animals it is very pugnacious, often killing larger fish with its repeated attacks.

Sheepshead minnows also provide a source of food for the larger predatory fish.

Fourbeard rockling (Enchelyopus cimbrius)

Range

Gulf of St. Lawrence to Long Island Sound in coastal waters; in deep waters as far south as the latitude of Cape Fear, North Carolina.

Life cycle and habitat requirements

The rockling is taken in very shallow water to a depth of over 700 fathoms, but it is most plentiful between 25 to 30 fathoms. The rockling is found most often on soft bottoms, chiefly muddy sand.

The spawning season for the rockling is from the beginning of April until the end of August. The months of May and June represent peak presence for eggs in the Millstone waters. The eggs of the rockling are buoyant and develop best at moderate temperatures.

The larvae of the rockling are also most abundant in May and June. It goes to the bottom after it reaches a length of two inches. These larvae comprise about three percent of the total larvae captured at Millstone in the years 1973 to 1975.

As an adult, the rockling seldom rises far above the bottom. It is doubtful that rockling are seasonal migrators, but rather are year-round residents in areas they frequent.

Adult rocklings have, thus far, not been taken in any of the Millstone samplings.

Abundance

As previously noted, no adult rocklings have been taken at Millstone, but their larvae are common in the area.

Food and other interspecies relationships

Rocklings feed chiefly on shrimps, isopods, and small crustaceans. They most likely form part of the diet of many predacious fish in the areas they frequent.

Common Mummichog (<u>Fundulus heteroclitus</u>)

Range

Present along the coast of North America, from the Gulf of St. Lawrence to Texas. In the Niantic Bay area it has been taken at White Point, Jordan Cove, and Giant's Neck.

Life cycle and habitat requirements

This species is present along sheltered shores especially where there are beds of eelgrass or salt hay. They are abundant in tidal creeks, in brackish water, and in muddy pools, creeks, and ditches. It is unlikely that they ever descend to a depth of more than a couple of fathoms.

The mummichog is very resistant to a lack of oxygen, to the presence of carbon dioxide, and unfavorable surroundings in general. Under adverse conditions they are known to burrow into mud. They winter in a sluggish state on the bottoms of deeper holes or creeks and they have been found buried as deep as 6-8 inches in mud.

Spawning, most likely, takes place in June, July, and early August on the southern coast of New England. They spawn in a few inches of water, generally in shaded areas. The eggs become sticky on contact with the water, adhering to sand grains or anything else they chance to settle on. Incubation is from 9-18 days, the variation due to temperature.

Abundance

Numbers vary at each locality, however, this is one of the more stationary species. The greatest numbers were taken at Jordan Cove. Even though the surroundings at Jordan Cove seem more suitable for this species, <u>F. majalis</u> always outnumbered <u>F. heteroclitus</u>.

Food and interspecies relationships

This species is omnivorous, feeding on diatoms, eelgrass, foraminifera, crustacea, mollusks, and some small fish.

Though the mummichog does not form the main food source for any one species it is preyed on by bluefish, stripers, and cunners.

Striped Killifish (<u>Fundulus majalis</u>)

Range

Coast of the United States from Boston, Massachusetts, to Florida. It is very abundant along the southern shores of New England and it was taken at all seining sites in the Niantic Bay area at some time during the year.

Life cycle and habitat requirements

Like the common mummichog, this species is restricted to the immediate shore line. However, it does prefer open beaches and keeps more strictly to salt water. If stranded on the beach with a receding tide, it can and will jump unerringly toward the water. Breeding occurs from late spring to late summer.

Abundance

The striped killifish is more abundant in the Niantic Bay area than the common mummichog with heaviest populations at Jordan Cove, White Point, and Giant's Neck, respectively.

Food and other interspecies relationships

Small animals including mollusks, crustaceans, fish, insects, and insect larvae make up the diet for this species.

No one fish is known to prey on F. majalis but is undoubtedly serves as food for the larger predacious fish.

Preexisting environmental stresses

This species, though hardier than many is not as resistant to adverse conditions as F. heteroclitus.

Atlantic cod (Gadus morhua)

Range

East coast of Labrador to New Jersey. Most common from Cape Cod to Northern Nova Scotia.

Life cycle and habitat requirements

The cod is present in the water column from the surface to a depth of 250 fathoms. However, it is probable that most cod frequent the five to seventy-five fathom range. The cod is most often taken off coarse bottom, usually gravel, sand, or a gritty clay - broken shell mixture. They can also be found foraging in and around Irish sea moss.

At Millstone, the cod spawns from early November until the end of April. This is consistent with the literature which states that as one proceeds south, the cod's spawning period is longer. The months from December to February represent peak periods for the presence of eggs in the waters of Millstone.

The larvae of the various cods are very difficult to distinguish from one another. Therefore, the Atlantic cod has not been specifically identified at Millstone. However, the cod family accounts for less than one percent of all larvae taken at Millstone.

The cod grows to maturity in about three years. As an adult, it begins a process of limited migration, keeping to waters of moderate temperature.

At Millstone, the cod has been gill netted, but it is most often captured in trawls. In the trawls, it is captured at almost all stations except those in the Niantic River.

Abundance

The Atlantic cod was not taken in gill nets until 1975 and, as such, represents less than one percent of the gill net catch for the period 1971 to 1975. For the period 1973 to 1975, it comprised less than one percent of the entire trawl catch.

Food and other interspecies relationships

Mollusks, collectively, are probably the largest item in the cod's diet. Cod also eat crabs, lobsters, shrimps, sea urchins, and on rare occasions seaducks. More often, however, they gorge on squid and on various small fish.

A young cod's most formidable enemy is the pollock; as an adult, it is the shark and spiny dogfish. In fact, if harrassed to a great extent, an adult population will often abandon a given locality.

Though not generally a schooling fish, large numbers of cod will at times travel together. It is then that the cod is most likely to prey on squid and small fish, though shell fish remain their staple diet.

Threespine stickleback (<u>Gasterosteus aculeatus</u>)

Range

Coastal and fresh waters of the Northern Hemisphere.

Life cycle and habitat requirements

The threespine stickleback is generally a shore-zone fish, although they have also been taken in some nearshore trawls in the Millstone Point area. Most of them live in estuarine situations, although they adapt equally well to ocean salinities and fresh water.

Threespine stickbacks are year-round residents in the Milstone Point area. They apparently spawn in the spring in brackish or fresh water. Few larvae have been collected in the ichthyoplankton around Millstone Point, but very young juveniles are abundant in the shore-zone seines in June and July.

Abundance

In terms of total abundance, threespine sticklebacks constituted to date three-tenths of a percent of all fish taken in the shore-zone seines. The year-round presence, however, makes them the seventh most relatively abundant fish in the shore-zone community. They also constituted one percent of all fish taken in trawls. Because they are a shore-zone fish, they represented 10 percent of all fish impinged during 1975.

Food and other interspecies relationships

The stickleback feeds on small invertebrates, small fish fry, fish eggs, and sometimes on diatoms.

Yellowtail flounder (Limanda ferruginea)

Range

From the north shore of the Gulf of St. Lawrence, southward to the lower part of Chesapeake Bay.

Life cycle and habitat requirements

The yellowtail is occasionally found in shallow water, but it is most often found at depths ranging from 5 to 60 fathoms. Almost any sandy bottom or a mixture of sand and mud is suitable for this flounder.

The spawning period of the yellowtail flounder begins in early March, peaks in June, and tapers off in early September.

The larvae of this flounder grow an average of five inches in the first year, and it is not until this time that the young fish seeks the bottom. At Millstone, the yellowtail accounts for one percent of all larvae captured in the period May, 1973, to May, 1975.

As an adult, the yellowtail rarely travels far from a given area. Although there are reports that this fish may be a seasonal migrator.

The yellowtail flounder has been taken only in larval form at Millstone. Its absence in other areas of sampling could be attributed to its preference for relatively deeper waters.

Abundance

As noted above, the yellowtail flounder is not abundant at Millstone, at least not within the confines of the sampling area.

Food and other interspecies relationships

The yellowtail feeds chiefly on smaller crustaceans such as shrimps, worms, and various mollusks. As it is a rather sluggish fish, it is doubtful that other fish play a large role in its diet.

Haddock (<u>Melanogrammus aeglefinus</u>)

Range

Most abundant from the Southern Grand Banks to Cape Cod. In winter, they range as far south as New York and New Jersey.

Life cycle and habitat requirements

The haddock is a cold water fish inhabiting depths from 5 to 100 fathoms. It is most common, however, between 25 and 75 fathoms. The haddock is essentially a ground fish, taken chiefly on broken ground gravel, clay, and broken shells.

The haddock is a prolific fish for its size. It spawns in the Millstone area from early February until late May. The months of February and March are when the haddock's eggs are most abundant.

As the larvae grow, they settle out on the bottom and grow to sexual maturity in three or four years at a rate of about six inches per year.

As an adult, the haddock is on a constant search for food; however, it generally does not stray far from his usual feeding ground. On occasion, haddock in warmer waters will move out to deeper and colder waters in the summer.

The haddock has so far been found only in the egg stage in the Millstone area.

Abundance

Haddock eggs comprised less than one percent of all eggs taken in the Millstone area.

Food and other interspecies relationships

During the first months of its life, the haddock feeds mainly on copepods; it then becomes a bottom feeder. Their diet includes mollusks, worms, shrimp, starfish, and almost any other invertebrate living on a given feeding ground. Small fish fill only a minor place in the haddock's diet, but they will feed on squid if the opportunity arises.

Tidewater silverside (*Menidia beryllina*)

Range

Cape Cod to South Carolina.

Life cycle and habitat requirements

The tidewater silverside is a shallow-water species. It is found in fresh, brackish, and salt water, but is not common in strictly salt water.

The spawning season of this silverside extends from April to August. The eggs are provided with gelatinous threads which enable them to adhere to objects in the water. The incubation period is about 10 days.

The larvae are about 3.5 millimeters when hatched, and grow to an adult size of not more than three inches.' At Millstone, larvae of the genus *Menidia* account for one percent of all larvae taken May, 1973 to May, 1975.

The adult tidewater silverside is generally a year-round resident in the shore zone, but some have been known to descend to deeper waters in winter in order to avoid extremely cold temperatures.

The tidewater silverside has been taken in shore-zone seines at all seining stations around Millstone Point. The silverside genus *Menidia* has been impinged on the rotating screens of Millstone's generating station.

Abundance

In 1973, 1974, and 1975, the genus *Menidia* represented three percent, six percent, and three percent, respectively, of the total number of fish impinged on the rotating screens. The tidewater silverside accounted for 2.9 percent of all fish taken with shore-zone seines in the period May, 1969, to December, 1974.

Food and other interspecies relationships

The tidewater silverside feeds on small crustaceans, shellfish, and worms, as well as seaweed. This silverside probably contributes heavily to the diet of larger predatory fish.

Silverside (*Menidia menidia*)

Range

Apparently there are two varieties. The northern form is common locally from the south side of the Gulf of St. Lawrence and the outer coast of Nova Scotia to Massachusetts Bay and then very abundant from there southward to Chesapeake Bay. It then mixes with or is replaced by the southern variety which extends at least to Florida.

Life cycle and habitat requirements

This species is known to frequent sandy or gravelly shores. Traveling in schools of similar-sized individuals they tend to follow the tide up and down the beach within a few yards of the water's edge. They are also found about the inner bays, in river mouths, and moving into brackish water.

In general, this species is a resident throughout the year, wherever they are found. However some have been found in the winter at depths of 5 to 27 fathoms and this may well have been to avoid low temperatures.

It appears that they need summer temperatures as high as 68 F for successful reproduction. However, the young fry and adults are indifferent to temperatures down to a degree or two above the freezing point of salt water.

Along the southern coast of New England the silverside spawns in May, June, and early July. They gather in schools to deposit their eggs on sandy bottoms or among sedge grass.

Abundance

This species was abundant at White Point, Jordan Cove, and Giant's Neck from July to December. This and *F. majalis* are the most abundant forms in the shore zones off Niantic.

Food and other interspecies relationships

Their diet consists of copepods, mysids, shrimps, small decapod shrimps, amphipods, Cladocera, fish eggs (including their own), young squid, annelid worms, and molluscan larvae.

Their importance in the economy of the sea is as food to predaceous fishes such as bluefish, mackerel, and striped bass. They are also used as bait for eelpots on the Rhode Island coast.

Silver hake (Merluccius bilinearis)

Range

Newfoundland to North Carolina. Common from Delaware north.

Life cycle and habitat requirements

This species occurs in large numbers at various depths from a few feet of water to about 400 meters.

In the Millstone Point area, eggs of the silver hake occur in the water from May through October with most occurring during June and July. Spawning apparently occurs all along the coastal area.

Hake are found throughout the water column, having been taken in trawls, gill nets, and shore-zone seines probably resting on the bottom during the day and hunting at night. Most of the hake captured in the Millstone Point area have been taken in Niantic Bay and at the outer stations, although some have been captured in the Niantic River.

Abundance

Silver hake comprised three percent of all fish taken in otter trawls in the Millstone Point area, and less than one percent of the total fish taken in gill nets and shore-zone seines. Usually only a relatively few hake are impinged, but in December, 1975, they represented 32 percent of all fish trapped on the intake screens that month.

Food and other interspecies relationships

Silver hake are voracious feeders, preying on herring and other small schooling fish such as young mackerel, menhaden, alewives, and silversides.

They generally do not school, but occasionally large bands swim together chasing other schooling fish such as herrings. They have been known to drive schools of herring ashore, frequently stranding themselves.

White Perch (Morone americana)

Range

Atlantic coast of North America from the Gulf of St. Lawrence and Nova Scotia to South Carolina, breeding in fresh or brackish water and many permanently landlocked in fresh water ponds. Common along southern New England.

Life cycle and habitat requirements

Although this species is present in undiluted sea water along southern New England it is most plentiful in ponds connected with the sea, in brackish waters, in estuaries, and in river mouths. White perch are found in shallow water of one or two fathoms, wandering from place to place in small schools. In winter they congregate in the deeper parts of bays and creeks hibernating in a sluggish condition.

Spawning, along the southern coast of New England, takes place from April to June in fresh or brackish water. The eggs stick together and stick wherever they sink. At 52 F, incubation takes about 6 days.

Based on personal interviews and catch records, it has been estimated that white perch spawn in the Thames River in April when the water temperature is around 50 F. Although the actual spawning sites were not determined, it is felt that white perch spawns in the shallow areas. Mansueti (1964) has described the eggs, larvae, and young of the white perch, with comments on its ecology in the estuary. He states that in the Chesapeake Bay, spawning takes place only from April to May and occasionally into early June, when temperatures are around 10 C to 15 C (50 F to 59 F). There, the perch spawn in tidal fresh water or slightly brackish water. The implications of Hildebrand and Schroeder (1928) and Bigelow and Schroeder (1953) that spawning takes place in winter were considered to be based on faulty observations (Mansueti, 1964).

The egg of the white perch is spherical in shape, except for an adhesive attachment disk. It has a high specific gravity and sinks rapidly to the bottom. The sticky eggs come together or can attach singly, but the adhesiveness soon disappears.

The larvae attempt to swin to the surface but sink to the bottom again. This behavior is kept up, resulting in a constant up and down motion, also observed in the larvae of the striped bass (Mansueti, 1958). The larvae also appear to be positively phototropic.

Eventually they generally tend to remain on the bottom where they are forage feeders.

Food and other interspecies relationships

White perch feed on small fish fry, young squid, shrimp, crab and other invertebrates. They are very destructive in that they eat the spawn of other fish.

Wherever abundant, it is of considerable commercial importance as food for man.

Striped bass (Morone saxatilis)

Range

Atlantic coast of eastern North America, from the lower St. Lawrence River and the southern side of the Gulf of St. Lawrence to northern Florida; also along the northern shore of the Gulf of St. Lawrence to Alabama and Louisiana; running up into brackish or fresh water to breed.

Life cycle and habitat requirements

This fish is active when water temperature is from 6-8 C (43-46 F) to 21 C (70 F) (Bigelow and Schroeder, 1953). They start to move when the temperature reaches 7 C (45 F), and they cannot long survive when the water temperature is higher than 25-27 C (77 to 80.6 F), for many were found dead in shallow estuaries in Connecticut and Massachusetts during abnormally hot weather in August of 1937 (Raney, 1952).

Their spawning areas are in either fresh or brackish water from April to July. The young remain in the spawning area until they are close to two years old (Raney, 1952). In Maryland, striped bass spawn in the upper reaches of fresh water rivers where the bottom is sand or mud (Vladykov and Wallace, 1952). Merriman (1941) reports that striped bass have been known to spawn in Connecticut but his study of the Thames River failed to reveal any young. Also, during his field study, no sexually mature fish were collected. At Cos Cob Harbor, Greenwich, young striped bass were taken in May of 1949 (Raney, 1952). The spawning season in the Hudson River is reported to be from mid-May through June (Neville, 1940).

Sexually mature fish were caught in the Roanoke River, North Carolina, when the temperature increased from 14.5 to 21 C (58-71 F) (Worth, 1884) and at Weldon at temperatures between 16 and 21 C (54 to 70 F), and in the lower Susquehanna River in temperatures of 15.5 to 21 C (60 to 70 F) (Pearson, 1938). Striped bass spawned in the San Joaquin River in California in water temperatures of 19.5 C (67 F) (Woodhull, 1947), and spawning occurred in temperatures of 14.5 C (50 F) and higher, and peaked at between 15.5 C and 19.5 C (60 to 70 F) (Raney, 1952).

When there is a current, the eggs are undoubtedly swept downstream, due to the semibuoyancy of the egg. Merriman (1941) stated for example that hatching may not take place until the eggs are close to the mouth of the Roanoke River.

According to Pearson (1938) the incubation period in an average water temperature 18 C (64.2 F) takes 48 hours. In water at 14.5 C (58 F) it takes 74 hours and in water at 19.5 C (67 F) it takes 48 hours (Bigelow and Welsh, 1925). In water from 21.5 C to 22 C (71 to 72 F) it takes about 30 hours and at 14.5 C to 15.5 C it takes from 70 to 74 hours (Merriman, 1941).

Newly hatched larvae are 2.5 mm long, according to Pearson (1938). Sixty hours after hatching, the larvae reach 3.2 mm in length, and sink to the bottom of still water. After 192 hours, when they are approximately 6 mm in length, if there is no food available, they will begin to die (Pearson, 1938).

Larval striped bass at the San Joaquin Delta area were found by Calhoun and Woodhull (1948) to be rather evenly distributed horizontally, but the vertical distribution was highly variable.

The distribution of the young fish, 7.0 to 8.0 mm, is not clear, but in the Parker River in Massachusetts they were found over mud and sandy bottom, where there was little gravel and a few scattered rocks (Merriman, 1941).

According to Tresselt (1952), spawning activity occurred in the Chesapeake Bay within the first 25 miles of fresh water. Also, large numbers of eggs were collected where the salinity was about 1 ppt.

Food and other interspecies relationships

Stripers feed on any small fish that are available and on many types of invertebrates. Stomach content analyses have found alewife, anchovy, croakers, channel bass, eels, flounders, herring, menhaden, mummichogs, mullet, rock eels, sculpins, shad, silversides, smelt, tomcod, white perch, lobsters, various crabs, shrimps, isopods, various worms, squid, Mya, and mussells.

When prey is abundant, bass are known to gorge themselves, then cease feeding while their food is digesting. They feed during the night hours.

The striper is essentially a game fish.

Smooth dogfish (Mustelus canis)

Range

The Bay of Fundy to Florida, common from Cape Cod to Virginia.

Life cycle and habitat requirements

The smooth dogfish is a bottom fish which is most commonly found in shallow waters, but is also found at depths as great as 90 fathoms. It will even on occasion enter fresh water.

The spawning period of the smooth dogfish extends from March until May. The dogfish bears its young live after a gestation period of approximately ten months. Birth actually takes place during the months of May, June, and July. The litters of the smooth dogfish average between ten and twenty young per year.

The young of the smooth dogfish are between eleven and fifteen inches in length when born. They reach sexual maturity at a length of about three feet and can grow up to a length of five feet.

The adult of the smooth dogfish follows a pattern of north-south migration. As the season progresses, the smooth dogfish moves northwards up the coast. In September and October they withdraw from their northern limits and begin to move south again. This migration generally encompasses those sharks which inhabit the area from Virginia to Cape Cod Bay.

At Millstone Point, dogfish have been collected in both trawl and impingement samples. They have also been taken with gill nets. According to data collected in 1975, the dogfish were most often netted at the offshore stations.

Abundance

In the period of 1973 to 1975, the smooth dogfish accounted for less than 1% of the total catch of all fish impinged at Millstone Point. It also represented less than 1% of all fish taken with trawls during the period of July, 1973, through December, 1975. However, in the period of December, 1971, to December, 1975, the smooth dogfish accounted for 2% of all fish taken with gill nets in the Millstone Point area.

Food and other interspecies relationships

The diet of the smooth dogfish consists chiefly of the larger crustacea, primarily lobsters and crabs, and small fish. They also feed on squid, especially in the spring, and on some mollusks on occasion.

In areas where lobsters and crabs are plentiful, the smooth dogfish can do enormous damage. In one such area it was estimated that 10,000 dogfish could devour 60,000 lobsters and 200,000 crabs in a single year.

Grubby (Myoxocephalus aenaeus)

Range

North American coastal waters from New Jersey to Northern Nova Scotia and the Gulf of St. Lawrence.

Life cycle and habitat requirements

In the Millstone Point area, grubbies are found from the shore zone out to the deeper stations in Long Island Sound. They are found on all types of bottoms, but usually among eel grass or kelp.

The spawning season around Millstone Point apparently occurs from early winter into early spring, with most larvae being caught in February, March, and April. The eggs of the grubby are demersal, falling to the bottom and adhering to any objects that they touch.

Abundance

Grubbies have constituted less than one percent of all fish taken by shore-zone seines and otter trawls in the Millstone Point area. They were, however, the fourth most abundant species impinged in 1975, most of them being impinged during the winter months.

Food and other interspecies relationships

Grubbies feed on the small animals on and in the bottom where it lives. These include annelid worms, shrimps, crabs, copepods, snails, nudibranches, and ascidians. They will also eat small fish, and will scavenge any kind of animal refuse.

Longhorn sculpin (Myoxocephalus octodecemspinosus)

Range

Regularly from Newfoundland to New Jersey and, on occasion, as far south as Virginia.

Life cycle and habitat requirements

The longhorn sculpin is a bottom fish which ranges in depth from a few feet to as deep as 105 fathoms. However, it is most common in depths above fifty fathoms. It is often in estuaries, salt creeks, and river mouths, but it never ventures up into fresh water.

The longhorn sculpin deposits its eggs from November until January. They are laid as a sticky mass which sinks to the bottom and adheres on contact with the substrate.

The larvae of the sculpins are difficult to distinguish, but larvae of its genus (Myoxocephalus) are present in Millstone waters from January until May. The peak period for larvae presence at Millstone is between the months of February and April. In the period 1973 to 1975, this same genus accounted for two percent of all larvae taken at Millstone.

The longhorn grows about two and one-half inches its first year and reaches sexual maturity no earlier than its third year.

The adult longhorn is generally a year-round resident. It does make periodic movements from one feeding ground to another, but these are usually only of a limited distance.

The longhorn sculpin has been taken with both gill nets and trawls. It has been taken at every Millstone trawl station except those in the Niantic River.

Abundance

In the period of July, 1971, to December, 1975, the longhorn accounted for less than one percent of all fish gill netted; in fact, only one was taken, and that was in 1975. It also comprised less than one percent of the total trawl catch from July, 1973, to December, 1975.

Food and other interspecies relationships

The longhorn's diet consists chiefly of shrimp, crabs, various mollusks, and juvenile fish. It is also a voracious scavenger, frequenting wharves, lobster cars, etc., in search of available refuse.

Summer flounder or fluke (*Paralichthys dentatus*)

Range

Continental waters of the eastern United States, from Maine to South Carolina, possibly to Florida, chiefly south of Cape Cod.

Life cycle and habitat requirements

Occurs most often in depths between eight and eighty fathoms. They prefer sandy or muddy bottoms, but they can often be found in eel grass.

The summer flounder spawns from the months of October through April. October is the only month which represents a peak period for eggs present in the Millstone waters.

The larvae of the summer flounder account for less than one percent of all larvae netted at Millstone in the period May, 1973, to May, 1975.

The summer flounder grows slowly - only about eight to ten inches in two years; but at this time, it is nearly an adult. As an adult, it spends most of its time on or near the bottom. Summer flounder follow a pattern of seasonal migration coming inshore in the summer and remaining in deeper waters during the winter months.

The summer flounder has been found impinged upon the rotating screens at Millstone, but it is most often taken in trawls. In the Millstone area, it is taken at all the inner stations along the shore and also in the deeper water stations.

Abundance

The summer flounder accounts for less than one percent of all fish impinged during the years 1973 to 1975. This flounder accounts for one percent of the total trawl catch for the period July, 1973, to July, 1975.

Food and other interspecies relationships

The summer flounder is a predacious fish, feeding largely on small fish, squids, crabs, shrimps, worms, and various other crustaceans. A study of this fish's stomach contents conducted in 1974 reports that their diet was primarily small fish (51 percent) and mollusks and annelids to a lesser degree. One flounder was found, however, whose stomach was three-quarters full of squid. It is fierce and active in its pursuit of prey and often drives them right up to and out of the surface of the water.

Butterfish (*Peprilus triacanthus*)

Range

The Atlantic Coast from Nova Scotia to South Carolina; in deep water ranges as far south as Florida.

Life cycle and habitat requirements

Butterfish are found in the water column from 1 to 120 fathoms. While it prefers deeper water, the butterfish comes inshore into sheltered bays and estuaries. It shows a decided preference for sandy bottoms as apposed to rocky ground or mud.

At Millstone, the butterfish spawns from early June until late August. The butterfish's spawning period peaks at Millstone during the month of June. The eggs are buoyant and take 48 hours to hatch. Butterfish spawn in deep water and then move back towards the coast.

Larvae are also most abundant at Millstone in the month of June, where they comprise three percent of the total larvae catch. The butterfish matures in about two years, when it is about seven inches in length.

As an adult, the butterfish travels in small bands or loose schools. Evidence has been presented suggesting that they are considerably more active by day than at night. The butterfish is a warm water fish which spends its winters in deep offshore waters in depths from 100-115 fathoms and in the summer is found inshore at depths above 35 fathoms. The largest butterfish do not exceed 12 inches and one and one-quarter pounds.

The butterfish has been captured with both trawls and gill nets; it has also been found impinged on the rotating screens at Millstone. The butterfish has been taken at most of the deep water stations around Millstone.

Abundance

The butterfish accounted for less than one percent of the total trawl catch in the period July, 1973, to December, 1975. However, it comprised two percent of the gill net catch between December, 1971, to December, 1975. The years 1974 and 1975 were when the majority of butterfish were gill netted, accounting for 44 percent and 49 percent of the total, respectively. The butterfish was found impinged in all years, 1973 to 1975. In 1973, it accounted for one percent of all fish impinged.

Food and other interspecies relationships

The butterfish feeds on small fish, squids, shrimp, and annelid worms. On occasion, it will also eat ctenophores.

Often, these fish are seen breaking the surface of the water as they are fed upon by predacious fish.

American Pollock (Pollachius virens)

Range

Continental waters on both sides of the North Atlantic in cool temperate and boreal latitudes, occasionally as far south as North Carolina.

Life cycle and habitat requirements

Pollock live at any level between bottom and surface and up to depths of 100 fathoms at least. It is the presence or absence of prey that governs the movements of this fish.

It is a cool water species. None have been caught at the surface when the water temperature was higher than 52 F. However, water temperatures of 38 F and somewhat higher are apparently needed for the incubation of its eggs and for the maturation of the sex organs.

The pollock spawns in late autumn and early winter. In Massachusetts Bay breeding begins when the water has cooled to approximately 47-49 F, climaxing usually late in December when the water has reached 40-43 F. Thus the pollock spawns in a falling temperature. Salinity preferences for spawning range from 32 parts per thousand to 32.8 parts per thousand. The actual breeding grounds are unknown.

Incubation takes nine days at 43 F and six days at 49 F. Young pollock live near the surface.

Larvae held in the Gloucester hatchery were strong and active in water temperatures of 38 to 48 F.

Abundance

Commercial quantities have been taken (in season) along southern New England and New York. In the past schools of pollock have been observed by SCUBA divers in the Niantic Bay area during the colder months only. Pollock are not commonly caught west of Rhode Island and it is chiefly as cold water visitors that they appear off the coasts of Connecticut, New York, and New Jersey.

Food and other interspecies relationships

Pollock destroy great quantities of small herring, launce, young cod, young haddock, young hake, and other small fish in their search for food. Pelagic crustaceans, especially euphausid shrimp, are also a chief source of food.

Bluefish (Pomatomus saltatrix)

Range

Widely but irregularly distributed in the warmer seas, its known range including the eastern coast of the Americas, northward regularly to Cape Cod, occasionally to outer Nova Scotia, south to Brazil and Argentina; Bermuda; eastern Atlantic off northwestern Africa; also Mediterranean; both coasts of southern Africa; Madagascar; eastern Indian Ocean and Malay Peninsula; southern Australia and New Zealand (Bigelow and Schroeder). It is abundant in the Niantic area in September.

Life cycle and habitat requirements

The bluefish is oceanic in nature although the juveniles are abundant along the shore zones of estuaries. It is a warm water species that has never been found in any numbers in temperatures lower than 58-60 F. They appear along the United States'coast as warm-season migrants only. They are first taken off Long Island during April and May and they have disappeared from the entire coast northward from the Carolinas by early November. It is not entirely known where they migrate for the winter. It is certain that at least some migrate far southward but it is not known whether they ever return.

Their spawning grounds have not been defined. However, with the regular presence of "snappers" in numbers inshore and the occasional captures of smaller fry in Chesapeake Bay and the Gulf of Maine it is believed that the spawning grounds of our northern bluefish are not too far away.

Abundance

Bluefish were plentiful off southern New England in colonial times. Essentially disappearing around 1764, they did not reappear until around 1810. There was another low in 1945. Yearly fluctuations in abundance continue to occur. It is said that in a poor year the large adults only come north as far as the south side of Long Island. This species has been extremely abundant over the past few years in the Niantic area.

Common searobin (Prionotus carolinus)

Range

Coastal waters of eastern North America from the Bay of Fundy to South Carolina; chiefly west and south of Cape Cod.

Life cycle and habitat requirements

Searobins are usually found on smooth, hard grounds, less often on mud or about rocks. They range in depths from five to 60 fathoms, sometimes being found right below the tide line.

The searobin spawns from June until September with July being the month of peak presence for eggs in the Millstone waters. The incubation period for these eggs is usually about 60 hours, but may be longer in cooler waters.

The larvae of the various searobins are very difficult to distinguish from one another. However, the genus Prionotus accounted for one percent of the total larvae catch at Millstone in the period May, 1973, to May, 1975.

The adult searobin, which seldom grows larger than one foot, prefers warmer waters and in winter migrates to deeper water.

While the common searobin has not been specifically identified in trawl catches or impinged fish, the genus Prionotus has been recorded in both. The searobin has been captured at all the Millstone trawl stations. The common searobin has been captured in both surface and bottom gill nets, chiefly in the waters in front of the Millstone generating station.

Abundance

The searobin (genus Prionotus) accounted for two percent of the total trawl catch in the period July, 1973, to December, 1975. This same fish represented one percent of all fish impinged both in 1974 and in 1975. In 1975, the months of May and June represented peaks for the number of searobins impinged. The common searobin represented less than one percent of the total gill net catch for the period 1971 to 1975; however, in 1973, the common searobin accounted for two percent of all fish taken in gill nets at Millstone.

Food and other interspecies relationships

The common searobin feeds voraciously on a diet consisting mainly of small crustaceans such as shrimps, crabs, and other amphipods. It has been also known to feed on mollusks, worms, and various small fish. These dietary habits are corroborated by a study done in 1974 at Millstone of the contents of the searobin's stomach. This study showed crustaceans as composing 82 percent of their diet, while annelids (eight percent) and mollusks (two percent) supplemented this basic diet.

Striped searobin (Prionotus evolans)

Range

The Atlantic Coast of North America from Cape Cod to South Carolina; occasionally north to the Gulf of Maine.

Life cycle and habitat requirements

The striped searobin is usually found on smooth, hard grounds, less often on mud or about rocks. They range in depths from five to sixty fathoms, sometimes being found right below the tide line.

The searobin spawns from June until September with July being the month of peak presence for eggs in the Millstone waters. The incubation period for these eggs is usually about 60 hours, but may be longer in cooler waters.

The larvae of the various searobins are very difficult to distinguish from one another. However, the genus Prionotus accounted for one percent of the total larval catch at Millstone in the period May, 1973 to May, 1975.

The striped searobin grows up to 18 inches in length. It prefers warmer waters and is a seasonal migrator which moves offshore in the winter in order to avoid cooler inshore waters.

While the striped searobin has not been specifically identified in trawl catches, the genus Prionotus has been frequently collected. The searobin has been captured at all the Millstone trawl stations. The striped searobin has been recorded in both gill net and impingement catches.

Abundance

The striped searobin was not recorded as impinged until 1975 when it accounted for less than one percent of the total impingement. For the period 1971 to 1975, the striped searobin accounted for less than one percent of the total gill net catch. The year of 1975, however, accounted for 80 percent of the striped searobins taken with gill nets.

Food and other interspecies relationships

The striped searobin's diet consists chiefly of small crustaceans and shows a marked preference for mysid shrimps. It has also been known to feed on mollusks and worms. These dietary habits are corroborated by a study done in 1974 at Millstone of the contents of the searobin's stomach. This study showed crustaceans as composing 82 percent of their diet, while annelids (8 percent) and mollusks (2 percent) supplemental this basic diet.

Winter Flounder (<u>Pseudopleuronectes americanus</u>)

Range

Atlantic coast of North America from the coast to the offshore fishing banks; common from the north shore of the Gulf of St. Lawrence to Chesapeake Bay. This species is very common in the area of Niantic Bay.

Life cycle and habitat requirements

The winter flounder is found from the tide line to depths of 10-20 fathoms. It seems to prefer muddy bottoms although they are also common on cleaner sand, clay, or pebbly bottoms. If the bottom is soft, they have a habit of burrowing in until only the eyes can be seen.

In areas where the water is shallow, the flounder tends to move to deeper waters to avoid both the hottest and coldest water.

Tagging work has been completed in Long Island Sound, along southern New England and in Maine; and this species is believed to be one of the most stationary forms. Fry produced in the bays and estuaries will move further offshore as they grow older.

Merriman and Warfel (1948) recorded commercial catches for July through September in approximately 20 fathoms, and in 10 to 15 fathoms during the remainder of the year.

The winter flounder migrates during January through April from deeper water up into shallow water for spawning when bottom temperatures range from $1^{\circ}C$ to $10^{\circ}C$ ($34^{\circ}F$ to $58^{\circ}F$). The spawning peak is in early spring when the temperature of the water if $2^{\circ}C$ to $5^{\circ}C$ ($37^{\circ}F$ to $41^{\circ}F$). Flounders spawn on the bottom, and the eggs stay in a mass on the bottom. These masses easily break up as the eggs advance to the embryonic stage. The incubation period is from 15 to 18 days.

After hatching, the post-larvae, which account for 13 percent of all larvae taken around Millstone Point, swim toward the surface by moving their tails, and remain suspended there at a 90° angle by the continuous movement of the tail. When they cease tail movement, they descend to the bottom head first and remain there.

Abundance

Winter flounder are among the most abundant fish species in the Millstone Point area. Rough estimates of the total winter flounder population in the Millstone Point area, based on the number of fish per area towed during the otter trawl collections ranged from a high of approximately 1,400,000 in 1973 to a low of 995,000 in 1975.

The winter flounder has been found impinged each year from 1972 through 1975. In 1972, it accounted for 12 percent of all fish impinged; in 1973, 18 percent; in 1974, 19 percent; and in 1975, 12 percent.

In the period December of 1971 through December of 1975, it represented one percent of all fish taken with gill nets and less than one percent of all fish taken with shore-zone seines during the period May of 1969 through December of 1975. From July of 1973 through December of 1975, the winter flounder accounted for 41 percent of all fish taken with otter trawls. It was present at all stations and was generally the most abundant fish at each station for that same period of time.

Food and other interspecies relationships

Food for larvae under 10 millimeters is mostly copepods, and under 25 millimeters polychaetes and amphipods (Pearcy, 1962). For the immature and small mature fish, small shrimp and polychaetes are the major food source. Adults are known to eat fish fry, shrimps, amphipods, other small crustacea, bivalve mollusks, sea worms, and a variety of other forms.

Ninespine stickleback (<u>Pungitis pungitis</u>)

<u>Range</u>

From the Arctic seas southwards to New Jersey.

<u>Life cycle and other habitat requirements</u>

The ninespine stickleback is found chiefly in harbors and salt marshes. It resides in both brackish and fresh water and is seldom found in the open ocean.

In the Millstone Point area, the ninespine stickleback spawns during the summer months. The male often (but not always) builds a nest in which the female lays her eggs. When this is the case, the male guards the nest until the eggs are hatched which is generally in about twelve days.

The newly hatched sticklebacks grow slowly, but by the end of their third year both males and females are mature. When fully grown, the adult sticklebacks measure between two and three inches in length. The female of the species lives longer than the male which often dies shortly after spawning.

The ninespine stickleback has been found impinged on the rotating screens of the Millstone Point generating station and has also been taken with the shore-zone seines. It is most prevalent at the Jordan Cove and Crescent seining stations.

<u>Abundance</u>

In the period of May, 1969, through December, 1975, the ninespine stickleback accounted for 0.9% of all fish taken by the shore-zone seine. It has been recorded as being impinged in only one year (1972). At this time, it accounted for less than 1% of all fish impinged in that year.

<u>Food and other interspecies relationships</u>

The ninespine stickleback feeds on various copepods, and also on assorted fish larvae and eggs. As such, it may at times be an extremely destructive force in regards to the propagation of other fish species.

When not fully matured, the ninespine stickleback undoubtedly contributes to the food source of larger predatory fish.

Clearnose skate (<u>Raja eglanteria</u>)

<u>Range</u>

Massachusetts Bay to both coasts of Florida.

<u>Life cycle and habitat requirements</u>

The clearnose skate occurs from shallow waters to a depth of 70 fathoms. It prefers smooth, sandy, and pebbly bottoms.

The eggs are laid in the spring, in cases, on hard, sandy bottoms. The incubation period for the clearnose skate is approximately three months.

The clearnose larvae grow to a length of about 15 inches in their first year of growth, then grow at a rate of about eight inches per year. The clearnose skate matures at an age of about four years and can reach lengths of up to three feet.

The adult clearnose skate avoids extremely cold waters by wintering in offshore waters. They do not move inshore until the summer when the coastal waters warm up considerably.

While the clearnose skate has not been specifically identified at Millstone, it's genus, <u>Raja</u>, has been recorded there. It has been taken at all the trawl stations, except the station southeast inland on the Niantic River. The offshore trawl stations, however, are where the skate is most readily captured in trawls. This same genus has also been both impinged and taken with gill nets.

<u>Abundance</u>

In the period July, 1973, to December, 1975, the skate (<u>Raja</u> sp.) accounted for seven percent of the total trawl catch. This same species comprised less than one percent of all fish gill netted between December, 1971, and December, 1975; the majority of these fish were gill netted in 1975. In each year, 1973 to 1975, the skate accounted for one percent of the total fish impinged.

<u>Food and other interspecies relationships</u>

A study conducted between 1954 to 1956 in Chesapeake Bay by Fitz and Daiber demonstrated that crustaceans, chiefly shrimp, make up the major part (74 percent) of this skate's diet. To a lesser extent, worms, fish, and bivalve mollusks contributed to its diet.

In their book, <u>Fishes of Chesapeake Bay</u>, Hildebrand and Schroeder suggest, based on the structure of their teeth, that mollusks as well as crustaceans should form the major part of the clearnose's diet. This was proved correct in a study done in 1974 on the stomach contents of the skates (<u>Raja</u>, sp.) found in the Millstone area which shows that mollusks accounted for 48 percent and crustaceans 37 percent of all food items. Over 81 percent of all skates analyzed contained some mollusks. However, because of the fact that 97 percent of all skates examined contained ingested material of some sort, the conclusion was made that skates are not extremely selective and will alter their diet according to the availability of food.

Little skate (Raja erinacea)

Range

The southern side of the Gulf of St. Lawrence to Virginia.

Life cycle and habitat requirements

The little skate is found from the tide line to a depth of 75 fathoms. It preferes a sandy or pebbly bottom, but it may also be found on mud. The little skate tolerates a wide range of temperatures, but seems to avoid waters which are especially brackish.

The spawning period of the little skate extends from March to September, with July and August the months of peak presence. The eggs are laid in shallow water and on a sandy bottom. It takes five to six months and longer for the eggs of the little skate to hatch.

The skate larvae, when hatched, descend to deep water by the beginning of their first winter. The little skate grows up to eight inches its first year and reaches lengths between 16 and 20 inches. By the end of their fourth year, both the male and female skate have reached sexual maturity.

As an adult, the little skate indigenous to Long Island Sound carries out a fairly complex seasonal migration pattern. That is - inshore in spring, offshore in mid- or late summer, inshore again in late autumn and offshore again in mid-winter.

While the little skate has not been specifically identified at Millstone, its genus, Raja, has been recorded there. It has been taken at all the trawl stations, except the station farthest inland on the Niantic River. The offshore trawl stations, however, is where the skate is most readily captured in trawls. This same genus has also been both impinged and taken with gill nets.

Abundance

In the period July, 1973, through December, 1975, the skate (Raja, sp.) accounted for seven percent of the total trawl catch. This same species comprised less than one percent of all fish gill netted between December, 1971, and December, 1975; the majority of these fish were gill netted in 1975. In each year, 1973 to 1975, the skate accounted for one percent of the total fish impinged. Based on monthly impingement data from 1975, the skate's migration pattern is roughly observable.

Food and other interspecies relationships

The diet of the little skate consists of crabs, shrimps, worms, mollusks, squid, and small fish. A study done in 1974 on the stomach contents of the skates (Raja, sp.) found in the Millstone area shows that mollusks accounted for 48 percent and crustaceans 37 percent of all food items. Over 81 percent of all skates analyzed contained some mollusks. However, because of the fact that 97 percent of all skates examined contained ingested material of some sort, the conclusion was made that skates are not extremely selective and will alter their diet according to the availability of food.

Atlantic mackerel (*Scomber scombrus*)

Range

From the northern side of the Gulf of St. Lawrence and strait of Belle Isle to Cape Lookout, North Carolina.

Life cycle and other habitat requirements

The mackerel is an open ocean fish which, since it is not dependent on either the coastline or bottom for food, is found over a wide range of habitats. It frequents depths from the surface to as deep as 100 fathoms.

June and July are the months when the Atlantic mackerel spawns in the Millstone area. The month of June is when mackerel eggs are most abundant at Millstone.

The larvae which are also most abundant during the months of June and July comprise eight percent of the total number of larvae caught at Millstone in the period May, 1973, to May, 1975. The larvae of the mackerel are found at all the Millstone sampling stations in both deep and shallow water.

The mackerel grows up to 10 to 11 inches in the first year and then grows slowly at a rate of around one-half an inch a year. It reaches sexual maturity after three full years of growth, and probably spawns yearly after that.

As an adult, the Atlantic mackerel is often found in schools especially where it is migrating to deeper water in the winter. As a general rule, the adult mackerel inhabits somewhat deeper waters than the juvenile mackerels.

The mackerel has been both impinged and taken with gill net at Millstone.

Abundance

In the period 1971 to 1975, the Atlantic mackerel comprised less than one percent of the total gill net catch. It also represented less than one percent of all fish impinged in the period 1973 to 1975.

Food and other interspecies relationships

The young Atlantic mackerel feeds chiefly on a diet of copepods and fish larvae. As it gets older, it depends more and more on a diet of small fish, squid, and shrimp. It will also, on occasion, feed off the bottom. It is during feeding that the Atlantic mackerel is most likely to disband from its school as it chases its prey.

The mackerel is an easy prey for larger fish such as bluefish, striped bass, and cod. If the predator is especially fierce, it may even drive small mackerel into shallow waters, leaving many stranded.

Windowpane flounder (Scophtalmus aquosus)

Range

Coastal waters of eastern North America, from the Gulf of St. Lawrence to South Carolina; most abundant west and south of Cape Cod.

Life cycle and habitat requirements

This species is a shoal water fish, occurring from below the tide mark to a depth of 30 fathoms. It is found chiefly on sandy bottoms, but may also frequent softer and muddier ground.

In the Millstone area, spawning begins in early May and extends until the end of August. The months of June and July are peak periods for the presence of this flounder's eggs in the waters around Millstone.

Larvae are also most abundant in this same June and July time span. In general, larvae are found at coastal stations throughout the spawning period, with the Niantic Bay area showing a slightly higher productivity. In the years 1973 to 1975, windowpane larvae comprised five percent of the total larvae catch.

The windowpane is taken at all the inshore stations at Millstone, but is most abundant at the two outer stations. Although it has been recorded in seines and gill nets, it is most often present in otter trawls. To a lesser extent, it is found impinged on the intake screen.

Abundance

The windowpane comprised 10 percent of the otter trawl catch in the years 1973 to 1975, less than one percent of the total fish taken in gill nets, and less than one-tenth of one percent of shore-zone seine catches. In that same period, they accounted for one percent of the total fish impinged each year. Based on data from 1975, windowpane impingement is fairly consistent through the year.

Food and interspecies relationships

The large mouth of the windowpane enables it to feed on active prey, generally the mysid shrimp. Though small fish are part of its diet, the windowpane is not classed as a fish eater. This was borne out in a study of their stomach contents conducted in 1974. The results showed that shrimp comprised 65 percent of the windowpane's diet and were present in 90 percent of the fish examined.

Although not a seasonal migrator, individual windowpanes often wander up and down the coast, thereby intermingling with local populations.

Spiny dogfish (Squalus acanthias)

Range

The Atlantic Coast from North Carolina to Labrador, occasionally to Greenland.

Life cycle and habitat requirements

The spiny dogfish is common inshore but is apt to be found anywhere between the surface and depths of up to 100 fathoms.

The spawning season of the spiny dogfish begins in the spring and may last until early autumn. The eggs of the spiny dogfish develop within the female and are released as living fish in the fall and winter, after a gestation period of 18 to 22 months. The average litter is between four and six but may be as many as eleven.

The newborn dogfish are between six and thirteen inches in length. The dogfish can grow up to four feet in length, but it seldom grows larger than three and one-half feet. The male dogfish matures at a length of two and one-half feet and the female at a length of three feet.

The spiny dogfish is an extremely gregarious fish and, as such, is often found in schools. These schools are usually segregated according to size.

In general, the spiny dogfish is a seasonal migrator. While there is some evidence that the dogfish moves up and down the coast from spring until autumn, he is for the most part an onshore-offshore migrator. Thus, his winters are spent in the deep offshore waters where he remains until spring, when he moves inshore for the period of spring to autumn. Other than this seasonal migration, his wanderings are controlled by the availability of prey.

The spiny dogfish has been taken with trawl and gill net in the Millstone Point area. The Niantic Bay gill net station has yielded more spiny dogfish than any other station in the area.

Abundance

Only one spiny dogfish was taken with otter trawl gear in the period of July, 1973, to December, 1975; this represented less than one percent of the total trawl catch for that period. However, from December, 1971, until December, 1975, the spiny dogfish accounted for two percent of all fish captured with gill nets.

Food and other interspecies relationships

The spiny dogfish is voracious. While it will eat squid, shrimp, and crabs, it's major diet consists of small fish. The dogfish preys upon mackerel, herring, cod, and other fish, not only devouring them but also driving these fish from their feeding grounds.

The spiny dogfish has often been known to bite through the nets of fishermen in his search for prey. Because of this and the fact that the dogfish drives fish from the usual fishing grounds, the dogfish enjoys a deservedly bad reputation with commercial fishermen.

Scup (<u>Stenotomus chrysops</u>)

Range

East coast of the United States from North Carolina to Cape Cod; occasionally found in the Gulf of Maine.

Life cycle and habitat requirements

The scup is found in water as shallow as two fathoms and as deep as 90 fathoms. They prefer a smooth bottom as opposed to a rocky one.

The scup spawns from May to August, but chiefly in June. The eggs are buoyant, and their incubation period is about 40 hours.

The larvae, which made up one percent of the Millstone larvae catch from May, 1973, until May, 1975, grow to a length of five inches in their first year. An adult scup may reach a length of 18 inches and a weight of three to four pounds.

Adult scups usually congregate in schools. They are seasonal migrators, wintering in deep water and moving inshore in the summer where they spawn. The scup is extremely sensitive to low temperatures and sudden cold spells, while the fish are still inshore, may cause great numbers to perish.

The scup has been both impinged and taken with gill nets; it has also been taken in the otter trawls. In the trawls, it is present at all stations, but it is most abundant at the inshore stations.

Abundance

The scup accounted for 19 percent of the total trawl catch in the period July, 1973, to December, 1975. In the period December, 1971, to December, 1975, the scup comprised three percent of all fish caught in gill nets; Nineteen hundred and seventy-two was the peak capture year when they accounted for 25 percent of the total catch. In the years 1973 to 1975, the scup was found impinged on the rotating screens; however, it made up less than one percent of the total number of impinged fish.

Food and other interspecies relationships

The scup is a bottom feeder feeding chiefly on amphipods, worms, sand dollars, squid, and other invertebrates. They will also eat fish fry and floating larvae. This is especially true of the young scup.

Pipefish (*Syngnathus fuscus*)

Range

Atlantic Coast from Nova Scotia to South Carolina.

Life cycle and other habitat requirements

The pipefish is found chiefly among eelgrass or seaweeds, in salt marshes, harbors, and river mouths. It is also found along open shores and in brackish waters. Occasionally, the pipefish is found in the open ocean, but it is seldom found far from the shore and is rarely reported at depths greater than 150 feet.

The pipefish spawns during a period of March through August, with a peak extending from April to July. The eggs of the pipefish are passed from the female to the male. The eggs, usually numbering one hundred, are then kept in a broad pouch which is located on the male pipefish. Incubation takes approximately ten days; the hatched eggs, however, remain in the pouch until they nearly reach a length of 9 mm, at which time they are released into the open ocean. Larvae of the pipefish account for 1% of all larvae taken at Millstone Point from May, 1973 through May, 1975.

Adult pipefish mature at one year. They may grow up to twelve inches in length but are generally four to eight inches. Pipefish are not seasonal migrators and may be found year-round in shallow waters.

At Millstone Point, pipefish have been found impinged on the rotating screens. They have also been taken with shore-zone seines and trawls. While they are present at most of the trawl stations, they have not been taken at the station that is farthest offshore.

Abundance

In the period of July, 1973, through December, 1975, the pipefish represented less than 1% of all the total trawl catches at Millstone Point. They also accounted for less than 1% of all fish taken with shore-zone seines from May, 1969, to December, 1975. Pipefish were found impinged, in each year, 1972 through 1975, on the rotating screens. In 1972 they accounted for less than 1% of all fish impinged, however, in each following year up through 1975, they accounted for 1%.

Food and other interspecies relationships

Pipefish feed chiefly on small crustacea, mostly copepods and amphipods. They will also eat fish eggs and small fish fry. Because their jaws can be distended, pipefish can swallow prey which are larger than their size indicates.

Pipefish have few known natural enemies and, as such, do not provide a major source of food for larger predators.

Blackfish (<u>Tautoga onitis</u>)

Range

Atlantic coast of North America from the outer coast of Nova Scotia to South Carolina. Most abundant between Cape Cod and the Delaware Capes and restricted to the immediate vicinity of the coast.

Life cycle and habitat requirements

Although more coastal than the cunner the blackfish ranges from the intertidal coast where they prey on the blue mussels to 10-13 fathoms. Their favorite places include steep rocky shores, breakwaters, submerged wrecks around piers and docks, over boulder strewn bottoms and over mussel beds. When not feeding, they often live on their sides, inactive until the tide stirs them.

Spawning occurs in June. The eggs are buoyant. Incubation takes 42-45 hours at 68 F water temperature.

Tautog are usually present from May to November and then spend the colder season among eelgrass in slightly deeper waters.

Abundance

There is a heavy local population of the blackfish in the area of Niantic Bay.

Food and other interspecies relationships

Tautog will feed on crabs, sand dollars, amphipods, shrimps, isopods, and lobsters. However mollusks are their chief source of food.

Cunner (Tautogolabrus adspersus)

Range

Atlantic coast of North America and the offshore banks from Newfoundland to New Jersey tapering off in abundance but present as far south as Chesapeake Bay. This species is commonly seen by divers and taken frequently in gill nets.

Life cycle and habitat requirements

The cunner is a coastwise fish with the greatest majority within 5-6 miles of shore. They are found from just below the tide marsh among eelgrass, around wharfs and floats.

This is not a schooling fish although they may be found in great clusters. They never depart from the bottom and spend much of their time resting quietly or swimming slowly among Irish moss and kelp.

The cunner is present year round although it may move to slightly deeper waters to avoid very low temperatures. Temperatures of at least 55-56 F are believed necessary for successful reproduction. The upper thermal limit is around 70-72 F.

Spawning takes place from late spring through early summer. Eggs are buoyant and incubation requires 40 hours at 70 F.

Abundance

Year to year fluctuations are not known. However, in the Massachusetts Bay very few were found in 1950.

This species is by far the most common and abundant form around rock pilings off Millstone Point.

Food and other interspecies relationships

Cunner is a busy scavenger, eating amphipods, shrimp, young lobsters, crabs, mollusks, hydroids, and annelid worms. They have been known to eat small sea urchins, bryozoans, and ascidians and on occasion capture small fish such as silversides, sticklebacks, mummichogs, pipefish, and the fry of larger species.

Red or squirrel hake (*Urophycis chuss*)

Range

Gulf of St. Lawrence southward to the Middle Atlantic States.

Life cycle and habitat requirements

The hake is a ground fish found most frequently on soft bottoms. It occurs chiefly in depths between 20 and 175 fathoms.

In the Millstone area, the red hake spawns from early July until the end of September. The month of July represents a peak in eggs present in the Millstone waters.

Hake larvae are at first free floaters. As they grow, they seek the relative security of the bottom. In Millstone, from 1973 to 1975, the hake comprised less than one percent of the total larval catch reported.

The hake grows up to eight inches in the first year and reaches spawning maturity within three years.

In Millstone, the hake has been taken in shore-zone seines and gill nets set on the bottom. It has also been captured at all trawl stations, both inner and outer.

Abundance

Hakes are not dominant species in Millstone. They comprise less than one percent of the gill net catch and were not taken until 1975. The hake accounts for less than one-tenth of one percent of all fish taken with shore-zone seines. In trawl catches, the red hake represents one percent of the total from 1973 to 1975.

Food and interspecies relationships

The hake is a rather sluggish swimmer; and as a result, fish are not a major part of its diet. Instead, the hake feeds on a variety of small shrimps and crabs and, when possible, squid.

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INVERTEBRATES:

Bay Scallop (*Aequipecten irradians*)

Range

The scallop ranges essentially from Cape Cod south to Florida. Occasionally it is reported north of Cape Cod in the Provincetown and Plymouth areas.

Life cycle and habitat requirements

The scallop has a life expectancy of about 20 to 26 months. It usually becomes sexually mature when one year old. Scallops are hermaphroditic. Spawning takes place from early June through August depending on locale and temperature. Each scallop is capable of producing approximately 2 million eggs. Eggs are fertilized in the water, and the larvae swim about for 10 to 12 days before settling to the bottom.

In general, scallops are found at salinities between 14 o/oo and 36 o/oo at depths of less than 25 feet, although they may be found deeper on occasion.

Food

Phytoplanton are assumed to be the primary source of nutrition, although detritus may also provide considerable nutrient value to the scallop.

Abundance

Populations of the scallop fluctuate greatly from year to year and location to location. The scallop is a commercially valuable mollusk, but sustained yields have not been possible in many locations because of the population fluctuations. The Niantic River estuary has traditionally been a center of the scallop industry for Connecticut, and much of New England. Recently, however, populations have fallen below what is commercially feasible.

In the period of July of 1973 through December of 1975, scallops accounted for less than one percent of all invertebrates taken with otter trawls and for less than one percent of all invertebrates taken in the benthic samples.

Only about 18 percent of the total weight of the scallop is considered edible, that portion being the adductor muscle. One bushel of scallops yields an average of 2-1/2 to 3-1/2 quarts of adductor muscles.

Environmental sensitivity

Scallops apparently were abundant before the decline of the eelgrass in the 1930's. It was felt that scallops required the eelgrass habitat for survival. Recently, however, eelgrass has returned to the Atlantic coast, but the scallops have not really come back in great numbers. There are probably other environmental factors important to the scallop that have only recently come under study.

Blue crabs (Callinectes sapidus)

Range

The blue crab is found from Cape Cod south to Florida.

Life cycle and habitat requirements

Blue crabs are found in bays, marshes, and up saltwater creeks. In general, they prefer estuarine conditions.

The spawning season of the blue crab extends from June through October, with a peak in July and August. After mating, the female crabs migrate to areas with high salinities where the eggs mature. Each female carries up to two million eggs, which hatch in about ten days, primarily at night.

After hatching, the young crabs migrate to areas of low salinity, where they can mature in an area relatively free of predators. Maturity is reached after about 25 molts, which occur in a period of twelve to sixteen months.

The adult blue crab grows to an average shell width of six inches.

Blue crabs have been found impinged on the rotating screens of the Millstone generating station.

Abundance

In 1972, blue crabs accounted for less than one percent of all organisms impinged at Millstone's generating station. In 1973 and 1975, blue crabs represented three percent of the total impingement. In 1974, they accounted for four percent of all organisms impinged on the rotating screens of the Millstone Point generating station.

Food and other interspecies relationships

Blue crabs are very predacious and eat a variety of food, both living and dead. Small fish of many species are eaten by this crab; however, mollusks seem to dominate their diet. They also eat crustaceans, organic debris, and plants.

Blue crabs are also very pugnacious and often fight among themselves. On occasion, when threatened, they burrow backwards into the mud for concealment.

American Lobster (Homarus americanus)

Range

The American lobster is found on the Eastern Coast of North America from Labrador to the Carolinas.

Life cycle and habitat requirements

Lobsters are found from the intertidal zone to the continental slope on almost every type of bottom, including silt, sand, and clay. However, they seem to prefer rocky areas which afford them shelter.

Lobsters mate shortly after the female has molted. Molting may occur at any time of the year, but is most prevalent during late spring and summer. After this molt, the eggs mature in the female for almost a year until the next molt. At this time, the eggs are fertilized. The eggs, as many as 100,000 of them, remain attached to the tail of the female for up to 12 months, after which they hatch, usually in the summer. Thus, up to two years may elapse between mating and the hatching of the young lobsters.

The young lobsters are free-swimming organisms which go through many larval stages. After the fourth such stage, the young fry sink to the bottom where they spend their lives. The lobsters can grow only when they molt. When less than one year, they molt frequently; after this, they molt on an average of once a year or less as they get larger. Growth rate is unpredictable so that a mature lobster generally a foot in length may be from four to seven years in age.

The adult lobster is territorial in nature but is, in general, non-aggressive unless disturbed. For the most part, it is non-migratory, except for some inshore populations which move offshore at the onset of cold weather.

Lobsters are found throughout Niantic Bay and the Millstone Point area. They have been found impinged on the rotating screens of the generating station and have been captured with the use of artificial habitats and lobster pots.

Abundance

Lobsters have been found impinged on the rotating screens of Millstone's generating station in each year from 1972 through 1975. Respectively, they accounted for six percent, four percent, seven percent, and four percent of all organisms impinged for this same period, 1972 through 1975. The highest impingement catches are made in the months May through August. In this same period, the pots and artificial habitats also yield their greatest catches. Estimates of the population of adult lobsters in the greater Millstone area ranged form 520 in May, 1974, to over 30,000 in April, 1975.

Food and other interspecies relationships

Lobsters feed primarily at night. While they are known as scavengers, they probably prefer fresh food. They eat many small fish as well as other invertebrates. Their diet is also supplemented by clams and other mollusks.

When young, lobsters are eaten by many small fish, including cods, skates, and dogfish. Lobsters are generally only cannibalistic when young.

Soft-shell clam (Mya arenaria)

Range

The soft-shell clam is found from Arctic seas to North Carolina.

Life cycle and habitat requirements

The soft-shell clam is found burrowed into tidal flats along the coast, most often in the intertidal zone. It seems to thrive especially well in estuarine situations.

Spawning of the soft-shell clam takes place from about May through August. At this time, male and female gametes are released into the water. Up to three million eggs may be released by a single female clam.

The fertilized eggs quickly develop into a swimming larval stage, which lasts for about two weeks. After this, they sink to the bottom and attach themselves to the substrate, where they remain until about one-half inch in length. They then detach themselves and using the foot burrow into the substrate.

The soft-shell clam generally matures in one year at which time it is up to three-quarters inches in length. The soft-shell clam may live up to 12 years and attain a length in excess of six inches.

The soft-shell clam has been found in benthic samples which are taken from the Millstone Point area. It has been taken most frequently at the Jordan Cove Station.

Abundance

In 1973, the soft-shell clam accounted for less than one percent of all mollusks taken in benthic samples.

Food and other interspecies relationships

The soft-shell clam is a filter feeder whose diet consists of plankton, bacteria, and decomposed matter of larger organisms.

In its swimming stage, soft-shell larvae are preyed on by many filter-feeding organisms. As adults, they contribute to the diet of green crabs, horseshoe crabs, and boring snails.

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ALGAE:

Species	Range	Habitat Requirements
Fucus vesiculosus	Artic to North Carolina; also along British coast and other northern European countries.	A brown alga; Sporophytes monoecious or dioecious, attached by a disc-shaped holdfast. Attached to rocks and stones in intertidal zone; produces eggs and sperm throughout the year. Usually Fucus is found growing in a band just above the mussels in the intertidal zone. Can withstand surf better than Ascophyllum so is usually on more exposed portions of rock.
Ascophyllum nodosum	Common species in north Atlantic Ocean on both European and American shores. In America, it is usually confined to New England coast.	Habitat requirements similar to that of Fucus. In New England, it can usually be found growing attached to rocks of intertidal zone, but in more protected areas than Fucus is found in. Fucus and Ascophyllum usually dominate the rocks in the intertidal areas.
Ulva lactuca	Common species from Arctic to Florida, and along European coasts.	One of the most conspicuous of the green algae in the ocean. Occurs in all seas and is often prevalent in brackish or polluted areas, or in salt marshes. Has been increasing slightly in the Millstone Point area, particularly on Fox Island South.

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SECTION 3

PLANT DESCRIPTIONS

3.1 Site Plan

Millstone Nuclear Power Station includes three nuclear powered electric generating units. Two units on the site are operating and the third is under construction (Figure 3.1-1).

Unit 1 which began construction in May 1966 and commenced operation on November 29, 1970 is a 652-MWe boiling water reactor (BWR) type of nuclear power plant. The performance of Unit 1, since going on line, is shown in Table 3.1-1, which gives for each month the gross daily mean MWe produced by the plant.

Unit 2 is an 830-MWe pressurized water reactor (PWR) nuclear power plant and began operation October 17, 1975. Construction was initiated in August, 1974 on Unit 3, which is a 1,150-MWe PWR, scheduled for commercial operation in May, 1982.

3.2 Intake Specifications

All three units will employ a "once-through" circulating water system comprising in each case an intake structure, circulating water pumps, condensers, discharge structures and associated piping. The circulating water systems will utilize Long Island Sound water for cooling steam entering the condensers. Cooling water will be drawn generally from depths greater than 4 feet below mean sea level (MSL) by three separate shore line intakes located along Niantic Bay on the southwestern shore of Millstone Point (Figure 3.1-1). The intake structures are typical of shoreline installations with trash racks and traveling 3/8-inch mesh screens. The rated circulating water flows for Units 1, 2 and 3 are 935, 1,220 and 2,000 cfs, respectively. The circulating water pumps are vertical and draw water from individual bays within the structures. Individual pipes connect each pump to one-half of one plant condenser and deliver the effluent to a tunnel ending at the discharge structures. The temperature rise across the condensers for Unit 1 ranges between 23^{o} and 25^{o}F. Units 2 and 3 are designed for ΔT's of 23^{o} and 18^{o}F, respectively. From the discharge structures the heated cooling water flows through the abandoned granite quarry and returns to Long Island Sound through a cut equipped with a fish barrier.

The intake structures also contain pumps which provide cooling water to the service water systems of each unit. Cooling water is provided to various heat exchangers within the plants and is eventually discharged to the quarry. Service water flow is only a small addition to the circulating water discharge. Total service water flow during normal operation of the power station will add about 187 cfs to the cooling water discharge.

Combined, the circulating water and service water pumps will utilize 4342 cfs of seawater. Compared to either the mean tidal flow through Twotree Island channel (120,000 cfs) or the average tidal exchange in Niantic Bay (100,000 cfs) the three unit cooling water intake flow represents about 4% of the tidal flow (Section 2.2.1).

Where possible, design philosophies have incorporated features to minimize impingement. The intake structures are located such that they are nearly contiguous with the shoreline. Cutoff (curtain) walls extend below normal low water decreasing the possibility of drawing surface swimming organisms into the structures. Approach velocities are also minimal and well below swim speeds most organisms common to the Millstone area can achieve. Approach velocities measured a few feet seaward of the Unit 1 trash racks were in all cases equal to or less than 1 fps (Vast, 1972). Water velocities were measured at the Unit 1 trash rack face at low tide to determine maximum values. These were less than 2.4 fps and most measurements were less than 2 fps (Table 3.2-1). Similar readings at Unit 2 indicated significantly lower water velocities through the trash racks (Table 3.2-1). Design velocities for Unit 3 are 1 fps below the curtain wall and 1.02 fps or less through the trash racks.

Additional detailed design features are provided below for Units 1, 2 and 3 condenser-cooling water intake structures.

3.2.1 Units 1 and 2

A generalized schematic of the Units 1 and 2 intake structures is shown in Figure 3.2-1. These units differ only in the capacity and location of certain components.

The Millstone Unit 1 cooling water intake consists of five bays each 11 feet wide. Each bay is equipped with coarse bar racks 3" on centers which extend to the bottom outboard of the curtain wall. Water enters through the racks and passes under the curtain wall (-4.0' below MSL) then through the 3/8" mesh traveling screens. For Units 1 and 2 the traveling screens are arranged in a loop with the upper end of the loop rising clear of the water in the intake structure. Periodically organisms too large to pass through the screens may become impinged. A water spray system directed onto the backside of the exposed screens, flushes the accumulated organisms and debris from the screens and directs it into a sluiceway leading to catch baskets outside the screen house. There the organisms are collected for identification and enumeration. The traveling screens are rotated both manually and automatically depending on water level differential in order to ensure a reliable continuous supply of cooling water and to limit velocities through the screens.

Behind the traveling screens, the Unit 1 intake houses four circulating water pumps which deliver the 935 cfs of condenser cooling water and four service water pumps rated at 22.3 cfs each. Two service water pumps are in the center bay and one each in the two adjacent pump bays. Normal operation calls for operation of all four circulating water pumps and three of the four service water pumps. Circulating water flow is shown in Figure 3.2-2. Transit time for cooling water in this system is approximately 90 seconds.

The Unit 1 intake structure is equipped with thermal backwash and chlorination capabilities. Gaseous chlorine is applied in front of the traveling screens simultaneously at each bay for approximately 1-1/2 hours every eight hours. Chlorine is injected in conformance with the limits set by the Connecticut State Department of Environmental Protection, NPDES permit and the Nuclear Regulatory Commission Environmental Technical Specifications. Thermal backwash and deicing is rarely practiced.

The Unit 2 condenser cooling water intake consists of four intake bays each approximately 16 feet wide. Coarse bar racks (3" on centers) are located behind the curtain wall which extends to a depth of -10.0 MSL. Preceding the 3/8" mesh traveling screens, Unit 2 is fitted with lateral openings (fish passages) designed to provide entrapped fish an escape route.

Each of the four intake bays contains a circulating water pump which together deliver the 1,220 cfs of cooling water. Three service water pumps rated at 26.6 cfs each are spread among the three northerly bays A, B and C. Normal operation calls for two service water pumps and four circulators. The flow schematic for Unit 2 is shown in Figure 3.2-3.

Unit 2 is also equipped with thermal backwash and chlorination capabilities as means to control biofouling. Gaseous chlorine is injected in front of the screens at each bay sequentially for 1-1/2 hours every eight hours. Applicable chlorine limits are met.

3.2.2 Unit 3

The condenser cooling water intake structure for Unit 3 will be located just to the north of Unit 2 along Bay Point Beach. Architecturally it is consistent with the reinforced concrete pump houses of Units 1 and 2. The 2,000 cfs of cooling water will be withdrawn from Niantic Bay at depths between -30 feet and -7 feet MSL by six circulating water pumps each in a separate bay (Figure 3.2-4). The pump house will also contain four service water pumps rated at 33.5 cfs each. Normally only two of these will operate. Circulating and service water flow is shown in Figure 3.2-5. Transit time through this system to the point of discharge into the quarry is estimated at 2.5 minutes.

The combined circulating and service water pumping is estimated to establish water velocities at various locations in the structure as shown below:

Location	Velocity (fps) Mean High Water El. +1.5 feet	Velocity (fps) Mean Low Water El. -2.0 feet
Curtain Wall	1.00	1.00
Through Bar Racks	0.91	1.02
Immediately Upstream of Traveling Screens	0.78	0.88

The cooling water pumps are protected with trash racks and traveling screens. The racks consist of 1/2-inch thick by 3-1/2-inch deep vertical bars with effective openings of 2-1/2 inches and are sloped at about 5 to 1.

Fish Handling System

The traveling screens for Unit 3 have been modified in conjunction with a fish protection system which also includes a lateral fish passageway and a fish handling facility. The lateral passageways permit fish to escape the intake screens without having to overcome the full current in front of the screens. The fish can swim along the lateral passages parallel to the screen faces and perpendicular to the flow until they escape at the lateral opening at the end of the intake structure. The lateral openings are protected with coarse bar racks.

Mortality to the organisms that become impinged will be minimized through the use of specially designed traveling screens and fish handling facilities. Each of the six pump bays is fitted with screens. These are approximately 16 feet wide, extending from the intake floor to 12 feet above the operating floor. The 3/8" mesh screens are fitted with metal trays extending the full width of the screen. The trays have been modified to act as fish buckets (Figure 3.2-6).

Organisms impinged on the screens are collected in the fish buckets as the buckets clear the water during screen rotation. The buckets are shaped to retain water and to prevent fish from cascading down the screen face.

The upstream side of the screen is provided with a bi-level trough system - the upper trough for debris and the lower trough to sluice away fish. As the fish buckets arrive at the lower level, a low pressure (23 psi) spray system gently flushes the organisms from the buckets and screen panels into the trough. Debris, which is generally matted to the screen cloth, is subsequently removed by a series of high pressure (90 psi) spray nozzles as the screen arrives at the upper level trough.

Outside the intake structure, a fish and trash handling facility will be provided. Trash and debris from the screens are directed to a trash pit area where they are accumulated in a basket. These trash baskets are collected, as needed, and the contents disposed of in an approved area. The organisms flushed from the screens are sluiced to a 25-ft. diam. fish holding pool. The water depth inside the pool will be 2.5 ft. This pool is supplied with a continuous circulation flow of 200 gpm of seawater to maintain the water temperature and oxygen content. The pool will also be covered to prevent overexposure to sunlight and to provide protection from sea gulls. Organisms are retained here to allow time for recovery and mortality studies before being returned to Niantic Bay. Initial plans require that the pool be drained through an 18 in. PVC pipe into the trash pit area. A specially designed fish tank will be placed at the end of this drain line to collect the organisms. Subsequently, the tank is placed on a truck, and the fish in the tank are returned to Niantic Bay at a location away from the intake area.

Traveling screens will be operated in accordance with the following design schedule:

Water Level Differential Across Screen	Screening Action
> 3 in.	Screens operate at low speed (5 fpm)
> 6 in.	Screens operate at high speed (20 fpm)
>18 in.	High level alarm
>30 in.	Circulating water pump shut off
< 3 in.	Screens continue for 1-1/3 revolutions and then stop

A differential level indication greater than 3 in. across any one screen will initiate the traveling water screens in all six pump bays. During initial operation of Unit 3 experimentation with screen rotation will be required to optimize survival in relation to plant operations.

Control of Biofouling

Unit 3 will be equipped with thermal backwash capabilities for controlling growth in the pump well house and in the condensers. The principal method for condenser cleaning will be the Amertap System.

Chlorination will be employed to control biofouling in the service water system. The point of chlorine injection is downstream of the pump house in order to prevent toxic effects on any organisms inside the intake structure.

Deicing capabilities have also been incorporated into the design although operating experience indicates this system will only receive intermittent use.

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SECTION 4

MARINE ECOLOGY STUDIES

4.1 Introduction

A program of studies to determine the potential environmental impact of nuclear powered electric generation at the Millstone Point site has been maintained since 1966. Initially the investigations were designed to establish ecological characteristics of the site, to evaluate the impact of the first operational unit, and to lay the foundation for estimating and evaluating any environmental changes which might result from construction and operation of additional units at this site. Based upon experience gained during the first years of study the investigations have been expanded to provide sufficient scope with respect to both the areas of concern and methodology available.

Biological monitoring was initiated at Millstone on a continuing basis in 1968. William F. Clapp Laboratories of Battelle Memorial Institute was retained for these studies and has conducted most of the biological field and laboratory analyses to date. Their efforts increased considerably after 1970 with the addition of seawater metal analysis, gill netting and trawling and again in 1973 with lobster and winter flounder population estimates, subtidal benthos studies and an intense ichthyoplankton program.

In 1970, Woods Hole Oceanographic Institution was chosen to conduct entrainment investigations of the effects on marine organisms from passage through the condenser cooling-water system of Millstone Unit 1. Normandeau Associates has continued these studies since July 1975. Their charge has been to insure entrainment sampling at Millstone provides the most representative and quantitative estimates available.

Hydrographic studies initiated in 1966 centered on determining the extent of offshore water area in the plant vicinity which might be affected by the thermal discharge. Numerous hydrothermal surveys were conducted subsequently. In the summer of 1973 and winter of 1974 intense field surveys were undertaken to collect data necessary for calibrating tidal circulation models being independently developed by Stone & Webster and the University of Rhode Island. Stone & Webster would use the model in predicting thermal plume distributions for two and three unit operation while URI would use the model in an assessment of entrainment impacts on the Niantic River winter flounder population.

Associated ecological studies conducted as an integral part of the Millstone impact assessment effort also include impingement monitoring which was initiated on a daily basis in 1972, siltation studies made in conjunction with construction of Unit 3 intake, intake water velocity measurements and finally menhaden mortality estimation.

This report section presents methods and results of the studies considered pertinent to the considerations of potential impacts from cooling water intake structures at Millstone and provides the data base for making assessments of three unit operation (Section 5). For the most part the following sections have been prepared by the principal investigators; Sections 4.3 through 4.10 - William F. Clapp Laboratories; Section 4.11 -Normandeau Associates; Section 4.12 - Stone and Webster.

4.2 Tidal Circulation - Model and Field Surveys

The following description of the tidal circulation model is taken directly or in paraphrased form from the Summary Report Ecological and Hydrographic Studies May, 1966 - through December, 1974 Millstone Nuclear Power Station, Sections 3.1 and 4.1.

4.2.1 Model Description

In order to better understand the tidal circulation patterns around Millstone Point it was desirable to develop a hydrodynamic model which could consistently simulate the oceanic circulation patterns at any instant of the tidal cycle.

The tidal dynamic model described herein was originally developed by J. J. Leendertse (1967) of the Rand Corporation, Santa Monica, California. Stone and Webster (S&W) and University of Rhode Island were contracted to independently apply Leendertse's model to the Niantic Bay area to describe the tidal circulation patterns around the Millstone site. The S&W and URI models are identical in theory, but differ in their approach to the grid orientation and model area. Verification studies, using field data, confirm the results obtained from the two models.

In addition to the tidal circulation information obtained, the URI model serves as the basis for a concentration transport model used in the study of fish larval motions. URI's modeling techniques are discussed in Section 4.11.4. The S&W model is discussed below.

The hydrodynamics of a tidal estuary can be determined from the conservation of mass and momentum. This model, developed specifically for estuaries, is capable of predicting surface elevation and flow patterns generated by the tidal action, wind, natural-water inflow or circulating-water discharges. The following input information is required to operate this mathematical model:

1. Boundary geometry
2. Bottom friction
3. Depth of water
4. Latitude of the area
5. Tidal information on the open boundary
6. River and power plant cooling-water discharge flow rates
7. Wind and atmospheric pressure data.

The limitations of this model are associated with its two-dimensionality and the following assumptions:

1. Vertical velocities appear only as fluctuations in the free surface.
2. Water is essentially homogeneous.
3. Molecular viscosity terms are small and negligible.

4.2.2 Grid Layout and Program Inputs

In utilizing the program, a collection of square cells, with the height equal to the average water depth, is used to simulate Niantic Bay and the adjacent portion of Long Island Sound. The size of the cells is determined by the required accuracy of the results and the cost of computer time. Preliminary modeling used a grid size of 1,500 by 1,500 feet square to study the general flow patterns in the vicinity of greater Millstone Bight. The refined model used a grid size of 1,000 by 1,000 square feet. There are approximately twice as many cells as the preliminary model and therefore the refined model gives a more detailed description of the same geographical area. Figure 4.2-1 illustrates the area modeled by 280 cells.

The solid line defines the closed boundary which was chosen to closely approximate the shoreline geometry from Black Point to Seaside Point. The dashed line defines the open boundary which extends through the open water of Long Island Sound.

The model boundary has been extended to include the Niantic River estuary. Thirty-seven cells approximate the general shape and surface area of the water body. Two boundary segments represent the bar separating the river from Niantic Bay and the restricted flow at the railroad bridge.

The effect of bottom roughness upon the water flow is simulated by a Manning's coefficient at each cell. Thus Bartlett Reef and Twotree Island are represented by cells of shallow depths and high roughness coefficients.

Manning's coefficients are assumed to take the values n=0.020, 0.030, or 0.045 depending upon the bottom roughess of the bay.

A single intake flow of 1,000 cfs and a single discharge flow of 1,000 cfs simulate the effect of Unit 1 plant operation in the circulation model. A circulating flow of 4,000 cfs is used to simulate the cooling water flow rate required for three-unit operation.

Tidal height variation caused by the open boundaries is the most important information necessary to the operation of the program. The tidal range in Niantic Bay averages 2.70 feet.

Dynamic solutions for the instantaneous tide wave height and velocity field can be obtained for the cases with or without the power plant in operation. From these solutions two types of output are obtained: (1) an instantaneous flow pattern, at any time during the tidal cycle, which shows the general motion of the water body by displaying the current speed and direction at each grid point in the model; and (2) an historical plot of tidal height and current speed and direction at selected points which can be compared to data collected by field survey instruments.

4.2.3 Circulation Pattern Development

Circulation patterns were generated by two different types of input to the basic model. During initial development, the tidal input along the open boundaries was simulated by a sinusoidal wave. The progress with this method is described below. The second stage of development used the actual tidal data collected during the February 1974 survey as input to the model. The success with and advantages of this method are discussed in Section 4.2.5, Model Verification.

The tidal height variation along the open boundaries produces tidal circulation throughout the model. Tidal heights and current velocities are calculated at each cell over a 12-hour cycle.

Several sets of input to the model have been tested to develop a circulation pattern consistent with field survey results. The addition of the Niantic River estuary to the grid insures a realistic volume of flow to and from Niantic Bay. The model predicts that the high tide occurs approximately 1 hour later in the upper river than at Millstone Point. This is confirmed by survey data. A boundary of one grid length was used at Twotree Island Channel, but was found to disrupt the flow pattern severely. Shallow depths and high friction coefficients produce more uniform flow patterns.

The general flow of water is along the east-west direction. The time of high and low tide occurs at Black Point several minutes later than at Seaside Point. A mean value of 10.5 minutes for this lag time was obtained from the summer field survey of 1973. The lag time affects the magnitude of current velocities predicted by the circulation model.

The tidal amplitude is slightly greater at Black Point than at Seaside Point. Comparison of several tide gages along the Connecticut side of Long Island Sound was used to establish a difference in amplitude of about 8 percent over the east-west axis of the model. These amplitudes at each end of the open boundary affect the time at which the high and low slack water is predicted by the model.

The plant intake and discharge flows are incorporated into the model. Circulation patterns have been generated with no flow, one-unit flow, and three-unit flow. Since the overall pattern is not significantly changed, only one set of predictions is included within this report. In addition, a version of the model that includes wind shear has been developed and tested. Upon verification of the basic circulation model, various wind conditions may be imposed to determine their effect.

4.2.4 Summary of Results

The circulation model that incorporates the most recent field data and grid design is presented in Figures 4.2-2, 4.2-3, 4.2-4 and 4.2-5. The reference point for time is the lower right cell (1,24). Each figure represents a synoptic picture of the tidal current speed and direction at all cells within the model. Times have been selected that represent the tidal current stages of strength of flood, high slack water, strength of ebb, and low slack water.

The tidal input along the open boundary is a sinusodal wave. The wave amplitude along the west boundary is 1.35 feet. The wave increases in amplitude and occurs progressively later along the south boundary. The amplitude at the south west corner cell is 1.45 feet and the lag is 10.5 minutes behind the reference cell.

The strength of flood in Figure 4.2-2 shows a general westward circulation with maximum velocities of 2 fps in the Twotree Island Channel. The high slack stage occurs approximately 0.52 hours after high tide. Figure 4.2-3 illustrates the low velocites and mixed directions characterizing this period of tide reversal. The tidal current stage of the Niantic River estuary lags in time and still shows a moderate flooding current.

The strength of ebb develops about 4.05 hours after high tide. The flow from west to east appears in Figure 4.2-4. Finally, in Figure 4.2-5, low slack water occurs and a general mixed flow pattern precedes a reversal of direction. The tidal current stage of the Niantic River still lags the outer bay and shows an ebbing flow.

The general flow patterns are similar to those observed in past field surveys. They also indicate two phenomena recently noted in the summer 1973 survey data. First, there are no completely slack water conditions between the flood and ebb tides, a characteristic of rotary tidal currents. Second, the time of lowest velocity does not always coincide with the high and low tide, as is observed in other bays along open coastlines, but a lag of from 1/2 to 1 hour usually occurs.

Quantified verification of the circulation model must be done by comparison with tidal current data collected during the two field surveys. Speed and direction histories at model cells closest to field instrument locations have been analyzed for agreement with actual data.

4.2.5 <u>Model Verification</u>

Hydrographic surveys were conducted in the Niantic Bay area of Long Island Sound during August-September 1973 and February 1974. The data collected consisted of tidal levels, current speed and direction, and wind speed and direction. These data have been analyzed; the tidal data were used as input for the two-dimensional tidal circulation model and the current data were used to verify this model.

The boundaries and instrument locations for the summer and winter surveys are shown in Figures 4.2-5a and 4.2-6 respectively. Tide levels were measured continuously at stations F, A, B1, B2 and C for a period of 4 weeks during the August-September 1973 survey and at stations T.G. 1 through T.G. 7 for a period of 2 weeks during the February 1974 survey.

In situ recordings of tidal currents, speed and direction were made at two depths: 0.2- and 0.8- foot depth (MLW). Measurements were made at stations D, I1, I2, I3, I4 and I5 for a period of 4 weeks during the summer survey and at stations C.M. 1 through C.M. 9 for a period of 2 weeks during the winter survey. The wind speed and direction recorded at the Millstone site during the time of the two surveys are also used in the development of the hydrodynamic model.

The 30-day Niantic Bay survey began August 8, 1973, with the installation of 6 Bass Engineering, Type STG/100 Tide Recorders, and 14 Braincon Type 1381 Current Meters at 7 stations, 2 per station.

The Bass Tide Recorders have the capacity to record long-period tidal levels with minimal effects from surface, short-period wave actions. They have a range of 0.0 to 5.0 feet with an accuracy of ±0.01 foot.

The Braincon Current Meters have a speed range of 0.0 to 4.2 knots with an accuracy of ±0.15 knot. They also measure current direction and instrument tilt from 0 to 360 degrees and 0 to 30 degrees, respectively.

During the period August 21 through August 24, 1973, a 2-week instrument check was performed. All instruments were reported operating properly with the exception of the rotor for the lower current meter at Station I3. The problem was solved and the instrument returned to operation.

The 48-hour Niantic River Survey began August 22, 1973, with the installation of 6 current meters at three current meter stations. Wind speed and direction were also measured. This survey yielded a 100-percent data return.

The 30-day survey ended September 10, 1973, with the removal of all instruments, except for two sets of current meters at offshore Stations D and E. These stations could not be located because of the loss of their surface marker buoys. There is a possibility that these instruments are still in place attached to their subsurface floats. Braincon has made two unsuccessful attempts to snare these floats using depressed dragging cables. Besides the loss of these four instruments, incomplete data was retrieved from Station I3, because of the entanglement of the lower current meter rotor as previously mentioned and a failure of the upper current meter film cassette. It was reported by Bass Engineering, after an onsite inspection, that all six tidal recorders had functioned properly.

The winter hydrographic field survey of the Niantic Bay area was completed as scheduled.

The revised scope of work expanded the previous summer survey boundaries and intensified instrumentation and sampling intervals. It supplied additional data for calibrating the tidal-circulation model and for a better understanding of the physics of the study area.

Several steps were taken to ensure a higher percentage of data return for the winter survey:

1) a chart indicating the location of offshore instruments

2) calibration of instruments

3) operational testing of instruments before installation

4) improved mooring and market systems

5) improved data processing and delivery

During the week of January 27, Braincon installed nine mooring systems and commenced installation of current meters. A time base was established by removing the starting magnets from each of the 18 Braincon Type 1381 Current Meters at 8:00 A.M., EST, Thursday, January 31. On that day 12 meters were installed, 2 each at stations C.M. 2, C.M. 3, C.M. 4, C.M. 7, C.M. 8, and C.M. 9.

Instrument installation continued on February 4 with the placement of the remaining six Braincon current meters, two each at stations C.M. 1, C.M. 5, and C.M. 6, plus the placement of two Bass Engineering Type STG/100 Tide Recorders, T.G. 1 and T.G. 2. The remaining five Bass Tide Recorders were installed February 5 at stations T.G. 3, T.G. 4, T.G. 5, T.G. 6, and T.G. 7.

The survey began at 0 hour, Wednesday, February 6.

Braincon conducted the 1-week instrument check February 13. Kelp was removed from around the rotor of the bottom instrument at station C.M. 3. A marker buoy pennant was removed from around the direction vane of the top meter at Station C.M. 2. In conjunction with the inspection, additional instruments were installed in Jordan Cove and midway between Fox Island and High Rock for conducting the 72-hour survey. A time base was established by removing the starting magnets at 8:40 A.M. EST.

Instrument locations for the 2-week and 72-hour survey are shown on Figures 4.2-6 and 4.2-7. On February 20, all instruments were recovered and inspected for marine fouling and bearing failure. Fouling was negligible, and all the rotor bearings were in good condition. These findings led to the decision to omit the post-survey calibration of current meters.

On February 21, Braincon cross-sectioned the Niantic River channel in order to provide information needed to estimate tidal exchange between the Niantic River and Niantic Bay. The approximate location of the cross-section is shown on Figure 4.2-8.

An inspection of the 2-week survey instruments disclosed that 2 of 18 current meters and 1 of 7 tide recorders had failed. Total data return was approximately 88 percent. The single current-meter set in the upper section of Jordan Cove had failed, yielding a 66-percent data return from the three current meters used for the 72-hour survey.

Statistically, the data collected during the summer 1973 field survey are not of a high enough quality for determining tidal lags or for model verification use. The August-September 1973 data are therefore not used because of these deficiencies as well as the following reasons:

1. There is no log on the current meter starting times.

2. The field data collected are not at the end points of the open boundaries of the tidal circulation model.

3. The sampling rate of every 10 minutes is not fast enough to reduce the error in the tidal lag measurements to an acceptable level.

When sinusoidal tidal input to the model was used, there was limited success in simulating tidal current velocities at specific survey instrument locations. The major problem associated with using a sine wave as input is that, in the field, the current velocities are dependent on the tidal range of the previous cycle. The model assumes a constant range with the sine wave input. Thus, at best, the sine wave input model can be only an approximation of the actual events in the field.

The two-dimensional model was then modified to take as input long-term tidal information, using data collected in February 1974 at stations TG 2, 3 and 6. The model was started from rest and run for 60 hours. After approximately 36 hours, the model and field tidal currents were in close agreement. Velocity direction and magnitude versus time plots were prepared for those points in the model grid system which most nearly approximated the location of the current meters (CM3 through CM9) used during the winter 1974 field survey. For comparative purposes, these plots are shown graphically along with the actual field data collected at those locations. For all locations there appears to be favorable agreement between field and model data as shown in Figures 4.2-9 through 4.2-15. Discrepancies between field and model data, as shown in Figures 4.2-10 and 4.2-11, partly evolve from poor correlation between the locations of the current meters and their associated model grid points, the simplfying assumptions used in the tidal model, and the effects of wind on the currents.

4.3 Exposure Panel Studies

4.3.1 Introduction

The traditional use of exposure panels in the marine environment has been to monitor cycles of fouling organisms and borers responsible for the biodegradation of ships, wharves, pilings, and other structures placed in the marine environment. Some electric utilities have used them to determine the presence or abundance of organisms which might foul intake pipes and tunnels, thereby reducing the efficiency of the cooling water intake system.

Recently, a number of investigators have recognized that the degree of complexity of the communities which grow on these panels has been indicative of the general quality of the environment in which the panels have been exposed and have used the exposure panel technique to monitor the environmental effects of power plant construction and operation (see, e.g., Markowski, 1960; Cory, 1967; Frame, 1968; Fairbanks, et al., 1971; Hillman, et al., 1973; Hillman, 1975). The community which is able to develop over a period of time depends on the availability of life cycle stages of the fouling forms usually present in the area at the time the artificial surface is immersed. The critical factors, here, are the water quality parameters, e.g., temperature, salinity, pH, nutrients, heavy metals, dissolved oxygen, turbidity, and toxic substances which limit or control the availability of the fouling organisms. These factors also dictate, to a large extent, which other populations or communities may exist in the area. For example, if a highly polluted area can support the growth of only a few fouling species, in all liklihood the number of fish species found in the area will also be limited. It is this principal on which the use of exposure panels as environmental monitors is based. By assessing the assemblage of fouling organisms and borers over time, one can define existing conditions in terms of community structure and then use possible changes in selected parameters to detect changes in the quality of the environment.

The animals and plants which make up a fouling community are primarily the sessile, or attached, species which occur naturally in coastal waters. There are, however, many free-living organisms such as polychaetes, amphipods, and gastropods which are integral parts of the fouling community. It is this tremendous diversity and the ease with which it can be followed that makes the use of exposure panels a valuable tool for monitoring the effects of changes in environmental quality.

To assess possible changes in the environment at the various exposure panel sites, each site was examined individually over time and compared and contrasted with other sites to allow inferences about spatial and temporal variations to be made.

4.3.2 Materials and Methods

Panel racks were placed at White Point, Fox Island-North, and Millstone Harbor in June, 1968. An additional rack was installed at Black Point in October, 1968, but was moved to Giants Neck in January, 1969, because of difficulties with the installation. A fifth rack was installed in the effluent quarry, suspended from a platform along the eastern bank of the quarry. The sites are shown in Figure 4.3-1.

Throughout most of the reporting period, it was extremely difficult to keep a rack at the intake because of wave action and surge. It was decided to anchor the rack approximately 100 feet in front of the intake screens. A 50-pound mushroom anchor with 40 feet of chain was attached to the rack, and the rack was floated just beneath the surface with two heavy-duty flotation buoys. This arrangement has, thus far, been quite successful.

Each unit, except the intake unit, was installed vertically immediately below low tide level. The unit consisted of a series of untreated southern white pine wood panels backed by transite, a hard asbestos-like material (Figure 4.3-2). The wood provides a soft substrate for the borers, while the transite allows for the settling of fouling organisms.

Each month, two panels were removed - one that had been exposed for one month and one that had been exposed for a 12-month period. The short-term (one month) panels enabled determination of those species which attached each month. The long-term panels allowed measurement of growth over extended periods of time and enabled determination of annual and seasonal variations due to fluctuations in water temperature and/or other environmental factors. Each panel, upon arrival at the laboratory, was held in running seawater for not more than three days until examined. A subjective determination of the percent of the panel covered by a given species was made (± five percent). Where possible, a detailed enumeration of all macroscopic biota was also made. The growth rates of the fouling and boring organisms were noted where possible.

A brief description of each site is given below.

White Point

The panel rack was suspended from the end of a pier on private property on the west side of White Point. The end of the pier is exposed to the prevailing westerly winds, although there is a rock breakwater approximately 50 feet to the left of the pier and extending westward, which protects the pier from extensive wave action. The tidal amplitude is about three feet so that the rack is suspended approximately 2 1/2 feet from the bottom.

Although this site is directly in the path of the thermal plume on an ebb tide, the plume does not normally extend to the pier.

Fox Island-North

The panel rack was suspended from the left side of the Millstone Environmental Laboratory dock which extends eastward toward the northern end of Fox Island, and is close enough to Fox Island to be in waters representative of that site. The site is relatively protected by Fox Island from wind and wave action, although it occasionally receives water from the thermal plume when wind blows it into Jordan Cove on an ebb tide. The rack was suspended approximately 1 1/2 feet from the bottom.

Effluent

The rack was suspended about one foot from the bottom from a platform on the east side of the quarry which receives the thermal discharge. Consequently, this rack is always in the thermal effluent unless the plant is not operating.

Millstone Harbor

The panel rack was suspended from the right side of the northern-most pier on the west side of Millstone Harbor. The site is protected from heavy wave action, and the rack was approximately two feet from the bottom. The site does not normally receive any of the heated discharge.

Intake

The panel unit was floated approximately 100 feet westward of the intake structures. It was the only rack positioned to always be approximately one foot below the surface. There is a three-foot tidal amplitude in the area, and a depth of about 30 feet at mean low water. The rack is directly in the path of the prevailing winds and waves and on a flood tide receives a small amount of water from the thermal plume.

Giants Neck

The Giants Neck site was originally chosen as a reference site because it is completely outside the range of any thermal influence from the Millstone Nuclear Power Station. The rack was suspended from a pier on private property, and faces due east, suspended about four feet from the bottom. The site itself is protected from heavy wave action.

Data Analysis

Chi-Square. In the analysis of exposure panel data for selected species, various two way cross-tabulations of the data were made in which one of the classifications was either percent coverage, grouped into deciles, or number of organisms, grouped into intervals of 10. The other classification variable was either month, year, or site. The purpose of these cross-tabulations was to test whether or not there was any significant relationship between the two classificatory variables; i.e., was coverage, measured in terms of either percent area or number of organisms, dependent on the month, or year, or site.

The statistical procedure used was to test the hypothesis that the two classificatory variables were independent by calculating a chi-square statistic and rejecting the hypothesis of independence if the chi-square value was too large and accepting the hypothesis otherwise. By accepting the hypothesis, we were saying that the amount of coverage was not related to the year, or site, or month.

The basic chi-square statistic used was

$$X^2 = \Sigma_i (f_o^i - f_e^i)/f_e^i$$

where f_o^i denotes the observed frequency in the i^{th} cell of the table, f_e^i is the expected frequency, and the summations (Σ_i) is over all cells in the table. The expected frequency is calculated as

$$f_e^i = c_i r_i / N$$

where c_i is the total frequency of the column containing cell i and v_i is the total frequency of the row containing cell i, and N is the total number of cases in the whole table.

The contingency coefficient is another statistic, calculated from X^2, by the formula

$$c = X^2/(X^2+N)$$

This quantity conveys the same information as X^2 itself but it always varies between 0 and 1. Furthermore, its upper limit can be shown to depend on the size (number of rows and columns) of a table but not on N, which makes it useful in comparing tables of the same size.

It should be pointed out that the X^2 statistic corresponding to a cross-tabulation analysis does not measure the degree of association between the classificatory variables. It merely indicates the likelihood of having a joint distribution that differs from statistical independence as much as the observed distribution does by chance alone.

Diversity Indexes. Diversity indexes were determined for algal and annelid species using a modified Shannon-Wiener H formula:

$$H = -\sum_{i=1}^{S} \left(\frac{N_i}{N}\right) \log_2\left(\frac{N_i}{N}\right)$$

where S is the total number of species, N the total number of individuals, and N_i the number of individuals of the i'th species (Pielou, 1966).

Similarity Analysis. Similarity coefficients were generated for species assemblages on all possible pairings of exposure panels both between stations and between sequential dates within stations. The term "species assemblages" is used in this context to refer to two characteristics of a biological population--species composition, and the abundance of organisms within each of those species present.

The similarity coefficient used for these analyses was the Pinkam and Pearson measure of evenness (Pinkam and Pearson, 1974), and is defined as:

$$S_{ab} = \frac{1}{k} \sum_{i=1}^{k} \frac{\min (X_{ia}, X_{ib})}{\max (X_{ia}, X_{ib})}$$

where:

S_{ab} = similarity between data set a and data set b;

k = numbers of species found at one or both sites;

X_{ia} = the number of individuals of species i in data set a;

X_{ib} = the number of individuals of species i in data set b.

Mutual absences of species, that is, values of i where both X_{ia} and X_{ib} were zero, were ignored, since the long species lists involved could lead to a pair of data sets with no species in common to have a high similarity coefficient simply by having a large number of mutually absent species.

The value of S_{ab} can range from a minimum of 0 to a maximum of 1. $S_{ab} = 0$ where data sets a and b have no species in common; $S_{ab} = 1$ where data sets a and b have exactly the same species present and the abundance of each species is identical. This is such a stringent requirement that it is very rarely achieved in field data.

The calculated similarity matrices were used in a computer program (Anderberg, 1973) which performed cluster analyses to link the sampling sites into a hierarchical "tree" structure, which is displayed in the form of a dendrogram.

The clustering algorithm used was the unweighted pair-group method which maximized the average similarity index between the merged pairs of groups (Kaesler and Cairns, 1972).

Similarity coefficients and cluster analysis provide a way of comparing and contrasting data sets which is different from that provided by analyses of variance. Two data sets could be demonstrated by an ANOVA and a Mean Separation Test to be similar on the bases of numbers of individuals, numbers of species, and species diversity; yet, it is still conceivable that these two data sets could have completely different species compositions from one another. On the other hand, a similarity coefficient directly measures the degree of overlap in species composition and species dominance between two sites because its computation utilizes information about the simultaneous occurrences of various species.

4.3.3 Results

To date, a total of 151 identifiable taxonomic groups representing three algal phyla and 11 animal phyla have occurred on exposure panels in the Millstone Point area. These are listed in Table 4.3-1. This does not include those organisms which could only be identified to family or genus, and which previously or subsequently might have been identified more specifically. For example, five species of the green alga genus, Enteromorpha, have occurred on the panels. Occasionally, when setting had just occurred on the panels, and only a green film was present, it was not possible to make an identification more specific than Enteromorpha spp. This group was not, therefore, included in the tabulation as it was probable that it included one or more of the species of Enteromorpha already identified. There were 50 such groups in the overall occurrence list since 1968.

In calculating diversity indexes, these groups were not included unless no other specific representative of that group was present in the sample for which the calculation was made.

Table 4.3-2 shows the number of taxonomic groups within each phylum that have occurred at each site throughout the study. White Point had the greatest number of groups with 94, representing 62 percent of all groups settling on panels in the Millstone area. The effluent rack collected only 23 percent (35 groups) of the total, but that site has been sampled for only two years.

The intake rack did not sample effectively for most of 1972, yet more groups were represented at that site than at Millstone Harbor, which has been sampled for the entire length of the study. The primary reason for the lack of groups at Millstone Harbor is the heavy Limnoria attack which destroys the surface of the wooden panel and limits setting of other organisms.

The phylum with the largest number of groups is Arthropoda, which include amphipods, barnacles, limnorids, and crabs. This dominance is reflected at all sites except Fox Island-North, where the arthropods are outnumbered by the annelid worms.

Most of the 151 groups appear only occasionally, or in relatively small amounts. Many have occurred only once in the eight years of the study. To assess the significance of the occurrence and abundance of the various groups at each of the sites, a chi-square contingency table analysis was carried out. The species found to have significiant site specificity are shown in Table 4.3-3.

Relatively few species showed any significant relationships or cycles, other than normal seasonal cycles, at any site. Some showed negative specificity, i.e., they rarely or never occurred at a certain site. The common sponge (Halichondria bowerbankia) was rarely found on panels in the effluent quarry, and the kelp (Laminaria agardhii) has never occurred at the site. The barnacle (Balanus eburneus) has not occurred at Giants Neck since 1973.

There has been a sharp increase over the past several years in the number of species appearing on panels at the various sites, although at only one site, Millstone Harbor, was there an increase in 1975 over what was found in 1974. Table 4.3-4 shows the total number of groups appearing at each site each year and the results of a regression analysis carried out to determine the statistical significance of the apparent increase. Strongly significant increases occurred at all sites except the intake where the probability level was between 90 and 95 percent. No time series analysis was carried out for the effluent panels, as there were only three years' data.

The greatest increases throughout the Millstone Point area have occurred with the algae and annelid phyla; however, these increases have been significant at only certain sites. Algal diversity indexes at each site are shown in Table 4.3-5. The only significant increases in diversity were at White Point ($.99<p<.999$) and Fox Island-North ($.99<p<.999$). There has been an increase in algal diversity at the effluent, but there have not been enough sampling years at that site to adequately assess the significance of the increase.

The annelid species diversity indexes for each year are show in Table 4.3-6. At all sites except the effluent, for which the data were not analyzed, there was a significant increase in diversity index.

The intensity of attack by both molluscan and arthropod borers has fluctuated considerably throughout the study. Table 4.3-7 shows the mean annual estimate of percent attack of the wooden portion of the exposure panel by a species of the shipworm *Teredo*. Until 1975, the only teredine borer found in the panels was *T. navalis*. In July, specimens of *T. bartschi* were found in the effluent panel. *Teredo* attack in the effluent panel dropped from virtually 100 percent to zero from August through December, 1975, accounting for the drop in the mean annual percentage. Attack at White Point was relatively low early in the year, but was up to over 75 percent by December. The mean percentage, however, dropped from 1974 to 1975.

The only site where there was an increase in the mean annual *Teredo* attack was at Giants Neck where the percentage went from 37 to 55.

The decrease in *Teredo* attack at Fox Island-North was probably due to the increase in the activity of the crustacean borer, *Limnoria tripunctata*, as seen in Table 4.3-8, which shows mean annual number of all species of *Limnoria* which occur in the Millstone Point area. *Limnoria tripunctata* attack increased at all sites in 1975, especially at White Point, Fox Island-North, the effluent, and Giants Neck. *L. lignorum* attack also increased at Giants Neck in 1975.

The influence of *Limnoria* attack on *Teredo* infestation is illustrated in Figure 4.3-3, a plot of *Limnoria* abundance versus *Teredo* infestation from new data from all panels. The relationship is strongly correlated at the $p = .\underline{95}$ level, even including the "wayward" point from White Point data during 1975.

The mean number of Limnoria tunnels increased considerably at all sites except the intake in 1975 (Table 4.3-9). The sharp increase from 27 in 1974 to 1,566 in 1975 at the effluent is probably the reason for the drop in Teredo attack at that site.

4.3.4 Discussion

Although there was a decline in 1975 in the number of species occurring on the panels at all sites except Millstone Harbor, the trend toward increased diversity has continued throughout the Millstone Point area. This increase is indicative of a change in water quality, as indicated by several authors (e.g., Wilhm, 1967; Bechtel and Copeland, 1970; Gallaway and Strawn, 1975). Generally, diversity should decline with a decrease in the quality of the water, and vice versa. The increase in diversity in the fouling forms in the Millstone Point area could be due, therefore, to an increase in water quality, or to some other change which would make the proliferation of certain species possible.

The relative similarity of species' composition of the panels was quite variable between stations. Figure 4.3-4 shows a series of representative dendrograms depicting the relative similarity between 12-month panels from all stations.

Each line on the dendrogram represents the maximum average similarity between the station referred to and any other station. Thus, stations with relatively high common similarity are connected by short branches, and those which are relatively dissimilar to them are connected by long branches. The four dendrograms portrayed in Figure 4.3-4 were selected from a total of over 100 dendrograms computed for 1974 and 1975 panel data to indicate the type of relationships in similarity between stations which occur. In all four examples, the species composition of the effluent station panels is least similar to the other stations.

Figure 4.3-5 was developed for dendrogram data of this sort during 1974 and 1975 and shows the maximum similarity between a given station and other station throughout 1974 and 1975. The species composition at the effluent station is unique in terms of its consistent dissimilarity to other stations. The species composition of the Intake and Giants Neck panels is also to some degree dissimilar to other stations.

Similarity analyses were also conducted on exposure panel species composition data at each station over time. Two types of comparisons were made: species composition at month i was compared with that from month i + 1; and species composition data from month i was compared with that from month i + 12. The first type of comparison was that of monthly changes in relative similarity. The second type of comparison was that of year to year redundancy in species composition. Taken in toto, the results are quite variable and show no clear-cut pattern of seasonality of year-to-year redundancy. We are currently conducting several kinds of cluster analyses to gain a better understanding of the nature and extent of this variation.

Temperature data are collected at most of the exposure panel sites (Figure 2.2-9). The average of the temperature ranges, reported on a weekly basis, from all of these sites (Figure 2.2-10) indicates that while the average maximum temperatures have not tended to increase over the past several years, the minimum temperatures have. This has narrowed the annual temperature range by only a few degrees each year since 1967. Although these changes are small, they could have major ecological implications.

Because the thermal plume from the power station is relatively small compared to the area sampled, there is no evidence to suggest that the elevations in minimum temperatures are due to power station activity.

Attack by the molluscan borer Teredo navalis has fluctuated from year to year and site to site, although it was most intense for a period of time in the effluent. In 1975, T. bartschi, generally occurring in areas south of Long Island Sound, was found in the panel from the effluent. It was found in July; however, molluscan borer attack on the effluent panel declined sharply from July until there was no attack from September through the end of the year. There was a concurrent rise in Limnoria attack with the decline in Teredo damage. Once Limnoria, which attack the panel surfaces rather than boring deep into the panel, destroy the surface it is difficult for any other species to attach to the surface or bore into it. Consequently, molluscan borer attack could not get started again in the effluent panel.

This "Limnoria effect" accounts for the lack of molluscan borers, as well as the low number of fouling species at the Millstone Harbor site. That site has always had the heaviest Limnoria damage, possibly because of a lot of untreated wood and old pilings in Millstone Harbor.

The effect of the narrowed water temperature range on the activities of all of the borers and fouling organisms occurring on the Millstone Point exposure panels can only be speculated on at this time, but it bears further investigation as it could explain many of the natural cyclic changes occurring in the Millstone Point area.

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4.4 Rocky Shore Communities

4.4.1 Introduction

The objective of this study has been to observe the dominant species of the sessile fauna and flora found at the seven intertidal rocky shore sites situated at varying degrees of proximity to the Millstone Point plant. From seasonal observations, qualitative changes in population and zonation can be detected; and from this information, natural environmental changes can usually be delineated from those possibly induced by plant activities.

It should be emphasized that this program is semiquantitative in nature. Sites are viewed as whole communities with many populations interacting and affecting each other. Through continual visits to the sites, the biologist becomes familiar with the individual character of each location, and through his intuitive interpretation it becomes readily obvious to him when, for example, there is a decrease in the size of the barnacle zone or an increase in the abundance of a particular algal form. This type of investigation is valuable as an adjunct to quantitative sampling and analysis.

The overlapping of observations of three of the rocky shore sites (White Point, the Fox Island area, and Giants Neck) with observations from the intertidal portion of the benthic program and the exposure panel program provides a good approach to the overall Millstone Point study, for it combines the biologist's observations with more quantitative analyses of abundance.

4.4.2 Materials and Methods

Since May, 1968, a survey of the rocky intertidal zone has been carried out at White Point, Fox Island-North, Fox Island-South, Bay Point, and Giants Neck. In February, 1973, two sites (the east and west sides of the Seaside Point jetty) were added. Figure 4.4-1 shows the location of the seven sites, and Figure 4.4-2 depicts the observed community zonation at each site.

Observations were made each February, May, July, September, and December in the period from an hour before to an hour after low tide. The most dominant or commonly observed organisms were identified in the field, and in most instances relative abundance was expressed as a percent of the study area covered. Accuracy was estimated to be ± ten percent. In the case of some invertebrate forms, a ranking of A through E was given, based on approximate numbers of the individuals in the sampling area. The ratings were as follows:

tr = trace
A = rare, occasionally occurring in the area
B = sparse, widely scattered along transect, but nowhere numerous
C = common, unevenly present along transect, occasionally numerous
D = abundant, unevenly distributed, but frequently numerous
E = very abundant and evenly distributed along transect

Representative samples of all species found in the area are collected and returned to the laboratory for identification. A reference collection has been maintained.

Hydrographic information, including surface water temperature, dissolved oxygen, salinity, and pH, as well as general weather conditions, including air temperature, wind direction, wind velocity, and cloud cover were taken at the time of each sampling.

Since September, 1974, readings of the hydrographic parameters (water quality) have been taken using a Hydrolab Model II B sonde and instrument assembly from Hydrolab Corporation, Austin, Texas. This instrument was calibrated daily for the water quality readings taken in conjunction with the ichthyoplankton sampling program.

A brief physical description of each site follows:

The coastline in the sampling area is generally in an east-west orientation. The prevailing winds are from the southwest (onshore) during the summer and from the northwest (offshore) during the winter.

Seaside Point is located about midway between the power plant and the mouth of the Thames River. The jetty chosen for observations consists of boulder-sized pieces of granite that add to and form an extension of some natural bedrock ledges. It was decided to treat the two sides of the jetty as individual sites due to their different exposures to wave action and the tidal current.

Seaside-East

This site is on the protected side of the jetty. The wave action is minimum, and the water is very shallow. The average high tide covers approximately 90 percent of the rocks. The subtidal area consists mostly of slab rock with pebbles and coarse sand intermixed.

Seaside-West

This side is exposed to the prevailing southwesterly winds and to wave action even on calm days. The grainte boulders of the jetty give way to bedrock which drops off suddenly at the southern end to a depth of 25 to 30 feet (mean low water).

The Seaside sites are outside the range of thermal influence of Unit No. 1.

White Point

This site lies east of the plant and has a southwesterly exposure. There is a sandy beach north of the site and a rock outcropping south of it. A jetty runs perpendicular to the transect approximately 20 feet offshore, so that some protection from wave action is afforded the study area. White Point is in the path of the thermal plume on an ebb tide, but the heated water does not reach that far.

Fox Island-North

Having a northern exposure, it is the most protected of the seven rocky shore sites. There is little wave action in the transect area. The water adjacent to the transect is relatively shallow and the circulation seems quite reduced, especially at the western end. The rocks in the area slope gradually toward a sandy bottom which is often covered with debris and broken shells at the eastern end of the transect to a mud-clay bottom at the western end. This site occasionally receives water from the thermal plume when southerly winds blow into Jordan Cove on an ebb tide.

Fox Island-South

The transect lies along an area of bedrock and artificial jetty, just east (approximately 150 yards) of the quarry cut. The slope of the rocks is gradual. The transect has an unprotected southwesterly exposure and is in the path of the effluent on an ebb tide.

Bay Point

The transect at this site has an east-west orientation and is subjected to a great deal of wave action generated by southerly winds. There is a large natural rock outcropping south of the transect area, but it offers little protection from the wind and waves. The slope of the rock is much greater here than at Fox Island-South, though the exposure is similar. At about the low water mark, the slope becomes almost vertical, with the rocks extending to a depth of 20 to 30 feet. This area is closest to the intake structures and should not be affected by the thermal plume from Unit No. 1.

Giants Neck

Although it has a south-southeast exposure, this site is partially protected by a large jetty. The slope of the rock is quite gradual at the western end of the sampling area, but quite steep at the eastern end. There is a sandy beach east of the transect area. Located approximately three miles west of the point, this area has been considered a control site.

4.4.3 Results

Estimates of the mean yearly coverage of the more common species making up the intertidal communities at each of the sampling sites from 1969 through 1975 are shown in Table 4.4-1.

Codium fragile continued to increase in coverage at Fox Island-South and Bay Point. At the former site, dense mats of the alga covered a sizeable portion of the outer edges of the transect, an area usually inhabited by *Chondrus crispus*, *Ulva lactuca*, and *Fucus* spp. The decrease in *Chondrus crispus* can be readily attributed to the replacement by *Codium*. *Codium* also poses a threat to normal development of bivalves because it attaches to shells and grows rapidly (Kingsbury, 1969). New growth of the alga was observed at Bay Point and Fox Island during each survey period in 1975, indicating that its potential for further expansion is quite good, particularly if it is able to attach to the substrate before the normal settling periods for other algae and invertebrates.

The abundance of Ulva lactuca and Enteromorpha spp. during 1974 at Bay Point and Fox Island did not carry over into 1975. Ulva lactuca showed a 10 to 15 percent decrease since 1974 in the average percent coverage at Bay Point; Fox Island-South showed a smaller decrease, and Fox Island-North showed a slight increase. Attention has been given to these species of Chlorophyta in the past because of their natural ability to proliferate in water temperatures warmer than those favorable for the Phaeophyta and Rhodophyta species. Ulva and Enteromorpha species have been more abundant at the Fox Island and Bay Point sites.

There have been slight declines in the abundance of Fucus spp. at Fox Island-North and South and Bay Point, as well as a decline in the abundance of Ascophyllum at Fox Island-South since observations began in 1969.

Some observable trends in invertebrate populations have occurred at certain sites since 1969. There has been a slight decline in the coverage of Balanus balanoides at Fox Island-North and a decline in Littorina littorea at Fox Island-South.

On a short-term basis, there were several noticeable changes in invertebrate dominance in 1975 from 1974. The Balanus populations expressed as yearly averages were consistent with 1974 data, but qualitative observations at Bay Point indicated a high mortality of barnacles in the upper littoral zone between June and December, 1975. Corresponding with this decline was the appearance in July, 1975, of a brown encrusting alga, Ralfsia verrucosa, which covered the dead barnacle shells. It was also observed as a large brown expanse over dead Balanus in September and December surveys at Bay Point. No direct relationship has been established between the appearance of Ralfsia and the mortality of Balanus.

Mytilus edulis continued to show dominance at Fox Island-North, Giants Neck, Bay Point, and White Point.

Mytilus favors exposed situations and a substrate which allows slow draining between tides. Figure 4.4-2 illustrates the low slope found at Giants Neck and Fox Island-North. Thus, Mytilus grows to good size despite the lack of exposure, although Fox Island-North also experienced a decline in Mytilus this year. Bay Point and White Point provide the exposure with their south-southwesterly orientation; both have an abundance of cracks in the rocks that supply some protection from the scouring effects of the surf.

Of all the sites, the topography for Mytilus appears most favorable at Fox Island-South, with a southwest exposure and a long, shallow slope. However, Mytilus has never been very abundant at this site and has shown a decline in presence over the past two years. It is felt that the increased mortality in the Mytilus populations at Fox Island-South may be the result of the increase in numbers of the oyster drill, Urosalpinx cinerea.

In an experiment done on the rate of feeding of the gastropod at controlled water temperature, Hanks (1957) studied the amount of mussels consumed per drill per week at different temperatures. He found the rate of feeding was slightly lower but comparable to that of oysters, and that predation increased with temperature (maximum 25°C). Although no mussel shells were obtained with drill holes, it is felt that the number of drills present and the lack of other suitable food sources, other than barnacles, points to this gastropod as a possible agent in the mortality of _Mytilus_ at this site.

Another factor affecting the mussel populations might be the sensitivity of _Mytilus_ larvae to temperature (Hanks, 1957). Within a suitable salinity range, the optimum temperature for larvae survival and growth is between 11 to 14°C, although this can vary with location. The data indicate that that optimum temperature conditions are present for a shorter length of time at Fox Island-South than at the other sites. However, more physical data must be obtained before any direct correlations can be made.

Table 4.4-2 lists all algal species collected in the study area since 1971, according to the year in which each was found. The species marked with asterisks indicate newly identified species found in 1975. Of these new species, most represent species that had been previously keyed out only to genus such as the three species of _Fucus_: _F. edentatus_, _F. spiralis_, and _F. evanescens_.

Asperococcus echinatus, a brown alga similar in appearance to _Scytosiphon lomentaria_, was collected in fruiting condition at Fox Island-North and White Point in July, 1975. This plant, found attached to rock substrate at the low water mark, favors quiet waters and can only be found between early spring and mid-summer.

It is interesting to note that _Bangia fuscopurpurea_ was found at Fox Island-South in November, 1975, since this had been a plant that has appeared in the upper intertidal zone in February and has usually disappeared by late summer or early fall.

Special attention was given in 1975 to clarifying the crustose forms of algae present on the rocky transects. _Hildenbrandia_ sp., a fairly common red crust, was positively identified at Seaside-East and White Point. _Lithothamnion_ spp., another red crustose form, was also collected at White Point. _Ralfsia verrucosa_, which has been mentioned before, is another crustose alga. So far, it has only been sighted at Bay Point on barnacle shells.

Sphacelaria cirrosa is a brown epiphytic plant first collected in 1975 on _Fucus_ at both benthic and rocky shore sites. Numerous other micro-epiphytic plants have been observed growing on _Chondrus_, _Fucus_, _Ascophyllum_, and _Chaetomorpha_. However, only a few have been positively identified at this time.

Acrochaetium spp., a small epiphytic red alga, was collected growing on *Zostera* at Fox Island-North for the first time in December, 1975.

Two other larger red species, *Spermothamnion turneri* and *Gelidium crinale*, were found in the latter part of the year at Bay Point and Fox Island-South, respectively. Both are species that should be native to the area.

No species not commonly found south of the Cape were observed in 1975.

4.4.4 Discussion

Although there have been fluctuations in the presence of individual species as cited previously, the dominant species found at each site remained consistent. *Fucus* spp. and *Ascophyllum nodosum* continued to be the dominant algal forms at all sites except Bay Point. Dominant sessile invertebrates continued to be *Mytilus edulis* (except Fox Island-South) and the two barnacle species, *Balanus balanoides* and *Balanus crenatus*.

Judging from the rapid increase in coverage of *Codium fragile* at Fox Island and Bay Point, this alga could become a dominant form in the near future.

The increase in *Ulva lactuca* and *Enteromorpha* coverage reported at Fox Island-South in 1974 was not continued through 1975. Growth of these two green plants seemed to level off in the beginning of the year.

Total numbers of species collected in the rocky shore areas in 1975 did not show a great increase from the previous year. The ten new species collected represent small species that have been either overlooked in previous years or taxonomically difficult species that had been grouped under one genus. No definitive increase in the overall abundance of either flora or fauna has occurred at any site in 1975. The large increase in the number of species observed since 1969 may be real considering the increase observed during the exposure panel studies (Section 4.3). However, more attention has been given recently to observations of epiphytic and crustose forms, and these constitute the major additions to the species list.

The low diversity at Giants Neck continued in 1975. Topography and exposure favor growth of *Fucus* and *Ascophyllum* and those forms which can resist desiccation, but the lack of heavy wave action and spray inhibit the presence of many species, such as *Chondrus* and *Corallina*, which require more moisture between low and high tides.

The influence of temperature on the physiology and growth of algae has been recognized as an important factor in its distribution.

Taylor (1973) discussed five geographic groupings of algae found from the arctic to the tropics along the Atlantic Coast. In each geographic region, there are characteristic algal species for that given range, with some species that are able to overlap. For the most part, the limiting factor is temperature.

An increase in water temperature causes a reduction in the solubility of oxygen and an increase in the respiration rate of alga. This results in an increase in depletion of reserved foods and the need for a higher light intensity for effective photosynthesis (Dawson, 1966).

Temperature changes can lead to changes in time of development, since for many species, a reproductive condition is induced by a slight increase or decrease in the water temperature. In temperate regions, a majority of the marine algae becomes fertile during the warmer seasons. The presence of warmer water earlier in the season, for example, could possibly have the effect of inducing earlier fruiting of a particular species. This, in turn, could cause an overall change in distribution if this species gains coverage prematurely, thereby taking up substrate occupied previously by another species.

Prescott (1968) has cited temperature isotherms of 10, 15, 20, and 25°C that represent different optimums for algal growth. A change of 5°C from the norm can induce a plant to enter a dormant or otherwise modified condition. Most plants have one temperature for vegetative growth and another optimum temperature for reproduction.

Beginning in September, 1975, records were kept on the reproductive conditions of algae collected at all intertidal sites. Although not all of the species have clearly distinguishable organs, there are several common flora which clearly show asexual and sexual phases. The following is a list of those species from the Millstone Point area which exhibit these phases and whose life histories can be monitored at the rocky shore intertidal sites. Special attention will be given to the sites common to both the rocky shore program and the intertidal portion of the benthic programs: White Point, Giants Neck, and Fox Island-South.

CHLOROPHYTA

Chaetomorpha linum
Ulva lactuca

PHAEOPHYTA

Ectocarpus siliculosus
Elachistea fucicola
Fucus vesiculosus
Spacelaria cirrosa

RHODOPHYTA

Antithamnion cruciatum
Ceramium rubrum
Champia parvula
Chondrus crispus
Polysiphonia fibrillosa
Porphyra umbilicalis

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4.5 Benthic Studies

4.5.1 Introduction

The objective of this study has been to describe the characteristics of the macrobenthic communities present on rock and sand substrata from stations located in the area of the Millstone Nuclear Power Station. The complexity of these communities varies at the different stations in part because of physical factors such as temperature, salinity, oxygen, turbidity, water currents, tidal conditions, and type and availability of substrate. Since their sedentary habits allow for integration of temporal conditions they can be monitored over time as indicators of change.

Many investigators have studied the benthic communities from sand bottoms (e.g., Sanders, 1958; Nichols, 1970: Field, 1971; Boesch, 1973; Lie and Kelley, 1970; and Parker, 1975), and these studies have done much to define species-sediment relationships (Rhoads, 1974) and seasonal cycles for a large number of invertebrates. There are relatively few studies on the floral and faunal components of the subtidal rock communities (Wood, 1968 and Kapraun, 1974), but Gray (1974) gives an excellent review of the work that has been done on animal-sediment relationship with emphasis on rocky shore species. Recently, emphasis has been placed on the effects of thermal discharges on benthic communities (Cory and Nauman, 1970; Naylor, 1965; and Pearce, 1969), and perhaps more importantly on the techniques and analyses that are being used to assess these effects. For example, Logan and Maurer (1975) state that the association of diversity with pollution has not been critically studied, and it is unwise to rely too heavily on, for example, a diversity index when one is evaluating the effect of a pollutant.

Because of a major change in the sampling technique effective in June, 1974, sand station data discussed cover the period from June, 1974, through September, 1975. Data from the rocky bottom stations extend from June, 1973, through September, 1975.

Parameters measured for the characterization of the communities have included number of species, total numbers and numbers within individual species, dry weight biomass, dominant species, proportion of phyla or species, common and perennial species, and composition of the sediments.

4.5.2 Materials and Methods

Sample Stations

Subtidal sand stations are in Jordan Cove (15 feet mean low water), between Buoy C3 and Twotree Island (25 feet mean low water), approximately 150 feet in front of the effluent quarry cut (20 feet mean low water), in the center of Niantic Bay (20 feet mean low water), near White Rock in Niantic Bay (30 feet mean low water), offshore of Bay Point (15 feet mean low water), in front of the intake structures for Units No. 1 and 2 (15 feet mean low water), and at Giants Neck near Long Rock (30 feet mean low water).

Subtidal rock stations are in front of the effluent (20 feet mean low water) and at Giants Neck near Long Rock (20 feet mean low water).

All subtidal stations are permanently marked with blocks and buoys.

Intertidal sand stations are at White Point at the southern end of the beach area used for shore-zone seining; at the western end of the Jordan Cove beach, approximately 200 feet from the outlet from the freshwater pond; and at Giants Neck at the western end of the beach where shore-zone seining is done.

Intertidal rock stations are within the transects established for the rocky shore program at White Point, Fox Island-South, and Giants Neck.

The locations of sampling stations are shown in Figure 4.5-1.

Sand Substrate

Benthic sand samples are collected during the months of March, June, September, and December. The present sampling effort for the sand substrate includes:

- eight subtidal sand stations, 80 samples per quarter
- three intertidal sand stations, 30 samples per quarter

Total 110 samples per quarter.

At each of the subtidal sand stations, divers took ten cores, 10 centimeters in diameter, to a depth of 5 centimeters (329.5 cm^3), within an area having a radius of 10 feet. Samples were transferred into a fine mesh (.33 millimeter) bag while under water and then returned to the laboratory where they were transferred into plastic bags and frozen until processed.

Rock Substrate

Benthic rock samples were also collected quarterly, concurrently with sand samples. The present sampling effort includes:

- two subtidal rock stations, 10 samples per quarter
- three intertidal rock stations, 15 samples per quarter

Total 25 samples per quarter.

At each of the subtidal rock stations, divers took five samples, each 25 by 25 centimeters within an area having a radius of 10 feet. A diver-operated suction device was used, and as the rock surface was scraped by the diver, sample material was drawn through a tube and collected in a fine mesh bag. When one quadrat had been scraped clean, the bag was removed, capped, and a new bag inserted onto the suction device. Most macroscopic flora and fauna within the boundaries of each quadrat were collected by this technique. Only calcareous algae, primarily red rock crusts of the phylum Rhodophyta, do not lend themselves to this type of sampling. However, when these algae were observed, the percent coverage was noted by the divers and recorded on the field data sheets.

All intertidal rock samples were obtained similarly, and all samples were taken along 10-foot transects to insure sampling at one tide level.

Laboratory Analysis

Details of sample processing include sorting, identifying, counting (where possible), drying, and weighing.

Sand Substrate

Each sand subsample was thawed and seived through a 0.028-inch screen (0.71 millimeters) using filtered seawater. All remaining sand was placed in a large beaker containing 70 percent ethanol.

Samples were hand-picked and sorted into three groups: crustaceans, polychaetes, and all other invertebrates. The ten samples from one station were identified consecutively, in order that the sorter be aware of the differences and similarities within an area. Identifications were to the lowest taxon possible. Counts were made, and the largest and smallest specimen of each species were measured to the nearest millimeter. All invertebrates from one sample were then pooled for one dry weight biomass determination.

Weights were made to the nearest hundredth of a gram, however, reporting is to the nearest tenth of a gram.

Rock Substrate

The subsample was thawed and washed with seawater on a one-millimeter screen. The larger and dominant organisms, e.g., *Fucus* and *Ascophyllum*, were picked from the screen as the sample was being washed, and each species was put into a separate, well-marked jar or dish. Those forms attached to the larger organisms were picked off later. The screen was partially submerged to allow many of the worms and arthropods to float to the surface where they could be skimmed off. The remaining sample was sorted by hand into visible varieties, one species or type per Petri dish.

Due to the time involved in sorting, the invertebrates (once sorted from the algae) were preserved in 70 percent ethanol. The algae, however, were placed in seawater and refrigerated until identified and readied for drying. The refrigeration technique did not interfere with the biomass determinations of the algae and it helped preserve the pigments and features necessary for identification. All algae were identified to the lowest taxon possible, dried, and weighed to the nearest hundredth of a gram.

Invertebrates from each sample were identified to the lowest taxon possible, counted, and then pooled for a determination of total invertebrate dry weight biomass. Also, the largest and smallest specimen of each species were measured to the nearest millimeter.

Individual sponges, bryozoans and hydroids, could not be readily counted because of their colonial nature. Therefore, these organisms were weighed separately for a biomass determination for each species. Furthermore, some bryozoans (Electra sp.), hydroids (e.g., Sertularia sp.), and polychaetes (e.g., Spirorbis sp.) were found attached to algae and could not be readily separated. In these instances, the organisms were left attached, weighed with the algae; and their weight estimated as a percent of the total biomass. The alga on which it was found was also noted.

It is realized that many of the bryozoans and polychaetes mentioned have calcareous material contributing to their biomass. Biomass figures reported for mollusks include their shell weights.

A reference collection has been maintained for the algae and invertebrates taken from both rock and sand samples.

Sand Grain Analysis

At all sand stations, intertidal and subtidal, two cores (3.7 centimeters by 5 centimeters) were taken for analysis of sand grain composition.

Only one of the two cores taken was processed. The other samples have been stored and could be processed, if necessary. The procedure for analysis was as follows:

- The sample was weighed (wet), dried for not less than one hour (at 258 F) and weighed again.
- To remove the silt, the sample was transferred to a five-inch diameter seive with a 0.099-millimeter mesh, shaken for five minutes, and then washed down with fresh water.
- The sample was transferred to a three-inch diameter brass seive with a 0.088-millimeter mesh, soaked in acetone (for faster drying), and dried for one-half hour.
- The sample was then shaken for three minutes to allow passage through a series of nine U.S. Standard seives.

Seive	Screen Opening in Millimeters
10	2
18	1
25	0.7
35	0.5
50	0.297
60	0.25
80	0.18
120	0.125
170	0.09

- The sand from each seive was weighed and the percent of total sand was calculated.

The seives were obtained from Newark Wire and Cloth Company. A torsion balance having a total capacity of 10 grams and calibrated in 0.01-gram divisions, was used for the weighing. All weights were made to the nearest hundredth of a gram. Samples were dried in a Precision Thelco Oven (Model #19) at 258 F.

The above procedure describes sediments in terms of particle size, and the proportion of the different fractions were related to the nomenclature given by Gosner (1971).

	Designation	Size, millimeters
Gravel	Boulders	500
	Cobbles	25-500
	Pebbles	10-25
	Fine gravel	2-10
Sand	Very coarse and	1-2
	Coarse sand	0.5-1.0
	Medium sand	0.230-0.500
	Fine sand	0.050-0.100
Silt	Coarse silt	0.020-0.505
	Medium silt	0.005-0.020
	Fine silt	0.002-0.005
Clay	Clay	0.002

4.5.3 Results

Subtidal Sand Stations

For the six sample periods from June, 1974, through September, 1975, 172 identifiable taxonomic groups representing 10 animal phyla have been identified from the eight subtidal stations. These are listed, by stations, in Table 4.5-1. The greatest number of groups were from phylum Mollusca (46), phylum Annelida (39 species representing 27 families), and phylum Arthropoda (68). This does not include those organisms which could only be identified to family or genus if they had previously been identified more specifically. For example, in counting numbers of species, Nereis spp. would not be included in the tabulation as it was possible that it included one or more of the species of Nereis already identified.

The total mean numbers of individuals per square meter (to a depth of five centimeters) are given for each subtidal station in Table 4.5-2. These numbers are extrapolated from the numbers of organisms taken in ten cores, each ten centimeters in diameter and five centimeters deep.

These data are graphically portrayed in Figure 4.5-2, which indicates the differences in invertebrate abundance between stations and over time throughout the six sampling periods. Invertebrate abundance at most stations was rather similar during most sampling periods. The exceptions to this are the Little Rock and Intake subtidal stations, where invertebrate abundance was greater during the Fall of 1974, and Niantic Bay, where invertebrate abundance was greater during 1975. None of these data indicate any seasonality in invertebrate abundance at any of the sampling stations.

From the standpoint of species composition, the Niantic Bay station also appears to be generally least similar to other subtidal sand stations. Cluster analysis of subtidal sand station species composition data was conducted, and a representative dendrogram is provided in Figure 4.5-3. (An explanation of the cluster analysis method used can be found in Section 4.3.2.) The predominant sand grain size (millimeters) for each station is presented in Table 4.5-3.

Although numbers of individuals have been used to compare relative yields among stations, more emphasis has been placed on how the numerical yield and the number and types of species present help to describe the faunal populations and community structure of the particular stations and how these factors changed with time.

<u>Habitat Variability</u>

One of the key variables influencing the characteristics of benthic infauna is particle size of the sediments. The results of sand grain analyses of sediment samples taken from subtidal stations in the sampling area indicate variability between stations. Size-frequency distribution of sediment samples from subtidal sampling stations are depicted in Figure 4.5-4. Each histogram represents percent composition by weight of various size classes, and was calculated from data pooled together from 1973 through 1975. Dots above and below the histograms represent maximum and minimum percent composition in any single data set, respectively.

The data in Figure 4.5-4 suggest that sediment size-frequency distributions fall into two broad categories. One category, represented by Niantic Bay, Intake, Little Rock, and Giants Neck, consists primarily of small grain sizes. The other category, represented by Effluent, Jordan Cove, Bay Point, and Twotree Island Channel stations, consists primarily of larger and more heterogeneous grain sizes.

Size frequency distributions of these sediments also changes over time. The Chi-square contingency test was used to test the hypothesis that size frequency distribution is independent of the season in which the sample is taken. The results of this test are listed in Table 4.5-4. In most cases ("O"s) station-season combinations show interactions, indicating that sand grain size-frequency distribution is usually dependent upon season. Also, sand grain size-frequency distribution may change from year to year.

The spatial and temporal variability of the physical characteristics of the sediments in the sampling area probably evoke a profound influence on the benthic fauna and flora.

The populations from the individual stations are described below.

Jordan Cove

The subtidal sand station in Jordan Cove is located approximately 100 feet north of High Rock at approximately 15 feet mean low water. The bottom contour has remained very stable over time and the sand grain analyses have consistently shown the predominant grain size to be 0.297 millimeters (medium sand). The Jordan Cove area is occasionally affected by the thermal discharge, particularly when southerly winds prevail on an ebb tide.

For the period June, 1974, through September, 1975, there were 70 species identified at this station. Only ten species were present in the December, 1974 samples, when there was also a significantly lower yield ($\bar{x} = 624$ invertebrates per square meter[a].). In June, 1974, there were 33 species identified and in June, 1975, there were 30 species. There was only a difference of five species between the September, 1974 (29) and 1975 (24) samples. Comparing the two years' data, there were four molluscan species and seven polychaete families that were common to both June samples and to both September samples.

The bivalve mollusk, Tellina agilis, and representatives from the polychaete families Lumbrinereidae and Terebellidae were taken in all sampling periods. The Lumbrinereids, most of which are burrowers and usually carnivorous, were dominant and, in most instances, fairly evenly distributed (low coefficient of variations).

The numerical yield was greatest in June, 1974, ($\bar{x} = 3,452$ invertebrates per square meter). The populations then showed a decline in September and by December the yield ($\bar{x} = 624$ invertebrates per square meter) was significantly lower than all other sample periods. The mean number then rose steadily through the next three periods though the numbers from the June and September, 1975, samples were slightly below those taken in 1975. The mean numerical yield for the six sample periods was 2,036 individuals.

Polychaetes consistently accounted for the greatest percentage of the total yield. Further, the relative percentages of the total yield for the three phyla - Mollusca, Annelida, and Arthropoda - remained very constant over time.

Intake

The intake subtidal sand station is located 125 feet from the buoy holding the exposure panels and 150 feet west of Unit No. 1 at 15 feet mean low water. Due to its proximity to the intake screens this site could potentially be affected by the plant or by short-term activities, such as dredging related to construction. This station is not affected by the thermal plume even though there has been some recirculation of cooling water during some flood tides.

The predominant sediment size was 0.297 millimeters (medium sand) in June, 1974, less than 0.09 millimeters (silt) for the next four sampling

a. The significance level used for this discussion is $p < 0.05$.

periods, and then largely 2.0 millimeters (fine gravel) in September, 1975. Often the bottom is covered with free floating Laminaria, particular' in late summer and fall.

Seventy-one species have been identified at this station with 16 to 39 being present each sampling period.

Comparisons of June, 1974/1975 samples indicate a decrease from 25 to 16 with 50 percent of the molluscan species common to both and 55 percent of the polychaete families common to both. Similar comparisons between September, 1974 and 1975 samples showed an increase of 14 species, with 18 percent of the molluscan species and 63 percent of the polychaete families common to both.

Only Tellina agilis was taken in all sampling periods, but there were usually few in the sample.

Unlike at any other station, amphipods accounted for the largest percentage of the numerical yield in all but the June, 1974 samples. Ampelisca verrilli, the most common amphipod, is usually abundant in coarse sand (Bousfield, 1973). The differences in faunal composition may be related to changes in the sediment.

The greatest numerical yield ($\bar{x}$ = 10,103 invertebrates per square meter) was taken in September, 1974, and this was significantly greater than all other periods. The lowest yield ($\bar{x}$ = 318 invertebrates per square meter) taken in June, 1975, was also significantly lower than at any other period. The mean numerical yield for the six periods was 3,176 invertebrates per square meter.

Effluent

The Effluent subtidal sand station is located approximately 100 feet offshore, mid-way between the quarry cut and Fox Island-South at 20 feet mean low water. Immediately south of the sampling area there is a submerged outcropping (where the subtidal rock samples are taken) which offers some protection from the prevailing southwesterly winds.

The station is in the path of the thermal plume and is most affected by the flow from the discharge. In June, 1975, divers observed that there were noticeable moguls and gullies in the area where the samples were taken and that sand had covered many of the low rocks at the sand/rock interface of the outcropping. By September, more rocks were covered and for an area of 2,000 square feet, there were ridges that were as high as one to two feet. The analyses for sand grain size show a predominant grain size of 0.297 millimeters (medium sand) in June, 1974, of less than 0.09 millimeters (silt) for September and December, 1974, and March and June, 1975, and of 0.297 millimeters once again in September, 1975. The shift in September, 1975, appears to correlate with the running of the circulating water pumps for Unit No. 2 in the early part of September. For the December, 1975 sampling, the bottom contour was described by the divers as "still hilly, with coarse sand and very little silt". However, the laboratory analyses of the sand grain samples have not been completed.

There were 91 species identified at the station. The greatest number per sampling period (40), was identified from June, 1974 samples, and the fewest (26) was identified from December, 1974. Generally, many of the same species overlapped sampling periods. As at the Intake, fewer species were taken in June, 1975 (30) than in 1974 (40), but there was an increase of two in September, 1975 (32) over that identified in September, 1974 (30).

Species common to all six sampling periods were Tellina agilis, Turbonilla interrupta, an epibenthic gastropod; and Sabellaria vulgaris, a tubiculous polychaete that tends to be found in aggregates and which has been very abundant periodically in the samples collected from the rock substrate. Cirratulid polychaetes and ampeliscid amphipods were found in large numbers in more than half of the samples.

No one species or phylum was dominant at this station.

The greatest yield ($\bar{x}$ = 7,096 invertebrates per square meter) was found in June, 1974, and it was significantly larger than the yields for the June and September, 1975 samples ($\bar{x}$ = 956 and $\bar{x}$ = 1,707 invertebrates per square meter, respectively).

In March, though the yield was not significantly larger than those from other periods at the Effluent station, there was a significantly larger yield when compared with yields from other stations except Niantic Bay. The mean numerical yield for the six periods was 3,576 invertebrates per square meter.

Bay Point

The samples are taken approximately 50 yards southeast from the rocky outcropping which lies immediately offshore from the western tip of Bay Point. The sediment is relatively coarse with the predominant grain size ranging between 0.5 to 0.7 millimeters. Although this station is in close proximity to the power station, it is not expected to be affected by the plant operations.

Seventy-seven species were identified over the six sampling periods. Only 17 were identified in December, 1974, and March, 1975, but there were 30 identified from the September, 1974 samples. Both June and September, 1975 samples had fewer species than from June and September, 1974, respectively.

The polychaete family Terebellidae and the amphipod Unciola irrorata were present throughout and the Terebellids were relatively common (low coefficient of variation) in December, 1974, and September, 1975 samples. In all samples but June, 1974, the polychaetes accounted for the greatest percentage of the total yield.

Numerical yields were greater in June and September, 1974, ($\bar{x}$ = 2,751 and $\bar{x}$ = 3,414 invertebrates per square meter) and were the lowest ($\bar{x}$ = 764 invertebrates per square meter) for March, 1975 samples.

Niantic Bay

This subtidal station was added to the sampling program in March, 1975. The marker buoy was anchored near Station 5 for the ichthyoplankton studies at 20 feet mean low water. The sediment is loose mud with the sand analysis showing less than 0.09 millimeters as the predominant grain size. With this high silt content, the bottom is easily disturbed resulting in reduced visibility. It can be safely assumed that this station is not affected by the operation of Unit No. 1.

In the three months that this station has been sampled, only 30 species have been identified. This is lower compared to the other sites with 10 to 17 species occurring at each sample period, but there had been very high numerical yields. The mean numerical yield for the three periods was 11,407 invertebrates per square meter.

Two bivalve mollusks (*Nucula proxima* and *T. agilis*) and three polychaete species (*Clymenella* sp., a tubiculous burrower; *Ninoe nigripes*, a burrower; and *Nephtys incisa*, a predatory burrower) were present in all three months. *N. proxima* accounted for better than 90 percent of the total yield for each period.

The numerical yield at Niantic Bay was always significantly larger than at all other stations.

Twotree Island Channel

The Twotree Island Channel subtidal sand station is located southeast of Buoy C3 at 25 feet mean low water. Although currents are strong at many of the stations, it is exceptionally strong here and most definitely affects the community structure of the benthic and epibenthic populations. The thermal plume for Unit No. 1 has extended as far south as Twotree Island.

The results of the analyses for grain size were variable and the predominant grain size ranged from 2.0 millimeters or greater (fine gravel) in December, 1974, and June and September, 1975, to less than 0.09 millimeters (silt) in September, 1974.

The shifts in sediment type were noticeable to the divers who were able to watch the formation of a sandbar and record how it has changed over time. It is crescent-shaped and stretches east-southeast from the northern tip of Twotree Island. The bar was first observed in the Fall of 1973.

There were 78 species identified at this station since June, 1974. The number of species taken per quarter ranged from 15 in March, 1975, to 34 in the September, 1975 samples. There were no species that were common to all six sampling periods nor did any one phylum dominate.

Beds of the blue mussel (*Mytilus edulis*) were very dense at times. In June, 1974, coverage was heavy and during the December sampling period nearly all available substrate was covered. When coverage was heaviest, it was impossible to take a sample which was not covered by this species; therefore, the numbers taken in the samples reflect the size of the population. There were no mussels in the March and September, 1975 samples; but there were small scattered beds in the station area. Many starfish, Asterias spp., were also recorded by the divers. They are known to be predators of the mussel and may be responsible for the fluctuations in the size of the mussel population.

When the mussels were most dense, mollusks accounted for 70 to 90 percent of the total number of organisms taken. When Mytilus was not present, it was not apparent that it was replaced by any other organism.

There were no significant changes in the numerical yield over the six sampling periods ($\bar{x}$ = 637 to 3,822 invertebrates per square meter) and the yields were comparable to those taken at the other stations. The mean number for June, 1974, through September, 1975, was 1,860 invertebrates per square meter.

Little Rock

Little Rock is a small rock ledge east of White Rock. The subtidal sand station is located approximately 100 feet northeast of White Rock at 25 feet mean low water; however, to avoid confusion with the White Point Station, the name Little Rock was used. Situated west of the entrance to Millstone Harbor and mid-distance from Bay Point and the effluent, there is little chance of the thermal plume reaching this area.

The sediment is muddy silt with scattered shell fragments over the surface. The predominant grain size was consistently less than 0.09 millimeters; however, it is firmer when compared with that at Niantic Bay.

There were 98 species identified from this station, ranging from a high of 44 in December, 1974 (the highest number of organisms identified for one sampling period) to a low of 25 species in June, 1975. In June of the previous year, there were 38 species identified. In September, 1975, there were 35 species - only one less than that taken in 1974.

Mollusks, particularly the bivalves, N. delphinodonta and N. proxima, dominated the yields for the first three sampling periods, whereas polychaete worms from several families were dominant from March, 1975 through September, 1975.

The two species of Nucula, along with Tellina agilis, Turbonilla interrupta, lumbrinereid, and terebellid polychaetes were present at every sampling period.

The mean number of invertebrates ranged from 11,084 per square meter in September, 1974, to 1,223 in September, 1975. The first three sample periods had significantly larger yields than the latter three, and the September, 1974, yield was significantly larger than all other periods. The mean numerical yield for the six sample periods was 4,444 invertebrates per square meter.

Giants Neck

Giants Neck is situated approximately three miles west of the power plant. This station was established as a control station.

The subtidal sand station is located off Long Rock at 30 feet mean low water. Unlike in the immediate vicinity of Millstone Point, the subtidal substrate is largely rock; therefore, when no suitable siting was found at 15, 20, or 25 feet mean low water, the divers decided on this location because it was most comparable in sediment type to the other stations.

The predominant grain size was consistently less than 0.09 millimeters (silt), but it is considered more similar to the sediment at Little Rock than at the Niantic Bay area.

A total of 82 species was identified at this station. The number identified per sampling period ranged from 15 in March, 1974, to 47 from the September, 1974 samples. However, there has been no dominant species at this station, and there were no species common to the six sample periods. Coefficients of variation for individual species indicate high variability each quarter, at least at the present level of sampling used for this program.

Numbers of species common to adjacent sample periods or to the June or September samples for 1974 and 1975 were relatively lower when compared to the other stations.

Polychaetes accounted for the greatest percentage (46 to 63 percent) of the total yield in all months except June, 1974, when the arthropods accounted for 77 percent of the actual numbers taken.

The mean number of invertebrates ranged from 459 per square meter in March, 1975 (significantly lower yield than June, 1974, and June and September, 1975 yields) to 1,928 per square meter in June, 1974. The mean numerical yield for the six periods was 1,279 invertebrates per square meter.

There were seven species and one polychaete family that were common to the eight subtidal stations. These included four mollusks - (Ensis directus, benthic bivalve; Tellina agilis, benthic bivalve; Odostomia seminuda, epibenthic gastropod; and Turbonilla interrupta, epibenthic gastropod) two polychaete species (Glycera americana, detritus feeder; and Nephtys picta, deposit-feeding burrower), and a species from family Cirratulidae, and one arthropod (Unciola irrorata).

Of these, only Tellina agilis was dominant at some of the stations for some or all sampling periods.

No species not commonly found south of the Cape and/or in Long Island Sound were identified from the subtidal sand stations.

Subtidal Rock Stations

For the six sample periods from June, 1974, through September, 1975, there were 49 algal species and 172 invertebrate species identified from the two subtidal rock stations. These are listed, by stations, in Table 4.5-5.

The total dry weights (grams) per square meter are given for the algae from each subtidal station in Table 4.5-6. These weights are extrapolated from the dry weights for each species collected from five samples, each 25 by 25 centimeters (625 square meters).

The mean numbers per square meter for the invertebrates, excluding the bryozoans, are given in Table 4.5-7. These numbers were extrapolated from the numbers of individuals taken in five samples.

Standing crops of algae (g/M^2) and invertebrates ($\#/M^2$) at the subtidal rock stations are plotted against time in Figures 4.5-5 and 4.5-6, respectively. Algal standing crops are very similar at both stations. However, the abundance of benthic invertebrates appears to be markedly greater at the Effluent station in comparison to Giants Neck.

The number of species identified at each station for each sampling period is given in Table 4.5-8 and the number of taxonomic groups from each phylum for the period June, 1974, through September, 1975, is given in Table 4.5-9.

Effluent

This station is on a rock outcropping which lies submerged approximately 150 to 200 feet south of the effluent quarry cut. The station is on the northeast side of the outcropping at 20 feet mean low water. It is in the direct path of the thermal plume and it receives maximum impact from the increased currents.

For the period, March, 1973, through September, 1975, there was a mean of 21 algal species and 50 invertebrate species present each sample period.

Since June, 1974, red algae, particularly *Phyllophora brodiaei*, accounted for at least 50 percent of the total dry weight of the floral component. In June, 1974, *Chondrus crispus* accounted for 58 percent and *P. brodiaei* only 20 percent; and again in June, 1975, another red alga, *Cystoclonium cirrhosum*, accounted for 54 percent and *P. brodiaei* only 24 percent.

The highest biomass was for the algae taken in the March, 1973 samples; the lowest was taken two years later in March, 1975. Maximum growth occurs in early spring with peak production (high dry weights) by June.

In general, twice as many invertebrate species as algal species were present each sample period.

The dominant species were gastropod mollusks, *Mitrella lunata* and *Lacuna vincta*; the bivalve *Mytilus edulis*; the annelid worm, *Sabellaria vulgaris*; and the arthropod *Corophium* spp. The species accounting for the greatest percentage of the numerical yield varied considerably.

The actual numbers of Mitrella were relatively constant over the last six sample periods, whereas there were more than 6,000 Sabellaria worms in the September and December, 1974 samples but only 111 worms in September, 1975.

Sabellaria vulgaris is known to occur in mass aggregates, forming reef-like structures in sand or on the rock substrate. However, the colonies are easily disturbed and/or washed away by heavy waves from storms. The drop in the population that occurred between June and September was probably due to the increased currents caused by the testing of the circulating pumps for Unit No. 2.

This species is known to recolonize quickly as long as some adults survive, for the young will only settle where others are already present (Curtis, 1975; Gray, 1974).

The yields for June, 1973 and 1974 were almost identical. By June, 1975, there was a decrease, but it was not significant. The yield for September, 1975 was numerically the lowest since sampling was initiated in March, 1973; however, it was not significantly lower than the September, 1974 yield.

Giants Neck

The Giants Neck subtidal rock station is located off Long Rock at 20 feet mean low water. As stated earlier, Giants Neck is three miles west of the power station and is never expected to be affected by plant operations.

This station was not added to the program until March, 1974; therefore, there are only data from seven sampling periods compared to 11 for the Effluent station.

There was an average of 15 algal species present each month. The fewest were identified from the March, 1974 samples (5). The most that occurred in one period was 21, and that was in June, 1975. This is slightly less than that found at the Effluent.

Dry weights for the algae ranged from two grams per square meter in March, 1974 (with five species present) to 129 grams in June of this year (with 21 species present). There seemed to be a seasonal cycle for the algal growth with maximum growth occurring in spring and summer.

The dominant alga was, once again, Phyllophora brodiaei, which accounted for better than 50 percent of the algal dry weight biomass. In both June, 1974 and 1975, it accounted for 57 percent and it accounted for 73 and 81 percent in the September, 1974 and 1975 samples, respectively.

For both the Effluent and Giants Neck stations, its dominance was most pronounced in the winter samples. This indicates that it is present year-round, and it is the contribution of the annuals to the biomass which lowers the percent contribution made by Phyllophora.

Numerical yields for the invertebrates were much lower than those taken at the Effluent. They ranged from 1,750 invertebrates per square meter in March, 1975, to 5,331 for December, 1974.

Mitrella lunata was taken consistently at this station, and the actual numbers per sampling period were comparable to those taken at the Effluent. It accounted for 51 percent of the yield in March, 1974.

Sabellaria was also present during every sample period, but in far fewer numbers. At most, it accounted for 49 percent of the yield in December, 1974.

The yields for March, 1973 and 1974 were similar as were the yields for June, 1974 and 1975, and September, 1974 and 1975.

Intertidal Sand Stations

There were 61 species representing four animal phyla identified from the intertidal sand stations. These are listed, by stations, in Table 4.5-10.

The numerical yields are given for each station since June, 1974, in Table 4.5-11. The number of species identified at each station for each sampling period is given in Table 4.5-12. The predominant sand grain sizes (millimeters) are given in Table 4.5-13.

White Point

This beach has a southwest exposure and is offered some protection from prevailing winds by a man-made breakwater. At high tide, there is often a considerable amount of plant material in the area (Shore-Zone Fish - Section 4.9).

The sediment is relatively coarse at White Point with a predominant grain size of 1.0 millimeters. In some months, there were equal amounts of the 0.18 millimeter (fine sand) grain size.

There were 30 invertebrates identified over the six sample periods. There were only four species taken in March, 1975; 15 were taken in September, 1974.

Polychaete worms dominated the yield and two polychaete families, Orbiniidae and Paraonidae, were present in all months.

Numerical yields ranged from 89 invertebrates per square meter in December and March, 1975, to 3,096 invertebrates per square meter in September, 1975. A similarly high yield was taken in September, 1974, but the yields for other periods were significantly lower compared to September, 1974 and 1975 yields.

The mean numerical yield ($\bar{x}$ = 1,043 invertebrates per square meter) for the six periods, and those taken in three of the six sampling periods, ranged between those taken at Jordan Cove and Giants Neck.

Jordon Cove

The beach at Jordan Cove is relatively sheltered and there is usually a considerable amount of detached eel grass (Zostera marina) in the shore zone along with extremely large amounts of detached algae in various stages of decomposition. This layer had to be removed before the sand samples could be taken. The site has a southeasterly exposure and there is a freshwater runoff from a pond located behind the beach which, depending on the currents, may affect communities occurring in the sample area. The bottom substrate is composed of a mixture of silt, detritus, fine to coarse sand, and some emergent rocks.

There was no predominant grain size at the Jordon Cove Station. Grain size ranged from 2.0 millimeters (fine gravel) to less than 0.09 millimeters (silt).

Forty invertebrates were identified at Jordan Cove. Only five were present in June, 1975, half the number identified in June, 1974; 15 were present in March, 1975.

The annelid worms once again were dominant. In fact, no mollusks were present in the June and September, 1975 samples. The polychaete family Nereidae was present each period and in four of the six periods it was the most dominant.

A low mean yield of 395 invertebrates per square meter was taken in June, 1975, and by the following September the highest yield (6,975 invertebrates per square meter) was taken. A similar pattern of low to high yield occurred between December, 1974, and March, 1975.

Giants Neck

This beach has a southerly exposure but is protected by Black Point, Giants Neck, and some offshore islands. The bottom substrate is medium to coarse sand and is often covered with detached algal material and detritus at high tide.

The sediment found at Giants Neck was far more constant than at Jordan Cove and not as coarse (0.297 millimeters) as that found at White Point or Jordan Cove.

Only 23 invertebrate groups were identified from the Giants Neck sand station. In December, 1974, just one worm (Family Lumbrinereidae) and one insect larva were found in the ten samples.

There were no species common to all periods, and there was no dominance by any phylum.

A mean numerical yield of 2,115 invertebrates per square meter was taken in June, 1975. This was far more than that taken at any other time, and it was significantly larger than the yields for that month at Jordan Cove or White Point.

Intertidal Rock Stations

For the six sample periods from June, 1974, through September, 1975, there were 61 algal species (representing 5 phyla) and 75 invertebrate species (representing 8 phyla) identified from the intertidal rock stations. These are listed, by stations, in Table 4.5-5.

The total dry weight biomasses (grams) per square meter (n=5) are given in Table 4.5-14. The mean numerical yields per square meter (n=5) for the invertebrates, excluding the bryozoans, are given in Table 4.5-15, and the number of species identified at each station for each sampling period is given in Table 4.5-16.

Standing crops of invertebrates versus time at intertidal rock stations are depicted in Figure 4.5-7. With a few exceptions, all stations exhibit similar patterns and some degree of seasonality is suggested. Generally, standing crops tend to be higher during the spring and summer months, and taper off to depauperate levels during the fall and winter.

The three intertidal rock stations lie within the transects where qualitative observations are made for the rocky shore program.

White Point

This station has a southwesterly exposure. It is in the path of the thermal plume on an ebb tide, but the heated water does not usually reach this far.

There were 102 species (Table 4.5-9) identified at this station since June, 1974, and since June, 1973, there was a mean of 17 algal species and 20 invertebrate species occurring each sampling period.

Algal dry weights ranged from 294 grams (nine species) per square meter in December, 1973, to 752 grams (33 species) in September, 1974. The dry weight yield was similar for September, 1975 (743 grams per square meter), but then only 13 species contributed to the dry weight..

The brown alga *Fucus* spp., was the largest component and accounted for 38 to 98 percent of the total weight (Table 4.5-17).

The weights showed little variation over the 10 months of sampling.

However, numerical yields were not as consistent. The June, 1974 yield (x = 83,251 invertebrates per square meter) and June, 1975 yield (x = 79,315 invertebrates per square meter) were significantly higher than that occurring in September, 1974. The barnacle *Balanus balanoides* accounted for the highest numbers.

Fox Island-South

The Fox Island rock station is situated 150 yards east-southeast of the quarry cut. It has an unprotected southwesterly exposure and is in the path of the effluent on an ebb tide.

There were 83 species (representing 4 algae and 8 invertebrate phyla) identified at Fox Island-South since June, 1974 (Table 4.5-9).

These samples show that *Fucus* has reestablished itself along the transect (Rocky Shore, Section 4.4), and the presence of *Ulva lactuca* and *Enteromorpha* spp. have decreased considerably from 29 percent and 24 percent of total algal dry weight in the March and June, 1974 samples, respectively, to less than one percent in March, 1975, and approximately eight percent in June 1975 (Table 4.5-17).

A green alga, Codium fragile, though still accounting for less than 10 percent of the algae weights, has shown a gradual increase since December, 1974. Prior to that, this species had not been taken at this station.

Algal weights in general were in the same range as those at White Point. By September, 1975, there was 1,088 grams per square meter which was significantly greater than for previous September samples.

The numerical yields for June, 1974 and 1975, were significantly greater than at all other stations.

Giants Neck

Although this station has a south-southeast exposure it is partially protected by a large jetty. The slope of the rock is steeper than that at White Point and Fox Island-South. This station is not affected by plant operations.

There were 96 species representing four algal and eight invertebrate phyla (Table 4.5-9) identified at this station since June, 1974. Approximately 13 algal species and 19 invertebrate species occurred each sample period.

Algal weights ranged from 384 grams (seven species) per square meter in September, 1973 to 2,610 grams (10 species) in June, 1973. In December, 1974, 28 algal species were identified, but the dry weight was only 612 grams per square meter.

Fucus spp. contributed 1,326 grams per square meter to the total dry weight in June, 1973, accounting for 51 percent. The other largest contributor was Ascophyllum nodosum.

Numerical yields ranged from 2,307 invertebrates (31 species) per square meter in September, 1974, to 99,670 invertebrates (only 14 species) in June, 1975. One of the largest contributors was again the barnacle Balanus balanoides.

4.5.4 Discussion

Due to the change in sampling techniques effective in June, 1974, no patterns of seasonal recurrence of dominant species have been discernable at this time.

Species variability was high. There were a great many species that were only taken once at a particular station from the period June, 1974, through September, 1975. However, this is felt to be more a reflection of the sampling technique used and the number of samples (replicates) that are taken at each station.

In general, the subtidal faunal communities were not dominated by any one species. However, at six of the subtidal stations one phylum usually accounted for the greatest percentage of the total numerical yield.

The picture has been further complicated by what appears to be patchy distribution for a great many of the forms that do occur at all of the stations. Numbers of particular species are often low, Nucula delphinodonta at Niantic Bay being an exception; and there was as much as a 38 percent decrease in the numbers of species taken in June, 1975, from the number taken in June, 1974.

When the numbers of individuals were used to assess relative yields among stations, only the Niantic Bay station (only sampled three times) had consistently larger numerical yields for any given month. The Effluent station did have a significantly larger yield in March, 1974, when compared to all stations except Niantic Bay while the yield at Giants Neck for this same month was the lowest.

In general, there are no striking similarities among the communities at all stations or between any two stations. The numbers of individuals or numbers of species do not appear to correlate with depth. Furthermore, there does not appear to be a correlation between shifts in grain size and numerical yield. For example, at Twotree Island, where there have been almost continuous shifts, there were no significant differences in the numerical yields.

There does, however, appear to be a correlation between the grain size and the proportions of populations from the different phyla (specifically mollusks, annelids, and arthropods) when expressed as a percentage of the total yield.

Benthic Habitat Association

The physical characteristics of subtidal sediments are variable in time and space. To some degree, the biological characteristics of benthic infauna are correlated with the physical characteristics of the substratum.

Table 4.5-18 lists correlation coefficients and corresponding levels of significance between sand grain size and several benthic population parameters. Numbers of species are significantly correlated with small to intermediate grain size, and species diversity is significantly inversely correlated with the smallest grain sizes. Accordingly, there is significantly more probability of finding larger number of species and less species diversity within these respective size factors.

Table 4.5-19 lists correlation coefficients between numbers of individuals in each of six taxonomic groups with each of ten sand grain sizes. Definite patterns of association between taxa and sand grain size are suggested. "Taxa 1" (Tellina spp.) negatively correlated with large grain sizes and positively correlated with intermediate size fractions. "Taxa 2" (Nucula spp.) is negatively correlated with large grain sizes and is positively correlated with small sized fractions. "Taxa 3" (Terebellidae, Amphitrite spp., and Pista cristata) is positively correlated with large grain sizes and negatively correlated with small grain sizes. "Taxa 4" (Lumbrineris spp., Ninoe nigripes) exhibits a similar pattern to Taxa 3. "Taxa 5" (Paraonidae spp., Aricidea spp.) is positively correlated with large grain sizes and negatively correlated with small grain sizes. "Taxa 6" (Ampelisca spp.) is positively correlated with smaller grain sizes. All of these correlations are significant at the p = .95 level, and lend credence to the notion that different kinds of closely related organisms have definite benthic habitat preferences, and are associated accordingly. These associations are summarized in Table 4.5-20.

The three stations that are considered most variable, based on direct field observations and the data through September, 1975, are: Twotree Island Channel, Effluent, and Intake.

The Twotree Channel Station appears, presently, to be the most variable. The grain size ranged from fine gravel to silt with almost continual shifts in predominant sediment type between each sampling period. No species were common throughout the samplings discussed for this report. When the epibenthic bivalve Mytilus edulis was not present, it was not replaced by any other dominant form.

The data from the Effluent Station showed changes in sediment composition, numerical yields, and dominance. There were significantly lower yields in June and September, 1975, when compared with comparable samples in 1974. Mollusks accounted for the greatest number of individuals taken in June and September, 1974; but by December, 1974, dominance had shifted to polychaetes.

At the Intake Station in June, 1974, the predominant grain size was 0.297 millimeters, and the numerical yield was significantly larger than for all other months. In June, 1975, when the substrate in the area was predominantly silt, the numerical yield was the lowest. In general, the arthropods, more specifically Ampelisca sp., accounted for better than 70 percent of the numerical yield.

Although the data from sand grain analyses indicated a possible similarity in the sediments at Giants Neck, Little Rock, and Niantic Bay, the mud/clay component varied and the numbers and types of organisms present were quite different.

The three stations considered most stable for the period June, 1974, through September, 1975, were Bay Point, Niantic Bay, and Jordan Cove.

Niantic Bay appears most unlike the other stations. The data are very similar over the three sample periods in that the numbers of individuals and the numbers and types of species are consistent. It is definitely the most productive station, due to the Nucula population.

There were no apparent changes in the community structure at Jordan Cove over the six sample periods. Representatives from the family Lumbrinereidae were common and usually dominant (except in the March, 1974 samples).

The animals and plants which make up the rock substrate community are primarily sessile forms which occur commonly in coastal waters and in Long Island Sound. There are, however, many free-living organisms present such as polychaete worms, amphipods, and gastropods which move about on the rock surface or on the algal fronds.

Compared to the subtidal sand stations, there was more uniformity between the floral and faunal communities at the Effluent and Giants Neck subtidal rock stations. While densities of the dominant algal and invertebrate species showed some variance, the community parameters (including numbers of species and total numerical yield) were similar. An average of 21 algae and 50 invertebrate species were collected at the Effluent and 15 algae and 46 invertebrate species at Giants Neck.

The subtidal rock stations were characterized by the dominance of the red algal species and comparatively high numbers of individuals from the phyla Mollusca and Annelida.

Usually the Effluent Station had a few more species, and slightly higher algal biomasses and numerical yields for the invertebrates.

The intertidal sand station communities differed from those present subtidally, in that there were fewer species making up the communities and the numerical yields were lower. This was expected though and was, in part, due to the coarser sediments that have predominated at these stations and the fact that fewer species can withstand the rigors of the intertidal zone.

No seasonal patterns were established but even with more samples these may be hard to discern because of the general scarcity of organisms. It is not uncommon, even at Jordan Cove, to have many of the samples taken at one station devoid of organisms. The fewest species occurred at both White Point and Giants Neck in the December and March samples, which would be expected for the colder winter months. However, the greatest number (15) occurred at Jordan Cove in March, 1975. There were three polychaete families that each accounted for more than 500 organisms per square meter and there was an equal number of the bivalve mollusk *Semele proficua*.

When the mean numerical yields for the six sample periods were compared, Jordan Cove yielded the most organisms (2,509 invertebrates per square meter), twice the yield of White Point (1,403 invertebrates per square meter), and almost five times greater than that at Giants Neck (556 invertebrates per square meter). The following groups were common to the three stations: Nematoda; the mollusk *Mytilus edulis*; three polychaete families, Cirratulidae, Nereidae, and Orbiniidae; and two arthropods, *Corophium insidiosum* and *Jassa falcata*.

The intertidal rock stations were characterized by the dominance of the brown alga *Fucus* spp., at least in terms of its contribution to the dry weight. At Giants Neck the algal biomasses were considerably higher, better than twice the values for White Point and Fox Island; and they were due to the high densities and/or coverage by *Fucus* and another brown alga *Ascophyllum nodosum*. Both species are particularly tolerant to desiccation.

Codium fragile accounted for as much as 10 percent of the algal weight from the quantitative samples taken at Fox Island-South and covered as much as 35 percent (September, 1975) of the intertidal study area (Rocky Shore Program, Section 4.4). As of December, 1975, there was an annual coverage by this species of 10 percent of the study area (approximately a 100 foot transect). If this continues to increase it will, in fact, change the structure of the community at Fox Island.

Balanus balanoides continued to be the most dominant sessile invertebrate. The greatest number of free-living forms were generally from the phylum Arthropoda, as well.

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4.6 Lobster Population Studies

4.6.1 Introduction

The lobster tagging program was initiated during 1973 and was designed to provide information about the lobster population in the Millstone Point area. For purposes of this study, the Millstone Point area was defined as the area between Black Point on the west and Goshen Point on the east. The southern boundary was determined by a line drawn from the southern tip of Black Point to the Bartlett Reef light and then to Goshen Point. It is assumed that most lobsters within this area comprise a single homogeneous population. Recent studies support this assumption. Wilder (1963) demonstrated that there was little movement of tagged lobsters away from a liberation area in Egmont Bay, Prince Edward Island (P.E.I.). Scarratt (1970) suggested that tagged lobsters liberated near Miminegash Harbor, P.E.I. only moved about two miles from the liberation point over a six-month period, and Cooper, Clifford, and Newell (1975) concluded from their work that there were no seasonal inshore-offshore movements of lobsters inhabiting shallow (less than 75 feet) onshore fishing grounds.

Artificial habitats were used as a means of supplying lobsters for tagging during October, 1973, and from April, 1974, through December, 1975. However, the catch of taggable lobsters from the habitats was insufficient to provide an accurate population estimate. Beginning in September, 1975, commercial lobster pots were set to increase the catch per unit-effort and thereby increase the capture of previously-tagged lobsters.

4.6.2 Materials and Methods

The artificial habitats were installed during the Summer of 1973 in front of the effluent; in Jordan Cove; near Bartlett Reef, approximately mid-way between the Spindle and Twotree Island; and in front of the intake (Figure 4.6-1).

The lobster habitat consisted of a 36-block array of concrete blocks. Each block measured 24 inches by 16 inches by 10 inches, with three "burrows" for habitation. The hole size (approximately 14 inches long by 6 inches wide by 7 inches high) housed the average legal size lobster taken in the Millstone Point area.

The blocks were laid within a rectangular area of 48 feet by 52 feet with six blocks to a side and eight feet separating each block. The openings were perpendicular to the prevailing current.

Collections were made monthly by SCUBA divers in October, 1973, and from April, 1974, through December, 1975.

Beginning in September, 1975, lobster pot trawls were set in the Millstone Point area at each of three sites: in the Bartlett Reef area, in Jordan Cove, and near the effluent quarry cut. Twenty single pots were set near the intake structure, as pot trawls would interfere with sampling efforts for the ichthyoplankton and trawl programs.

Lobster pot trawls consisted of five, four-foot double entry wooden commercial lobster pots, fastened about 100 feet apart by a rope leader to a common haul line. The first and fifth pot of each trawl had a surface float attached via a buoy line one and one-half times the water depth at each site. All pots were checked several times each week and baited with fish caught in the Millstone Point area.

All lobsters were banded (chelipeds) and brought to the laboratory for tagging. Lobsters taken in standard trawls, gill nets, or other sampling devices were also brought to the laboratory for tagging. Lobsters collected by divers at the artificial habitats were measured to the nearest millimeter from the posterior edge of the eye socket to the posterior end of the carapace (carapace length) and from the anterior tip of the rostrum to the posterior edge of the telson (total length). Sex, crusher claw position (right or left), berried females, molt stage, and the general condition of all lobsters were recorded. No measurements were recorded for lobsters taken in pots.

All lobsters with a carapace length greater than 55 millimeters were marked with a sphyrion tag with a stainless steel anchor and No. 20 vinyl tubing. Identification is stamped in black letters on the International orange vinyl tubing. The anchor was inserted dorsolaterally, with a No. 20 hypodermic needle, through the thoracic-abdominal membrane and anchored in the right or left dorsal extensor muscle. The membrane breaks down at ecdysis, and the lobster extrudes itself through the separation between the carapace and abdomen, thereby retaining the tag in the extensor muscle (Scarratt, 1970). All lobsters were immersed in sea water during tagging to prevent inclusion of air bubbles in the body cavity, which can result in loss of equilibrium in the lobster.

All tagged lobsters were held for several hours in a holding tank with continuous seawater circulation to observe recovery from tag insertion. All lobsters were released the same day as tagged, near the site from which they had been captured. A $2.00 reward was offered for each tag returned by commercial lobstermen, or others who might be lobstering for a limited period of time.

The tag number, general condition, and point of capture for all recaptured lobsters were noted. Carapace length, total length, sex, crusher claw position, molt stage, and point of capture were also recorded for lobsters recaptured at the habitat sites by the divers.

4.6.3 Results

As of the end of December, 1974, approximately 937 lobsters were captured from the habitats, of which 751 were tagged. In 1975, approximately 1,049 lobsters were captured from the habitats, of which 808 were tagged. From the new pot method, 2,950 lobsters have been captured, tagged, and released as of May 31, 1976.

Mean carapace lengths (millimeters) for all lobsters taken from the habitats and other sampling gear (except the pot program initiated in September, 1975) during 1974 and 1975 are given in Table 4.6-1.

Monthly comparisons of bottom water temperatures and total numbers of lobsters caught at the habitats and the total number impinged on the intake screens of Unit No. 1 are shown for 1974 and 1975 in Figures 4.6-2 and 4.6-3.

Monthly comparisons of bottom water temperature, total numbers of lobsters caught in pots, and total number impinged on Units No. 1 and No. 2 intake screens are shown in Figure 4.6-4.

A sex ratio and the percent occurrence of either a right or left crusher cheliped were calculated. Males comprised 49.0 percent, and females 51.0 percent of the total catch for 1974, 1975, and 1976. For 49 percent of all lobsters captured, the right cheliped was the crusher claw, and 51 percent had the left cheliped as the crusher claw.

Points of recapture have been recorded for 65 tagged lobsters released in 1974, 198 tagged lobsters released in 1975, and for 168 tagged lobsters released in 1976. Most recaptures (96 percent) were taken within two miles of their release point. Six lobsters tagged in 1974, 12 tagged in 1975, and one tagged in 1976 were recaptured outside the study area, the furthest having moved approximately 15 miles (straight line distance). Recapture data also indicated random movement of lobsters among sampling stations.

Population estimates were calculated using the Jolly (1965) method. Estimates of the instantaneous population of lobsters in the Millstone Point area for the sampling period October, 1973, and April, 1974, through June, 1975, ranged from 519 to 33,000 lobsters (Table 4.6-2).

Monthly estimates of the instantaneous populations for the first 9 months (September, 1975, through May, 1976) of the pot program ranged from 3,339 to 17,614 lobsters (Table 4.6-3).

4.6.4 Discussion

The total numbers of lobsters caught and the number of lobsters impinged on the Unit No. 1 intake screens for each month during 1974, 1975, and on the Unit No. 1 and No. 2 intake screens during 1976 seemed to correlate well with bottom temperatures. The highest catches and the higher impingement counts occurred in May, June, July, and August of 1974 and 1975 when water temperatures were highest and lobster "catchability" the greatest (McLeese and Wilder, 1963). The 1976 data results seem to follow the same general trends. During the late fall and early winter months of 1974, 1975, and 1976 catches increased, although the bottom water temperature decreased. However, the percentages of lobsters in the total catch exhibiting imminent molt stages increased, indicating a molting period (Table 4.6-4). Wilder (1963) stated that catch increase during molting periods was common.

Nearly all lobsters taken from the intake screens during 1974 and 1975 were between one and three inches (25 to 75 millimeters) in carapace length, which is in agreement with the size distribution data determined for the lobsters taken from the habitats during that time period.

Sex ratios and the frequency occurrence of right and left crusher chelipeds agree with the other published results, e.g., (Dexter, 1965; Scud, 1966; and Cooper, et al., 1975).

The initial efforts to quantify the lobster population using the artificial habitats as a means of capture did not prove feasible. This may have been because not enough habitats were installed (originally there were six; two were quickly covered over with silt) or because of their location. As early as 1969, when a few commercial lobstermen were supplying us with their catch data, it was observed that there were not many pots in the immediate vicinity of Millstone Point. In general, the commercial lobstermen did not consider the area to be as productive as, for example, Bartlett Reef and Seaside.

The new lobster pot program allows a much larger area to be sampled, with more sampling flexibility. This program has resulted in a greater catch per unit-effort. In nine months, 2,961 lobsters have been taken in comparison to 1,986 lobsters taken from habitats during October, 1973, and from April, 1974, through December, 1975.

To date, the majority of the monthly and/or weekly estimates indicates a population of less than 20,000 lobsters.

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4.7 Phytoplankton

4.7.1 Introduction

Information on phytoplankton populations in Long Island Sound around Millstone Point has been gathered primarily through entrainment sampling. Most observations were made at Millstone Unit 1 intake or throughout the discharge area. Methods and results are appropriately detailed therefore in Section 4.11, Entrainment Studies.

Phytoplankton availability was determined in the greater Millstone bight through measurements of Chlorophyll. These data are reported here.

4.7.2 Materials and Methods

Total chlorophyll determinations were made on a quarterly basis between May 1969 and October 1970. Additional measurements were made biweekly from March through June 1972. Measurements of chlorophyll-a were made on a quarterly basis in 1975.

In 1969 and 1970, water samples were taken with a Van Dorn Sampler at the surface and at 15 feet periodically along lines established by drifting current drogues (Figure 4.7-1). Drogues released near the Nuclear Power Station discharge on the ebb and flood tides were followed for 3 miles or 3 hours whichever came first. Chlorophyll (total) was eluted with acetone and analyzed spectrophotometrically.

In 1972, five replicate samples were taken at seven stations identified in Figure 4.7-1 with the letters A-G. Chlorophyll was measured using the method of Yentsch and Menzel (1963).

Seven replicate surface and bottom water samples were collected in 1975 at ichthyoplankton stations 5, 8, 10 and 11 (Figure 4.7-1). Chlorophyll-a analysis followed the procedures recommended by SCOR/UNESCo (Strickland and Parsons, 1972).

4.7.3 Results and Discussion

Chlorophyll levels in Long Island Sound around Millstone Point between 1969 and 1975 are shown in Tables 4.7-1 through 4.7-3 and diagramatically in Figure 4.7-2. According to the 1969-1970 data, chlorophyll concentrations peaked in August at a maximum of 9.8 mg/m^3 and declined to lowest levels in May. Measurements made in the March-June 1972 period correspond to those in May of 1969 and 1970. The trends in phytoplanton availability provided by these chlorophyll measurements mirror actual phytoplankton cell counts, as one would anticipate. Total phytoplankton cell counts observed at the Unit 1 intake in 1970-1971 and at the Unit 1 and 2 discharge in 1975-1976 indicate seasonal peaks in summer (July-August), low levels in late spring and a moderate winter bloom (Figures 4.11-4 and 4.7-2).

Chlorophyll levels were also analyzed to determine any distributional differences among sampling stations or depths. Analysis of variance was applied independently to data shown in Tables 4.7-2 and 4.7-3. The results are as follows:

1972 ANOVA

Source	d.f.	m.s.	F	P
Stations	6	.068572952	1.065	N.S.
Dates	4	4.646772285	72.3038	***
Dates x Station	24	.253346286	3.9421	***
Error	140	.064267286		

1975 ANOVA

Source	d.f.	m.s.	F	P (> F)
Stations	3	.665780167	1.254622	N.S.
Months	3	17.4166635	32.82065706	***
Depths within Months	4	6.002609408	11.31155717	***
Error	213	.530661634		

N.S. = Nonsignificant, $P > .1$
*** = Significant, $P < .0001$

The analyses suggest chlorophyll concentrations are not significantly different over a wide area of Long Island Sound around Millstone Point. Chlorophyll levels were not significantly different at the stations sampled either in 1972 or 1975 ($p > 0.1$). No analysis was applied to the 1969-1970 data since the stations were not fixed.

Beside obvious seasonal changes, analysis of variance also indicated a significant difference between surface and bottom chlorophyll concentrations in 1975. Except for June 1975, mean chlorophyll was higher in bottom samples than in surface samples.

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4.8 Zooplankton Studies

4.8.1 Introduction

An intensive program to provide information on the seasonality, abundance, and distribution of zooplankton, fish eggs and fish larvae in the waters around Millstone Point was begun in May, 1973. This information was deemed necessary for an understanding of the general ecology of the dominant zooplankton and fish species in the area and was, in addition, to be used by staff from the University of Rhode Island in the development of a mathematical model which would assist in predicting the effect of entrainment of winter flounder larvae through the cooling system of power station on subsequent winter flounder populations in the area.

The effect of the Millstone Nuclear Power Station is expected to be minimal with respect to zooplankton populations in the area, since the populations have a rapid turnover rate. Nevertheless, zooplankton exhibit strong seasonal patterns as well as being sensitive to other environmental factors and, in this respect, their cycles of abundance and distribution could be indicators of environmental quality.

Zooplankton data have been analyzed through December, 1975, and are reported in this section. Icthyoplankton data have been analyzed through December, 1975, and are likewise reported herein.

4.8.2 Materials and Methods

Collection

The ichthyoplankton sampling techniques were generally those recommended by the National Marine Fisheries MARMAP field group. Zooplankton were obtained concurrently.

Originally 10 stations were sampled. In February, 1974, three stations were added to the program, and in October, 1974, another station was added. In February, 1975, two more stations were added, making a total of 16 stations for zooplankton sampling. The locations of these stations are shown in Figure 4.8-1.

Plankton samples were taken using a bongo frame, mouth diameter 61 centimeters, supplied by General Oceanics, Inc., with .333 and .505 millimeter mesh plankton nets (General Oceanics 5360-333 or 5360-505). These nets were fabricated from Nitex cloth and have an effective filtering area to mouth opening ratio of five to one. Estimates of the volume filtered were calculated using a General Oceanics Model 2030 flowmeter mounted within the mouth of each net. Clogging of the plankton nets was monitored by comparing the readings of the flowmeters within each net to the reading of a third flowmeter mounted on the outside of the frame.

Plankton tows were generally 15 minutes in duration and usually resulted in a filtered volume of about 200 cubic meters. Vessel speed was maintained between one and one-half and two and one-half knots, and a 150-pound lead weight was used to depress the sampling gear.

Initially, smaller, 20-centimeter bongo nets were tried, but they proved unsuitable for this study. Avoidance of this sampling gear by larger larvae was shown to be substantial and the small volume filtered did not provide numbers of larvae adequate for statistical treatment.

Oblique tows were used to sample the entire water column. Tows were begun with the bongo sampler at the surface, then lowered at a constant rate to the depth of the water column using wire angle and cable length to calculate sampler depth. The sampler was then gradually brought again to the surface and the cycle of raising and lowering repeated until the tow was complete, the number of cycles depending upon depth.

Stratified surface tows were taken by holding the nets just below the surface for the duration of the tow. Stratified bottoms tows have been done since March, 1974, by mounting the bongo frame in a sled which rides along the ocean bottom. Prior to the construction of the sled, a constant distance above the bottom was extremely difficult to maintain due to variations in the depth of the water.

After completion of a tow, the plankton nets were spray-washed from the outside with pumped seawater. Plankton were concentrated in the cod-end jar, then transferred by washing into a sample jar. Samples were preserved immediately with a volume of five percent formalin in seawater (buffered with sodium borate) that was at least equal to the volume of settled plankton. A sequence number label was affixed to the field data sheet and to the sample jars and remained as the identifying characteristic throughout the processing procedures.

Surface and bottom water readings for temperature, conductivity, pH, and dissolved oxygen were recorded at each station using a Hydrolab Model 6 D surveyor. Water transparency was measured using a Wildco secchi disc. Other parameters recorded were estimates of percent cloud cover, air temperature, estimated wind direction and velocity, water surface conditions, time and tide stage.

Processing

Zooplankton. The samples were returned to the laboratory where the fish eggs and larvae were removed. The total volume of zooplankton was determined for each sample after which the sample was stirred with either a two-milliliter or 10-milliliter Stempel pipette to assure homogeneous mixing. A subsample was taken with the Stempel pipette, the volume recorded, and the subsample was then put on a Sedgewick-Rafter slide. The organisms in the aliquot were identified to the lowest taxon possible and counted using a Bausch and Lomb stereo viewing microscope. The counts were made on the basis of 300 organisms. If there were not 300 organisms in the subsample the total number of organisms in the subsample was determined. For extremely dense samples, the aliquots were diluted with a known volume of water and the counts were then made as described above.

Occasionally in late summer, the samples contained large quantities of cnidarians, ctenophores, detached eel grass (*Zostera marina*), and detritus. In those cases, the samples were seived through a 125-millimeter mesh seive to remove the unwanted material and then processed in the manner described above.

Ichthyoplankton. The collected plankton samples were returned to the lab and hand-sorted using a dissecting microscope and a shallow plexiglas tray. In cases where the number of eggs collected was quite large, a Folsom plankton splitter was used to provide quantitative aliquots of the sample. All fish larvae in each sample were sorted, since no accurate method for aliquoting these larvae has been found. For samples collected after April 30, 1975, a density-separation method using Ludox AM solution was used to separate eggs from other zooplankters. For that technique, the samples were drained, and the formalin was rinsed out of them. The condensed plankton sample was put into a nine percent Ludox solution (specific gravity 1.02) and agitated. When the eggs floated to the top of the solution, they were removed by aspiration and put into a vial and preserved in neutral formalin until identified and counted.

Eggs and larvae were placed in separate labeled vials. An outline of the sorting procedure follows:

- Sign out the next unpicked sample, both .333- and .505-millimeter mesh.
- Check field sheet to make sure you have all containers for that sample.
- Label pick sheets and egg and larvae vials, double-check numbers, especially for mesh size.
- Drain formalin from sample by pouring through Nitex cloth of proper mesh size.
- Rinse sample contained in cloth using tap water.
- Clean extraneous debris out of sample, taking care to rinse each piece as you lift it out (NOTE: Seaweed, eel grass, and rocks may be thrown out, and jellyfish and ctenophores may be discarded - even mesh. 333 - if care is taken to count carefully). Do not discard arrowworms, crustaceans, or any other larvae.
- Wash sample into graduated beaker, fill with tap water.
- Thoroughly mix sample and extract a measured volume for estimate of total number of eggs. Estimate total number of eggs by:

$$\frac{\text{Total volume of samples}}{\text{Volume of aliquot}} \times \text{\# eggs found in aliquot} = \text{Total \# eggs}$$

NOTE: These eggs should not be picked, only counted, then put back into the beaker.

- Use total egg estimate to guide aliquoting so that the following minimums may be met:

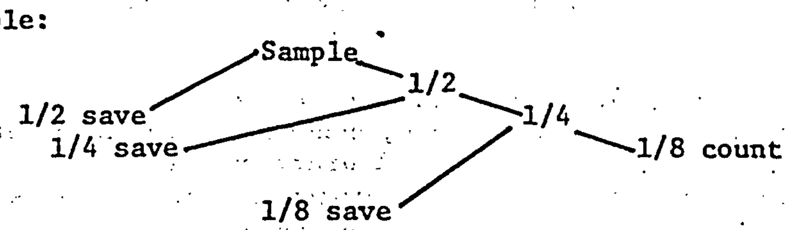
Split Fraction	Minimum # of Eggs to be Picked
1/2	100
1/4	100
1/8	200
1/16	300
1/32	400

NOTE; As the fraction of the sample picked becomes smaller, error increases. These minimum egg values are to compensate for the error.

o Split sample to fraction calculated above.

a. Save each split half that is not resplit in a separate, marked container.

Example:



By saving each split half one may back up one step if there was an error made in the aliquoting.

b. Pick last leftover split (saved fraction) if number of eggs expected (calculated earlier) is not found. If this still does not match, check next larger leftover split, etc.

c. Each subsequent split should have makeup water added to keep volume in splitter to 500 milliliters.

NOTE; Initial split may be done in Woods Hole Oceanographic Institution's large splitter. If sample is contained in several jars, all should be combined after debris is pulled out and before splitting starts.

d. Enter fraction picked on pick sheet.

o Pick eggs from subsample, record number of eggs.

o Pick larvae from subsample, rechecking for eggs.

o Pick larvae from rest of sample, enter number of larvae on pick sheet.

o Go over entire sample again for missed larvae.

- o If sample picked was from the .333-millimeter mesh, recondense and put back in sample jar to be sent to Duxbury (formalinize). If .505-millimeter mesh, discard if there is no question of accuracy.
- o Recheck sample number and sign.
- o Put data sheets in proper place.

NOTE: <u>Unfinished Sample Storage</u>

If a sample is not finished before leaving, it should be labeled, covered, and stored in the refrigeration or reformalinized.

If someone cannot finish a sample, they should make a specific arrangement for someone else to finish it.

Clearly label everything. Check and recheck sample numbers.

Identification of larvae and eggs was accomplished through the use of various keys and descriptions, consultation with other scientists, use of drawings and photographs, library research into the seasonal and life history background, and morphometrics. All eggs and larvae were studied under a dissecting microscope capable of magnification to at least 40 X, and equipped with both a stage and an ocular micrometer.

Initially, all samples were rechecked for accuracy, then later, only random checks were made. Representative subsamples of each species have been sent to the National Marine Fisheries Laboratory in Sandy Hook, New Jersey, and/or to the Woods Hole Oceanographic Institution in Woods Hole, Massachusetts for confirmation.

The sampling schedule has changed several times since the study's inception. In general, daytime oblique tows were taken each week at all stations and nighttime oblique tows were taken every fourth week. Daytime stratified tows were taken at half of the stations every other week and night stratified tows at half of the stations every fourth week.

From June through September, 1975, day oblique sampling was reduced from weekly to alternate week sampling, and was further reduced to monthly sampling from October through December, 1975.

The sampling schedule followed during 1975 is essentially that followed from the inception of the program except for the previously-mentioned station additions and sampling frequency changes. The 1975 schedule is shown below.

Ichthyoplankton Sampling Schedule

February through May, 1975

Weekly Samples

Station Sets: A1 - 1, 3, 7, 12, 16
A2 - 5, 8, 10, 11, 14
B1 - 2, 4, 6, 9, 13, 15
B2 - 5, 8, 10, 11, 14

Week 1, 5, 9, 13, 17, 21

Day 1. Stations 1-16 single oblique tows
2. Triplicate tows at two random stations
3. Ebb and flood oblique tows at 3, 7, 9

Week 2, 6, 10, 14, 18, 22

Day 1. Stations 1-16 single oblique tows
2. Triplicate tows at two random stations
3. Ebb and flood oblique tows at 3, 7, 9
4. Stratified tows at Sets A1 and A2
5. Replicate stratified tows at one random station from each Set A1 and A2

Week 3, 7, 11, 15, 19

Day 1. Stations 1-16 single oblique tows
2. Triplicate tows at two random stations
3. Ebb and flood oblique tows at 3, 7, 9

Night 1. Oblique tows at Stations 1-16
2. Triplicate tows at two random stations
3. Stratified tows at Sets B1 and B2
4. Replicate stratified tows at one random station from each Set - B1 and B2

Week 4, 8, 12, 16, 20

Day 1. Stations 1-16 single oblique tows
2. Triplicate tows at two random stations
3. Ebb and flood oblique tows at Sets 3, 7, 9
4. Stratified tows at Sets A1 and A2
5. Replicate stratified tows at one random station from each Set - A1 and A2

At Station 3, ebb samples to be taken at least three hours after high tide. Flood samples to be taken at least two hours after low tide.

June through September, 1975

Biweekly Samples

Station Sets: A1 - 1, 3, 7, 12, 16
A2 - 5, 8, 10, 11, 14
B1 - 2, 4, 6, 9, 13, 15
B2 - 5, 8, 10, 11, 14

Week 2, 6, 10, 14, 18, 22, 26, 30, 34, ...

Day 1. Stations 1-16 single oblique tows
2. Triplicate tows at two random stations
3. Ebb and flood oblique tows at 3, 7, 9
4. Stratified tows at Sets A1 and A2
5. Replicate stratified tows at one random station from each Set - A1 and A2

Night 1. Oblique tows at Stations 1-16
2. Triplicate tows at two random stations
3. Stratified tows at Sets B1 and B2
4. Replicate stratified tows at one random station from each Set - B1 and B2

Week 4, 8, 12. 16, 20, 24, 28, 32, 36, ...

Day 1. Stations 1-16 single oblique tows
2. Triplicate tows at two random stations
3. Ebb and flood oblique tows at 3, 7, 9
4. Stratified tows at Sets A1 and A2
5. Replicate stratified tows at one random station from each Set - A1 and A2

At Station 3, ebb samples to be taken at least three hours after high tide. Flood samples to be taken at least two hours after low tide.

October through December, 1975

Monthly Samples

Station Sets: A1 - 1, 3, 7, 12, 16
A2 - 5, 8, 10, 11, 14
B1 - 2, 4, 6, 9, 13, 15
B2 - 5, 8, 10, 11, 14

Week 2, 6, 10, 14, 18, 22, 26, 30, 34

Day 1. Stations 1-16 single oblique tows
2. Triplicate tows at two random stations
3. Ebb and flood oblique tows at 3, 7, 9
4. Stratified tows at Sets A1 and A2
5. Replicate stratified tows at one random staton from each Set - A1 and A2

Night 1. Oblique tows at Stations 1-16
2. Triplicate tows at two random stations
3. Stratified tows at Sets B1 and B2
4. Replicate stratified tows at one random station from each Set - B1 and B2

At Station 3, ebb samples to be taken at least three hours after high tide. Flood samples to be taken at least two hours after low tide.

4.8.3 Results and Discussion

Zooplankton from numerous phyla were encountered during the sampling program commencing in 1973. Table 4.8-1 lists species and groups encountered by phyla through 1975. In this discussion, zooplankton are defined as invertebrates and invertebrate larvae collected in the plankton sampling program. Ichthyoplankton were sampled concurrently but are discussed separately in sections which follow.

The frequency of occurrence of different species and groups of zooplankton varied tremendously. Figure 4.8-2 is a histogram depicting the number of samples in which each species or group of zooplankton were encountered. Those species which were encountered frequently can be considered to be characteristic representatives of the zooplankton community in the Greater Millstone Bight, while infrequently encountered species and groups can be considered as rare and/or atypical in this habitat, or at least at the stations utilized in the sampling program. No relationship is implied between frequency of occurrence and overall abundance of different species, although abundant (asterisked) species did tend to occur more frequently. The relative abundance of various species must vary tremendously on a seasonal basis as does the total standing crop of zooplankton. Independent of season or station, the relative abundance of zooplankton species throughout the entire sampling period is plotted in Figure 4.8-3. As is evident from the histogram, calanoid copepods Acartia tonsa, A. clausii, Tortanus discaudatus, and Pseudocalanus elongatus (minutis) dominate the standing crop.

The following is a discussion of the seasonality of some of the more important species of zooplankton which comprise the zooplankton community of the Greater Millstone Bight.

Monthly standing crops of Acartia tonsa at various stations are shown in Table 4.8-2. On the average, A. tonsa is the most dominant species in the area. Standing crops are largest during the summer and fall months, and taper off at the onset of colder winter temperatures. Largest concentrations of A. tonsa tend to be found at Stations 1 and 2, probably due to the greater abundance of river and marsh derived detritus as a food source for zooplankton in the area. No clear-cut pattern of distribution at various onshore and offshore marine stations is evident.

Acartia clausii replaces A. tonsa during the winter, and high standing crops remain through the spring months. Monthly standing crops of A. clausii are shown in Table 4.8-3. As with A. tonsa, the increases in abundance occurred first and were most pronounced in the Niantic

River. Maximum seasonal standing crops of both A. tonsa and A. clausii at these stations has tended to increase over the past three years.

Temora longicornis is another copepod which is both prevalent and abundant at most of the stations in the Greater Millstone Bight. Monthly standing crops of T. longicornis at various stations are shown in Table 4.8-4. This species tends to increase rapidly during the spring months, tapers off in abundance throughout the summer and fall, and is largely absent during the winter months. Largest standing crops occurred at Stations 7, 9, and 10, while smallest standing crops generally occurred in the Niantic River. In this sense, the overall distributional pattern of T. longicornis was in sharp contrast to that of A. tonsa and A. clausii. Pseudocalanus elongatus (minutis) and Paracalanus parvus are two more calanoid copepods which were abundant and prevalent in the Greater Millstone Bight, but which are not nearly so dominant as A. tonsa, A. clausii, or T. longicornis.

Monthly standing crops of P. elongatus and P. parvus at various stations are listed in Tables 4.8-5 and 4.8-6, respectively. Both species tend to increase in abundance in the late spring and early summer months and tend to decrease in abundance during the fall months. Standing crops at both onshore and offshore marine stations are generally greater than those at the stations in the Niantic River.

In addition to calanoid copepods, several species of marine Cladocera constitute an important fraction of the zooplankton in the Greater Millstone Bight. These are Evadne sp. and Podon sp. Monthly standing crops of Evadne sp. and Podon sp. at various sampling stations are listed in Tables 4.8-7. and 4.8-8, respectively. Neither species was as numerous as the copepods, nor were they present in the general area for the length of time throughout the year that the calanoid copepods were. The peak abundance of both species tended to occur during the spring and early summer months during the same general time periods characterized by increased A. clausii populations. In general, both Podon sp. and Evadne sp. occurred rather uniformly throughout the area, whereas A. clausii was predominantly in the Niantic River. During the past three years, a consistent decline in maximum average abundance of both species has been observed.

In addition to temporal variations in zooplankton standing crops, there are also spatial variations in abundance. Spatial variation in probably influenced by many factors, and is extremely complex due to patchiness. The average standing crop within any given year of all zooplankton species at each station is plotted in histogram form in Figure 4.8-4. In a broad sense, there are three categories of sampling stations--those in the Niantic River, those in inshore marine areas, and those offshore in Niantic Bay and Long Island Sound. Throughout the study period, at least one of the Niantic River stations consistently had the greatest zooplankton abundance, caused by the extensive productivity of A. tonsa and A. clausii in this habitat. This is probably attributable to greater influx of allochthanous detritus as a food source. No readily apparent differences are observable between average zooplankton standing crops in inshore-versus-offshore marine areas.

Table 4.8-9 lists the results of an analysis of variance of average yearly zooplankton abundance at each station and an analysis of average monthly abundance for all stations lumped together. Significant differences are not consistent from year to year, as would be expected due to distributional patchiness. In general, Niantic River stations have significantly greater zooplankton abundance than inshore marine stations in Niantic Bay. Taken collectively, abundance at all stations is, in general, significantly greater during the spring and fall months than during the mid-summer and mid-winter months. This is representative of the degree to which standing crops of the dominant A. tonsa and A. clausii influence the abundance of the total zooplankton community in the Greater Millstone Bight.

Fish Eggs

Eggs from at least two species of fish in the Millstone Point area can be found in the water at any time of the year. Figure 4.8-5 shows the spawning periods for the species whose eggs comprised the majority of the egg portion of the ichthyoplankton.

Most of the spawning periods occur in the spring and summer. There are, however, some late fall and winter spawners like the cod, (Gadus morhua) which spawns from November to early April, and the haddock (Melanogrammus aeglefinus) which spawns from February into May. Eggs of the summer flounder (Paralichthys dentatus) can be found in the area from October (peak period) through April, the longest period for any of the species.

It appears from the peaks of abundance of menhaden (Brevoortia tyrannus) eggs that it has two spawning periods in the Millstone Point area (Figure 4.8-6). Data from May 6, 1973, through June 27, 1975, were subjected to analyses of variance to determine whether more eggs were caught at one station or another, or whether the abundance of eggs was dependent on such parameters as the depth at which they were found, whether they occurred in the day more often than at night, whether more were taken on the ebb tide or the flood tide, and whether there were differences in abundance of each species depending on the sampling station. The data from weekly collections were pooled for analysis in two-week sample sets. Only the results from those analyses where the significance level was .90 or better will be discussed in this report.

Table 4.8-10 shows the result of the analysis of variance for the total number of eggs at each station.

The largest number of eggs occurred in samples from Station 1 and 2, and from Station 3 when sampled on an ebb tide. Generally, the fewest eggs were taken at the outer stations, although a few eggs were taken at Station 3 when it was sampled during a flood tide. During the second year of sampling, a large number of eggs were collected at Station 11 near the intake structures.

Analyses of variance were used to test for significant differences in the abundance and distribution of the eggs of selected species when correlated with locations, tide, depth, or diurnal effects. The results of the test for sampling station differences were presented in increasing order of mean number of eggs and underscored by lines using the Duncan's Mean Separation

Test, which indicates grouping and separation of means. Stations underlined by the same line have similar means, whereas any stations not connected by the same line have significantly different means. Of the species that were analyzed, only those which were significant at a level of .90 or better were reported.

The analysis of variance for the total number of eggs (Table 4.8-10) collected in the first sampling year (May, 1973, through April, 1974) indicated that Station 10 had a significantly higher mean number of eggs from November to February and that Station 12 and 13 often had relatively high numbers of eggs from February to May. Station 1 had a significantly low mean number of eggs from February to May. Station 1 had a significantly low mean number of eggs from December to April.

During the second year of sampling (May, 1974, through April, 1975), Station 1 occasionally showed a high mean number of eggs around September and October and a relatively low mean in May and early June, and again from February to April. Station 10, 13 and 14 often had relatively large numbers of eggs.

The high mean number of eggs at Station 10 coincided with the spawning period of the cod (Gadus morhua) and the haddock (Melanogrammus aeglefinus) which tends to inhabit deep water (Table 4.8-11). The relatively high number of eggs at Stations 12 and 13 from February, 1974 to April, 1974, was probably due to the presence of fourbeard rocklings (Enchelyopus cimbrius), mackerel (Scomber scombrus), and the Labridae/Limanda ferruginea type. During the months of September and October, menhaden (Brevoortia tyrannus) eggs were predominant, contributing to the high mean number of eggs at Station 1.

Analyses were conducted to determine whether there were diurnal and/or stratification differences in the abundance of fish eggs. Data from May 6, 1973, through June 27, 1975, were analyzed. In the two-year period, there were relatively few weeks when significant differences occurred between the numbers of eggs collected from surface as opposed to bottom tows, or night opposed to day tows.

Table 4.8-12 shows the periods when there were significantly different numbers of eggs collected in either the day or night oblique tows. For the most part when differences did occur, there were significantly more eggs in the oblique tows taken at night than in the daytime. Only for brief periods in mid-February and mid-April, 1974, were there greater number of eggs collected in the day oblique tows, which may have been due to the presence of cod, haddock, or mackerel (Table 4.8-13).

For the most part, more eggs were collected at night on the surface than in day surface tows during those weeks when significant differences occurred (Table 4.8-14). This diurnal effect was also evident when differences occurred in the results of the bottom tows (Table 4.8-15).

Generally, the eggs were distributed evenly through the water column. When stratification occurred, the eggs were predominantly at the surface, both in the daytime (Table 4.8-16) and at night (Table 4.8-17).

There was little difference in the numbers of eggs collected in the area on an ebb as opposed to a flood tide, except for occasional differences at specific stations, particularly those in the Niantic River. Table 4.8-18 indicates that when differences did occur, there were usually more eggs taken on the ebb tide. The times when more eggs were taken on the flood tide occurred in mid-October, once in 1973 and the second time in 1974.

Figure 4.8-7 shows the mean numbers of .3 millimeter eggs taken at each station (Station 7 during the ebb and flood tides is omitted because of the few numbers of eggs taken).

As noted earlier, Stations 1, 2 and Station 3 during an ebb tide had a greater number of eggs than the outer stations, with the exception of a large number of eggs taken at Station 11 in late July and August of the second sampling year.

The most abundant eggs from May through August were of the Labridae/Limanda ferruginea type and of the bay anchovy (Anchoa mitchilli). Samples taken from March through May consisted mostly of mackerel eggs. From November through April, the largest number of eggs collected were those of the cod, haddock and fourbeard rockling.

The majority of the eggs taken annually were of the Labridae/Limanda ferruginea type, making up 80.896 percent of the total collection taken in day oblique tows in the first sampling year and 79.450 percent in the second year (Table 4.8-13). The Labridae/Limanda ferruginea type is comprised of yellowtail flounder, cunner, and tautog eggs and were grouped this way because of the difficulty in distinguishing them from one another due to the overlapping spawning periods and the eggs being in the same size range with similar characteristics. These eggs were found frequently at the Niantic River stations from May through August (Figure 4.8-8).

Anchovy eggs were usually found at Stations 1 and 2, especially at 1, than at any of the other sites (Table 4.8-19). Their peak period of abundance was from mid-June through July (Table 4.8-20).

Menhaden apparently have two spawning periods in the Millstone Point area. Their eggs were found in greatest abundance in the Niantic River at Station 1 in July and again in September (Figure 4.8-6).

In the first sampling year, mackerel eggs accounted for 5.571 percent of all eggs collected in day oblique tows and 9.004 percent in the second year. They were usually found at the outer stations, particularly at Stations 10, and 8, and at Station 9 during both the ebb and flood tide stages (Figure 4.8-9). Their peak spawning period is from April through May (Table 4.8-21).

Fish Larvae

The species lists for 1974 and 1975, ranked by order of overall density, are shown in Tables 4.8-22 and 4.8-23. These tables also show the percentage that each species represents of all larvae taken that year and the average monthly densities for each species. Since sampling began in May, 1973, the ranked species list for 1973 would have disproportionately represented the spring and summer larvae and has not been included.

The number of species collected during each month of 1973, 1974 and 1975 are shown in Figure 4.8-10, and the average overall densities of fish larvae for each month are shown in Figure 4.8-11.

Figure 4.8-12 shows the density of fish larvae at each station for each year, 1973, 1974, and 1975.

The overall yearly density of fish larvae in the Millstone bight increased from $0.327/M^3$ in 1974 to $1.134/M^3$ in 1975. This marked increase was mainly due to the increase in densities of Scomber scombrus, Engraulidae, and Scophthalmus aquosus larvae.

Twenty-one species accounted for 99 percent of the yearly larval population in 1974, while seventeen species accounted for 99 percent in 1975. At least fifty species of larvae were taken in 1974, while at least forty-six species were taken in 1975.

The greatest density of larvae and the greatest number of species occurred during the months of May, June, July, and August (Figures 4.8-10 and 4.8-11). Both densities of larvae and number of species increased from winter to peak in the summer.

The greatest overall densities of larvae were generally found at outer stations, averaging about one larva per cubic meter of water filtered. Lowest overall densities occurred in the Niantic River, averaging about one larva per ten cubic meters, while overall densities in Niantic Bay were intermediate or about one larva per two cubic meters of water.

Table 4.8-24 shows the percentage of each of the most frequently occurring larvae in samples for 1974, 1975 and the mean percentage of samples for both years that contained each of the most frequently occurring species of larvae.

Table 4.8-25 shows the overall night/day catch ratios of the most abundant species of larvae for night or day oblique samples.

Specific details on the abunance and distribution of the most abundant species are given below.

Anchovies (Anchoa spp.)

Anchovy larvae were first taken in plankton samples during the last week of June in 1973, 1974 and 1975. Peak overall densities of one to ten larvae per cubic meter occurred in the last three weeks of July in each year. A second, smaller peak in overall density (about one larva per two cubic meters) occurred from mid-August to mid-September of each year.

Offshore stations usually had higher densities of anchovy larvae overall, with bay stations being a close second. Although densities of anchovy larvae were similar at all stations during weeks of peak abundance in 1973 and 1974, densities were generally lower in the river (Figure 4.8-13 and 4.8-14). Concentrations of larvae were markedly higher in offshore stations than in river stations in 1975.

In the daytime, anchovy larvae exhibited a strong preference for the bottom at most stations. At night, there were still more larvae on the bottom, but there was more variability in the density from station to station.

Anchovy larvae were the most abundant larvae in 1974 when they comprised about 23 percent of all larvae taken during the year. Although the average yearly density of anchovy larvae rose from about 76 larvae per 1,000 cubic meters of water filtered in 1974 to 210 larvae per 1,000 cubic meters in 1975, they ranked second in overall abundance (about 19 percent of all larvae in 1975).

Atlantic mackerel (Scomber scombrus)

Mackerel larvae were first taken in plankton samples in mid-May of each year. Peak concentrations occurred in June and mackerel larvae were usually absent in collections after mid-July. Peak overall concentrations of mackerel larvae have increased each year; about 0.3 per cubic meter in 1973, 2 per cubic meter in 1974, and 27 per cubic meter in 1975.

During their period of occurrence in 1975, mackerel larvae averaged about 70 to 95 percent of all larvae taken at bay and offshore stations, and comprised almost 40 percent of all larvae taken for the year, ranking first in abundance.

Their average yearly density for 1975 was almost one per two cubic meters of water despite the fact that only two percent of the samples contained mackerel larvae. Mackerel ranked second in 1974, averaged 0.05 per cubic meter for the year, and were 16 percent of all larvae taken.

Concentrations of mackerel larvae were generally highest at offshore stations, lowest at river stations, and intermediate at bay stations. The occurrence of mackerel larvae in the Niantic River is most certainly by passive transport of the larve into the river by tidal current (Figure 4.8-15).

Mackerel larvae were generally found to be somewhat more numerous in surface than in bottom samples during the day, and markedly more numerous in surface than in bottom samples at night.

Clupeidae

Clupeid larvae were the eleventh most abundant larvae in 1974, comprising about two percent of all larvae for the year. They were more abundant in 1975, ranking seventh and accounting for three percent of all larvae.

Highest concentrations of clupeid larvae occurred in June or early July of each year with a second smaller peak occurrence in the fall. They were found in nearly all months.

Densities of clupeid larvae were generally highest at offshore stations and lowest at river stations. Vertical distribution favored bottom strata during the day and surface strata at night, although there was considerable variation.

The majority of clupeid larvae were probably Brevoortia tyrannus.

Cunner (Tautogolabrus adspersus)

Cunner larvae ranked third in overall yearly density (0.04 per cubic meter) in 1974, representing almost thirteen percent of all larvae taken. Cunner dropped to eighth in overall yearly density (0.02 per cubic meter) in 1975 and were two percent of all larvae taken.

Mean concentrations of cunner larvae were higher at Niantic Bay and offshore stations than at Niantic River stations, markedly so in 1973 and 1975. Peak concentrations of cunner larvae (one larvae per two cubic meters) were found during the last week of June through mid-July in all three years (Figures 4.8-16 and 4.8-17).

Overall concentrations of cunner larvae were higher in day surface samples, although many individual bottom samples had densities higher than corresponding surface densities. Depth bias varied in night-stratified samples.

Sand Lance (Ammodytes spp.)

Sand lance larvae were eighth in overall abundance in 1974 and comprised about four percent of the year's larvae catch. In 1975 they ranked fifth and represented three percent of all larvae for that year. Larvae were most abundant in the winter and spring and were not taken after May (Figure 4.8-18). Larvae were generally found in smaller densities at all stations but exhibited a consistent preference for the surface layers, both day and night.

Tautog (Tautoga onitis)

Larvae of the tautog ranked fourth in overall density in 1974 and fifth in 1975 and were nine and three percent, respectively, of the total larvae catch for each year. Overall yearly density, however, was 0.03 per cubic meter for each year of 1973, 1974 and 1975.

Tautog larvae were taken in samples from mid-May through the end of September and reached peak overall densities (0.2 to 0.7 per cubic meter) in mid-June through mid-July.

Densities at offshore and bay stations were, as a rule, higher than those in the river (Figures 4.8-19 and 4.8-20).

Daytime vertical stratification varied, but densities of tautog larvae were slightly higher in bottom samples overall. Night densities of tautog larvae, however, were generally higher in the surface than in bottom samples.

Windowpane (Scophthalmus aquosus)

Windowpane larvae were first taken in plankton samples in mid-May of each year. A bimodal occurrence of windowpane larvae was found in each year. The first peak in density (0.5 to 1.0 larvae per cubic meter) occured in June and July; the second (0.02 to 0.3 larvae per cubic meter) in September and/or October of each year (Figures 4.8-21 through 4.8-23).

Windowpane larvae were the sixth most abundant form in 1974 (six percent of all larvae) and third most abundant (18 percent of all larvae) in 1975.

Overall yearly mean concentrations rose from 0.02 larvae per cubic meter in 1973 and 1974 to 0.2 larvae per cubic meter in 1975. Densities were generally higher in offshore stations than in the Niantic River. Bottom densities were more often higher than surface densities during the day, while a marked overall surface preference was found at night.

Winter flounder (Pseudopleuronectes americanus)

Winter flounder larvae were first taken in late January of 1974 and 1975, and were rarely taken after June of either year. Flounder larvae comprised 6.7 percent of all larvae taken in 1974 and ranked fifth in overall density (0.2 per cubic meter), while they accounted for 6.6 percent of all larvae and ranked fourth in overall density (0.7 per cubic meter) in 1975. Due, in part, to their long period of occurrence, flounder larvae were taken in more samples in these two years than any other larvae; almost nine percent of all day oblique samples taken contained flounder larvae. At their peak density in mid-April, flounder larvae represented over half of all larvae taken in 1975.

The mean concentration of flounder larvae was higher in the Niantic River than in Niantic Bay during February and March of both 1974 and 1975. The mean concentrations of flounder larvae in Niantic Bay was higher than that of offshore stations during the same periods (Figures 4.8-24 and 4.8-25). Mean concentrations of flounder larvae were highest in Niantic Bay during April, while offshore stations had the highest mean concentrations during May and June.

Tests for curves fitted to 1974 and 1975 larvae densities for the river, bay, and offshore stations show that, within each year, the best-fit lines for each group are significantly different at a $p < .001$. However, graphs of the concentrations of flounder larvae for each station group suggest that curves for the groups are similar but displaced in time. When river data were shifted four weeks later, and bay data two weeks later, best-fit lines were more similar and differed only at a $p < .16$. When 1975 data are shifted in time, four weeks later for river stations and two weeks later for bay stations, the curves for larval densities also appear much more similar and differed at a $p < .405$. This apparent later shift in the density curves for more offshore locations may be related to spawning activity or incubation time and their temperature dependence.

Winter flounder larvae exhibit a depth preference that changes both as the mean length of the larvae population increases and by location of sample. Little or no difference is noted in concentrations of larvae in surface or bottom daytime samples when the mean length is less than four millimeters. However, during the day, bottom densities are usually higher than surface densities whenever the mean length of the larvae is greater than four millimeters. Nighttime surface densities are higher than bottom densities where the mean length is less than four millimeters, but surface and bottom densities are similar when the mean length is equal to or greater than four millimeters.

River stations have similar overall densities for both surface and bottom samples, while all bay and offshore stations exhibit higher overall bottom densities. The lack of depth preference in the river is probably due to the mixing in the shallow (3.5 meter) stations.

Curves fitted to weekly mean flounder larvae lengths from day oblique .333 mesh samples for 1974 and 1975 were tested for similarity and found to be identical. An exponential curve for the mean length of flounder larvae for each week was fitted to the data and is shown in Figure 4.8-26.

No discernable trends were noted when flounder larvae length data were broken into river, bay, and offshore groupings.

4.9 Fin Fish Studies

4.9.1 Shore-Zone Seines

Introduction

Shore-zone fish communities in the area of the Millstone Point Nuclear Power Station were studied over a seven-year period beginning in June, 1968. The sampling techniques were standardized by May, 1969, and the data reported on here are from May, 1969, through December, 1975. The power plant (Unit 1) began consistent operation in December, 1970, following the December sampling.

Since environmental change may eliminate certain species or reduce their relative abundance in a given situation (McErlean, et al., 1973), periodic comparisons of communities in the general area of a nuclear power station over a relatively long time should indicate whether a sufficient change had taken place to cause alterations in the communities.

In order to determine whether any trends in shore-zone fish community makeup exist in the Millstone Point area due to construction and operation of the nuclear power station, seasonal and annual assessments were made of the number and diversity of species collected at each sampling site over the study period. Parameters studied included species diversity (Pielou, 1966a), species richness (Dahlberg and Odum, 1970), species evenness (Pielou, 1966b), and percent similarity (Whittaker and Fairbanks, 1958).

The effects of thermal discharges from power stations on the diversity of fish populations have not been discussed well in the literature despite the number of such studies taking place. Bechtel and Copeland (1970) showed that diversity indexes tended to decrease under unfavorable conditions in a Texas estuary, and Grimes (1971) showed that species richness increased toward a thermal discharge in the winter and away from it in the summer. McErlean, et al., (1973) reported no marked effects on the diversity of fish populations in the Patuxent River due to thermal discharges. On the other hand, Gallaway and Strawn (1974, 1975) showed a reduction in fish species and diversity index in the area of a power station discharge into Galveston Bay, although it was not clear whether the reduction was a natural cyclic phenomenon or due to the warm water. Haedrich and Haedrich (1974) compared fish diversity indexes from the Mystic River in Boston, Massachusetts with diversity indexes reported by a number of other workers.

The importance of shore-zone fish populations to estuarine and near-shore ecology has been pointed out by a number of authors, including Warfel and Merriman (1944), June and Reintjes (1957), Gunter (1958), de Sylva, Kalber, and Shuster (1962), and Carr and Giesel (1975). These shore-zone populations include not only the resident species which provide food for commercial and sport fish, but also juvenile stages of these and other fish.

Although a number of studies of fish populations in Long Island Sound have been reported on (e.g., Baird, 1873; Bean, 1903; Warfel and Merriman, 1944; Merriman and Warfel, 1948; Richards, 1963; Perlmutter, 1971), only Warfel and Merriman (1944) and Perlmutter (1971) considered the Long Island Sound shore-zone populations in any comprehensive manner, and neither has studied the populations for more than two consecutive years.

This report deals with samples collected from a total of seven sites around Millstone Point although not all sites have been sampled with the same intensity throughout the period of the study.

Materials and Methods

Sampling Sites

During the period from May, 1969, through December, 1972, seine hauls were made at four sites: White Point, Jordan Cove beach north of Fox Island, Bay Point, and Giants Neck, each February, May, July, September, and December. In February, 1973, two additional study sites were added: one immediately east of the State Sanitarium at Seaside Point and the other at Crescent Beach on Black Point. In 1974, the sampling frequency was increased to include samples during June, August, and October as well. In February, 1975, a site in the Niantic River at Sandy Point was added, and quantitative sampling was discontinued at Bay Point, although one qualitative tow per sampling period was maintained.

The seven sampling sites are shown in Figure 4.9-1.

Seaside Point beach faces due south and is exposed to direct wave action from Long Island Sound, so that there is usually relatively heavy surf action. The bottom substrate consisted of medium to fine sand with no emerging rocks. It is also completely free of attached vegetation, and only rarely are there more than small amounts of detached plant life in the surf zone.

White Point beach has a southwest exposure, but is offered some protection by a man-made breakwater. The bottom sand grain is medium-sized, and there is often a considerable amount of plant material in the shore zone. There is a brackish water runoff into the seining area from a small pond located behind the beach. The stream created by this runoff has a tendency to alter the beach contour at the southern end of the seining area, so that the seining site is usually not quite the same from one sampling period to the next.

The beach at Jordan Cove is sheltered, and the seining area is quite shallow, usually being only about 2 1/2-feet deep for a distance of 50 to 75 feet from shore. Generally, considerable detached eel grass (Zostera marina) was in the shore zone, along with extremely large amounts of detached algae in various stages of decomposition. The beach has a southeasterly exposure, and has a freshwater runoff from a pond located behind the beach. The bottom substrate is composed of a mixture of silt, detritus, fine to coarse sand, and some emergent rocks. During spring low tides, the whole seining area is often completely exposed.

The beach at Bay Point has a south-southeasterly exposure and is usually subjected to heavy surf action. The bottom consists of coarse sand and rock-rubble with no attached vegetation. There is usually a moderate amount of unattached algal material floating in the shore zone. Because of construction of the intake structure for Unit No. 3 in the Bay Point area, quantitative sampling was temporarily discontinued at that site in 1975.

Crescent Beach has an easterly exposure with moderate wave action. The bottom is of medium-grained sand, and there is virtually no attached vegetation in the shore zone, although there is occasionally some detached algae in the seining zone.

Sandy Point, in the Niantic River, is subjected to the least amount of wave action. The bottom is of medium-sized sand grains and occasionally there is a great deal of detached plant life in the sampling area.

Giants Neck beach has a southerly expoqure but is protected by Black Point, Giants Neck, and some offshore islands. The bottom substrate is medium to coarse sand with some large emergent rocks. A considerable amount of detached algal material and detritus is usually in the shore zone. The Giants Neck site, approximately three miles west of the power plant and outside the zone of effect, has been considered as a reference site for assessing the effects of the power plant on the marine environment.

<u>Collections</u>

Three adjacent 100-foot hauls were made at each site[1] with a 30-foot by 4-foot knotless, nylon seine of 1/4-inch mesh on the schedule outlined above. The hauls were approximately parallel to the beach. The person closest to the shore hauled the full 100 feet; the offshore person arched into the beach at the end of each tow. Tows were made within the two-hour period immediately before high tide. The fish from each haul were preserved in ten percent formalin, and identifications, counts, and measurements were made after preservation. When the catch was large, 50 fish of each species were selected randomly for measurement. Standard tables of random numbers were used for selecting the fish. The length from the nose to the last vertebra of the fish was measured (standard length).

Water and air temperature were recorded at the time of seining, and water samples were taken for salinity and oxygen determinations. Through 1973, dissolved oxygen was determined using a modified Winkler technique, and salinities were titrated using Copenhagen water, obtained from the Woods Hold Oceanographic Institution, as a standard. From February, 1974, water quality parameters have been determined through the use of a Hydrolab Surveyor, Model 6D.

[1]During 1975, Bay Point received only one 100-foot tow for qualitative purposes only.

Analysis Techniques

The total numbers of individuals of each species were determined for each site at each seining period. The various species were ranked according to abundance at each site and throughout the general area. Because of unusually large but infrequent catches of certain species, such as the ninespine stickleback (*Pungitius pungitius*) or seasonally high catches of such species as juvenile menhaden (*Brevoortia tyrannus*) relative abundance was determined by the technique of Warfel and Merriman (1944). Using this technique, the most abundant species during a given period was assigned ten points, the second most abundant species, nine points, and so on down to the tenth most abundant species, which received a single point. Beyond that, no points were given. The points for each species over the entire study period were totaled and the species ranked according to the point total. In this way, any species taken only once during the study (if it was the most abundant species at that time) would receive only ten points for that single catch. Its low total point score and subsequent low ranking would be more reflective of its actual presence in the area.

Species diversity indexes for each site at each seining period, and for the sites for the whole year, were calculated using a modified Shannon-Wiener formula:

$$\text{Diversity index } (\hat{H}) = -\sum_{i=1}^{S} \left(\frac{N_i}{N}\right) \log_2 \left(\frac{N_i}{N}\right)$$

where S is the total number of species, N the total number of individuals, and N_i the number of individuals in the i'th species category (Pielou, 1966a).

For each sampling period, the diversity index was calculated from pooled catches from the three hauls at each site. The yearly diversity index was calculated from pooled catches for the year.

The diversity index $\hat{H}$ emphasizes the contribution of an individual species and reflects community structure.

Two other indexes of diversity which contribute to an understanding of community stability or fluctuation and which should be used in conjunction with the species diversity index $\hat{H}$ (Grimes, 1971) were calculated for each site each sampling period and for each year. They were species richness (Dahlberg and Odum, 1970) and species evenness (Pielou, 1966b).

The species richness index uses the formula:

$$D = \frac{S-1}{\log_2 N}$$

This index gives more weight to the number of species present than to total abundance and does not consider community structure or the numbers of individuals within a given species.

Species evenness was calculated using the formula:

$$J = \frac{\hat{H}}{\log_2 S}$$

This index measures how evenly numbers of individuals are distributed within their species categories. Log S is the maximum possible value of H, so the closer the index gets to unity, the more evenly distributed are the individuals within their species categories.

Percent similarity (e.g., Whittaker and Fairbanks, 1958; Sanders, 1958; Ruddiman, Tolderlund, and Be, 1970) determination, or the overlap of the percentages of individual species in a given sample, provides an indication of the degree of similarity of faunal assemblages between any two samples under comparison.

For this technique, the percentages of the number of individuals in each species in the sample were determined, and the lesser of the two percentages for each species-match between pairs of samples were summed. The similarity between catches for any two years during a given sampling month were calculated. For example, the May, 1969, and May, 1970; May, 1970, and May, 1971; May, 1971, and May, 1972, etc., were compared for each seining site. If the percentage of similarity between two samples is high, the communities are reasonably similar. If the similarity percentages remain high over time, the community structure has not varied considerably. If, after a given time period, the similarity percentages become low, the community structure has changed.

These similarity figures are best used in conjunction with species diversity indexes to assess changes in diversity in an area. The species composition may change without a change in diversity index, but there will be, in that event, a noticeable decrease in percent similarity.

Results

Abundance

From May, 1969, through December, 1975, 86,905 fish representing at least 35 species were captured in the shore zone around Millstone Point. This total resulted from 287 samplings at seven sites, two of which were not sampled until 1973 and one of which was not sampled until 1975.

In terms of actual abundance, approximately 95 percent of all fish caught thus far were represented by six species (Table 4.9-1). The Atlantic silverside (*Menidia menidia*) accounted for about 64 percent, while the striped killifish (*Fundulus majalis*) and the common mummichog (*F. heteroclitus*) ranked second and third respectively, each comprising close to seven percent of the total catch. Immature silversides of the genus *Menidia*, too small to be identified to species, amounted to slightly over five percent; while juvenile menhaden (Brevoortia tyrannus), the sand lance (Ammodytes americanus), and the tidewater silverside (M. beryllina) comprised approximately five, four, and three percent, respectively.

The total for Menidia menidia was increased considerably by the catch of over 27,000 individuals at Jordan Cove in a single sampling period in July, 1971. That catch alone accounted for about 48 percent of all M. menidia collected throughout the entire study. Similarly, at Giants Neck during that same sampling period, 443 alewives (Alosa pseudoharengus) were captured, accounting for 97 percent of all alewives collected during the program. Catches of juvenile menhaden, the fourth most abundant fish in terms of total numbers caught, were on a strictly seasonal basis when large schools migrated along the shore in late summer. The numbers of menhaden captured fell off sharply after 1970, yet earlier totals enables this species to maintain its fourth-place ranking in terms of absolute abundance. For these reasons, figures of total abundance may not be as reflective of actual shore-zone fish community structure as relative abundance figures.

When relative abundance is calculated (Table 4.9-2), M. menidia, while still the most abundant shore-zone fish, accounted for only 17 percent of the total number of points amassed by all species. The mummichog (F. heteroclitus) moved into a virtual second-place tie with F. majalis in the relative rankings, each with about 12 percent of the total points. Juvenile menhaden, third place in terms of actual abundance, dropped to a relative abundance ranking of twelfth.

While the Atlantic silverside was generally the most abundant fish throughout the area, the community composition at each of the sampling sites differed considerably. Tables 4.9-3 through 4.9-8 list the species which comprised 95 percent of the actual abundance and the top 80 percent of total points at each site for each year.

In terms of actual abundance, the Atlantic silverside usually ranked first at all sites every year, with only a few exceptions. In 1969, juvenile menhaden at White Point accounted for 46 percent of all fish caught at that site, most of them being captured in July, and the striped killifish was the most abundant fish at Jordan Cove. In 1970, heavy seasonal catches made juvenile menhaden the most abundant fish at Bay Point. Silversides continued to dominate catches at all sites until 1974 when the common mummichog accounted for 47 percent of all fish at Crescent Beach, a site not sampled until 1973. At White Point in July, 1975, 2,744 sand lances (Ammodytes americanus) were taken, comprising about 80 percent of all fish taken at that site throughout the year. The tidewater silverside (M. beryllina) was the most abundant fish at Giants Neck in 1975, outnumbering M. menidia by only 14 fish.

When community composition was examined in terms of relative abundance of individual species, the relative importance of some of the species changed. For example, silversides were numerically the most abundant fish at Jordan Cove throughout the study. In terms of relative abundance, silversides ranked first only once, and that was in 1973. One or the other species of killifish ranked first for each of the other six years.

The number of fish collected at each site each sampling period is shown in Table 4.9-9. There are obvious seasonal factors in the catches, with most fish per tow generally being taken in the summer and fall samples, reflecting catches of the resident species, those using the estuarine areas as nursery grounds, and the migratory species such as juveniles of bluefish and menhaden.

Jordan Cove and Sandy Point, the most protected sites, and nursery areas for several species such as the silversides, killifish, and sticklebacks, had the highest catches per tow. These sites had the highest summer temperatures, although this was due to the nature of the habitat rather than the thermal discharge. The least protected sites, where primarily only foraging and migratory fish were collected, were Seaside and Crescent Beach, and these had the fewest catches per tow.

Total numbers of fish caught each year reflected, in large part, the increase in sampling effort that began in 1974. The numbers of fish caught per tow at each site on a yearly basis are shown in Table 4.9-10. These, too, show site differences due to the type of habitat sampled.

No yearly trend in catch per unit-effort at any of the sites could be determined.

Seasonal and yearly fluctuations in the relationships between numbers of species and numbers of individuals of each species are reflected by the various indexes of diversity and by the percent of similarity between one year's collections and the next. The fluctuations are discussed below.

Species Diversity and Community Similarity

Table 4.9-11 shows the number of species collected at each site each sampling period, and Tables 4.9-12, 4.9-13, and 4.9-14 show the species diversity, species richness, and species evenness, respectively, for each site at each sampling period throughout the study. As with numbers of species, there are seasonal aspects to these parameters, although they are somewhat less pronounced. In the winter months, especially February, only one or two species are collected, if any. These are usually the year-round residents such as the silversides and killifish. Generally not many individuals are collected, so the diversity is either quite low if only one species is collected, or high if two or three are taken with low numbers of individuals evenly distributed through the species categories.

Diversity increases in the spring with some of the spring migrants being collected with the year-round residents. Species richness and evenness also have a tendency to rise.

Summer indexes usually reflect the increase in numbers of species and, in the resident species, a large increase in the number of individuals. These resident species dominate the catches, and the diversity and evenness indexes decrease somewhat, while species richness remains at about the same level, or increases slightly.

In the fall, large catches of migrants such as juvenile menhaden, along with the expected large catches of resident dominants, cause the diversity and evenness indexes to go up slightly. In some cases, however, unusually large catches of migrant juveniles or residents will be reflected in a drop in diversity.

The aspect of diversity that is being concentrated on here is the trend in the various diversity indexes over the course of the study. As stated previously, if the construction and operation of the power plant were to reduce or eliminate species over some time period, it should be reflected as a significant trend in the diversity indexes. The annual indexes were calculated from pooled catches at each site, and these indexes have been plotted against time and are shown in Figures 4.9-2 through 4.9-6. Because a change in the community can occur without a change in index (e.g., if one species is replaced by another, with a similar number of individuals within the species category), the percent of similarity in the community at each site from year to year was also plotted and is also shown in Figures 4.9-2 through 4.9-6.

It would be premature to discuss trends over a three-year period at Seaside and Crescent Beach, particularly in light of the kinds of fluctuations in the indexes at the sites where seven years of data are available. However, when regression analyses were carried out on the indexes over time, no significant trend was seen at any site.

The graphs of percent similarity, on the other hand, show that some major changes in the communities at some sites have taken place, particularl between 1974 and 1975. These changes are discussed below in more detail for each site.

White Point

It was stated earlier that the silverside, especially the Atlantic silverside (M. menidia) was generally the dominant shore-zone species throughout the study area. This was particularly true at White Point, and changes in percent similarity there reflect changes in the relationship of the percent of M. menidia collected each year to the percent of one or two other species present in the sampling.

In 1969, seasonally large catches of migratory juvenile menhaden resulted in that species comprising about 46 percent of the annual total of all fish at White Point. M. menidia only constituted 32 percent. In 1970, M. menidia amounted to 68 percent of the catch, with menhaden dropping to only eight percent, and the striped killifish (F. majalis) representing 20 percent.

Silversides continued to dominate the 1971 catch, but by only 52 percent of the total. Juvenile menhaden again were taken in seasonally high catches and represented 41 percent of the total number of fish collected. In 1972, silversides were again 52 percent of the catch, but menhaden dropped to only five percent, and killifish (F. majalis) rose to 15 percent of the total.

In 1973, Atlantic silversides were only 39 percent of the total and the sand lance (Ammodytes americanus) previously collected only occasionally, amounted to 25 percent of the collected fish. The common mummichog (F. heteroclitus) and F. majalis were 19 percent and 14 percent of the total, respectively. This resulted in a rise in all three diversity indexes but a decline in the percent similarity.

Percent similarity between the 1973 and 1974 communities declined sharply when, in 1974, the two species of Menidia accounted for 91 percent of the total catch. An even sharper drop in percent similarity between 1974 and 1975 occurred as the sand lance dominated the 1975 catches (81 percent) in terms of total abundance. In terms of relative abundance, (Table 4.9-3) however, killifish and mummichogs replaced M. menidia as the dominant fish for the first time in the study.

Jordan Cove

In 1969, the striped killifish (F. majalis) was not only the most abundant species numerically at Jordan Cove, but also relatively. By 1970, silversides became the most numerically abundant species at that site, and remained so through 1975. The communities at Jordan Cove showed little change from 1970 through 1974. The sharp decline in species diversity and species evenness in 1971 was due to the extremely large catch of M. menidia in July. Species richness, however, increased somewhat that year.

The decrease in percent similarity between 1974 and 1975 at Jordan Cove was due primarily to catches of juvenile silversides, which were too small to be identified to species. They were in all probability, M. menidia, since catches of M. beryllina were not large. If these juveniles could have been categorized as M. menidia, the percent similarity between 1974 and 1975 would have remained high, thus reflecting a stable community at Jordan Cove from 1970 throughout the study period.

There is no evidence available to suggest that the change in community similarity from 1969 to 1970 was the result of power plant construction. The site was, however, established as a wildlife sanctuary in 1970, and repairs to a culvert leading from a pond behind the beach to Jordan Cove and the construction of a small protective weir-like device around the mount of the culvert could have caused a change in current flow along the beach, thus altering the habitat, although there are no other data to support this observation.

Bay Point

Because of construction activities for Unit No. 3 at Bay Point beach, this site was not sampled quantitatively in 1975. It was one of the most difficult sites to sample because of the lack of protection from onshore winds and surf, and these factors were undoubtedly reflected in the fluctuations in numbers and species of fish caught and in the various diversity indexes.

Construction of the intake structures for Units Nos. 1 and 2 probably had some effect on the sites, and also affected the numbers and species collected. The major factor contributing to the lack of community similarity between 1969 and 1970 and between 1970 and 1971 was the unusually large number of juvenile menhaden taken at Bay Point in July, 1970. This catch alone (1,275 individuals) accounted for 97 percent of all fish caught at Bay Point that year.

From 1971 through 1974, catches of M. menidia dominated the collections and percent similarity remained high, especially from 1973 to 1974.

Giants Neck

Giants Neck was originally chosen as the control site. From 1969 through 1974, catches of M. menidia dominated the collections, resulting in relatively low species diversity and species evenness indexes and high percent similarity from year to year. Species richness fluctuated little throughout that time period. In 1974, a few individuals of a number of other species resulted in an increase in species richness.

In 1975, tidewater silversides (M. beryllina) were slightly more abundant than Atlantic silversides, each however representing almost a quarter of the entire catch. Catches of the sand lance (A. americanus) previously not taken at Giants Neck (except for three individuals in December, 1974), rose sharply in 1975 to where they accounted for 10 percent of all fish caught at that site that year. The increase in both the numbers of individuals and species other than M. menidia resulted in the sharp increase in species diversity and species evenness and the decrease in percent similarity from 1974 to 1975.

Seaside

In 1973, M. menidia accounted for 61 percent of the catch at Seaside, and A. americanus 30 percent.

In 1974, M. menidia fell to 40 percent, and M. beryllina comprised 25 percent of the total collection. The striped mullet, (Mugil cephalus) amounted to 19 percent of the catch, and no sand lances were taken. The number of species collected increased with catches of juvenile menhaden (three percent); sheepshead minnows (Cyprinodon variegatus), (two percent); striped killifish (one percent); and grubbies (Myoxocephalus aenaeus), (one percent). The result was the large increase in species diversity and richness.

In 1975, silversides (M. menidia), 66 percent and M. beryllina, 17 percent) dominated the catches, and diversity and richness declined.

Crescent Beach

As at the other sites, fluctuations in catches of the silversides, because of their numerical dominance, dictated the fluctuations in the various indexes of diversity. Total numbers of fish taken at Crescent Beach were relatively low, however.

In 1973, M. menidia comprised 59 percent of the annual collection, and a seasonal catch of juvenile blueback herring (Alosa aestivalis) resulted in that species making up 32 percent of the annual total.

Common mummighogs dominated the 1974 catch (47 percent) with M. menidia comprising only 27 percent. In 1975, M. menidia accounted for 59 percent and M. beryllina 23 percent of all fish taken at Crescent Beach.

Discussion

The ecological perspective taken here was to examine the shore-zone fish communities in the Millstone Point area over an extended time period to see whether trends in diversity indexes, which are reflective of changes in water quality (Bechtel and Copeland, 1970), had become established. No such trends at those sites that had been sampled for six years or more (i.e., White Point, Jordan Cove, Bay Point, and Giants Neck) were noted. It is too early to tell whether any trends at Seaside and Crescent Beach are evident, although the fluctuations in diversity indexes would tend to eliminate that possibility.

At the long-term sites sampled quantitatively in 1975, i.e., White Point, Jordan Cove, and Giants Neck, there was a sharp drop in percent similarity with 1974 communities. This drop was accompanied by an increase in species diversity and species evenness, supposedly criteria of an increase in the quality of the water in the area.

The sites most apt to be affected, Jordan Cove and White Point, both showed sizeable increases in diversity for 1974, especially Jordan Cove.

No species common to the area over the past seven years showed any significant declines, and one species Ammodytes americanus showed an increase. It would not appear, therefore, that plant operations have had an adverse effect on the shore-zone fish communities as reflected in the indexes of diversity, richness, and evenness.

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4.9.2 Gill Net Studies

Introduction

Gill nets are used for capturing the pelagic fishes which may not be caught by otter trawls or beach seining, the other two methods of adult fish collection currently used in the Millstone Point Ecological Study. From the locations sampled during 1975, it was possible to generate a species list for pelagic as well as near-bottom dwelling fish for the general Millstone Point area, as well as some limited information on relative abundance of some of the more prevalent species.

By setting the gill nets on a monthly basis, patterns of seasonal occurrence of fish species may also be noted. The surface and bottom sets (done at five of the seven stations) provided some data relative to stratification preferences by some species. The locations of the seven gill net stations (Figure 4.9-7) allowed for comparison of the catch per unit-effort at different areas around Millstone Point.

Some problems were encountered while trying to set the nets at the surface and near the bottom. Boats often hit the surface nets, in spite of efforts to better mark their location by using lights and/or more buoys. The bottom nets were often found tangled with *Libinia emarginata* (spider crabs), especially during the summer.

For those reasons and the fact that the sampling effort has changed each year, the gill nets do not provide accurate quantitative data, and no major significance was put on comparisons among locations or among sampling years. Nevertheless, some comparisons were made and will be discussed generally.

Materials and Methods

Collection

Gill nets were set overnight near Twotree Island and Bay Point on a quarterly basis beginning in December, 1971. In June, 1973, sampling sites were added near Black Point and Jordan Cove, and the sampling frequency increased to bimonthly beginning with the July, 1973 sample. In January, 1974, the sampling frequency was increased to monthly.

Standard monofilament experimental nets from Sterling Marine Products made up of six 25-foot panels, six-feet deep, with a stretch mesh ranging from end to end of 2, 1 1/4, 1, 3/4, 1 1/2, and 2 1/2 inches were used during the sampling period from December, 1971, through January, 1975. They were placed as perpendicular to the prevailing currents as possible and set so that the float line was approximately two feet below the surface at low tide.

In February, 1975, there was a further increase in effort. Sampling continued at monthly intervals, but sites were added and stratified nets were set at the surface and approximately 18 inches off the bottom at the Twotree Island Channel site; off Bartlett Reef in the vicinity of plankton Station 14; in Niantic Bay; off Bay Point in front of the existing intake structures for Units No. 1 and No. 2; and on either side of the plume from the effluent quarry cut (the westerly net being a surface set, the easterly net being a bottom set). A surface net was set in Jordan Cove and off Black Point. The locations of the gill net sites are shown in Figure 4.9-7.

In May, 1975, the nets were changed to a multifilament experimental net (Nylon Net Company) made up of eight 25-foot panels with a stretch mesh ranging from end to end of 4, 2 1/2, 2, 3/4, 1, 1 1/2, 3, and 5 inches. Standard lengths to the nearest millimeter were recorded for individuals of the class Osteichthyes captured, while total lengths to the nearest millimeter were recorded for species from the classes Petromysoniformes (lamprey eel) and Chondrichthyes (sharks).

Analysis

The actual numbers of each species were determined for each site at each gill net period. The various species were ranked according to abundance at each site and throughout the general area. Because of unusually large but infrequent catches of certain species such as the striped anchovy (*Anchoa hepsetus*) or seasonally high catches of such species as the Atlantic herring (*Clupea harengus*) a ranking by relative abundance using the technique of Warfel and Merriman (1944) was also made. Using this technique, the most abundant species during a given sampling period was assigned a point total of 10. The second most abundant species received nine points and so on down to the tenth most abundant species, which received a single point. Beyond that, no points were given. Fish with the same actual abundance were given the same number of points. The points for each species were totaled for all sampling periods prior to 1975 and totaled for the year 1975, due to changes in sampling gear and the stations sampled. The species were then ranked according to their point totals for 1975. In this way, a certain species taken only once during the study, but whose actual abundance at that one period could cause it to be ranked highly over the entire period, would receive only 10 points for that single catch (if it were the most abundant species at that time). Its low total point socre and subsequent low ranking would be more reflective of its actual presence in the area.

Species diversity was determined using a modified Shannon-Wiener H formula:

$$\text{Diversity index } (\hat{H}) = -\sum_{i=1}^{S} \left(\frac{N_i}{N}\right) \log_2 \left(\frac{N_i}{N}\right)$$

where S is the total number of species, N the total number of individuals, and N_i the number of individuals in the i'th species category (Pielou, 1966a).

The diversity index $\hat{H}$ emphasizes the contribution of an individual species and reflects community structure.

The species richness index (D) of Dahlberg and Odum (1970), which gives more weight to the number of species present than to total abundance, and the species evenness indexes (J) of Pielou (1966b), which measures how evenly numbers of individuals are distributed within the species categories were also calculated. The formulas used were:

$$D = \frac{S-1}{\log_2 N}$$

and

$$J = \frac{\hat{H}}{\log_2 S}$$

Results

Eleven species were captured during 1975 that had not previously been caught by gill nets:

Anchoa hepsetus	Striped anchovy
Anchoa mitchilli	Bay anchovy
Etrumeus teres	Round herring
Gadus morhua	Atlantic cod
Menidia menidia	Atlantic silverside
Menticirrhus saxatilis	Northern kingfish
Microgadus tomcod	Tomcod
Myoxocephalus octodecemspinosus	Longhorn sculpin
Petromyzon marinus	Sea lamprey
Scomber japonicus	Chub mackerel
Urophycis chuss	Squirrel hake

Eight species were not caught in 1975 that had previously been captured in the gill nets:

Alosa mediocris	Hickory shad
Caranx crysos	Hardtail
Cynoscion regalis	Weakfish
Morone saxatilis	Striped bass
Mugil cephalus	Mullet
Myoxocephalus aenaeus	Grubby sculpin
Osmerus mordax	Smelt
Urophycis tenuis	White hake

Table 4.9-15 shows the number of species and individuals captured in the Millstone Point area each year along with the yearly catch per unit-effort. Species ranked according to abundance throughout the study are shown in Table 4.9-16.

Through 1975, a total of 3,799 fish was captured in the gill nets. The Atlantic herring (Clupea harengus) accounted for 57 percent of all fish taken, and it was collected every year except 1971 when only one sampling at two sites was conducted in December. Twelve species of the 40 collected made up 95 percent of all fish taken during the study. Only three of these Clupea harengus; the dogfish (Squalus acanthias); and the alewife (Alosa pseudoharengus) were captured every year.

The most intense sampling throughout the study was done in 1975, when 1,495 fish (39 percent of all fish taken) and 32 species (80 percent of all species taken) were collected. The 1975 ranking by actual abundance is shown in Table 4.9-17 and the ranking by relative abundance in Table 4.9-18.

C. harengus ranked first by actual abundance because of large winter catches, whereas the menhaden Brevoortia tyrannus present year-round, ranked first by relative abundance.

Some species were caught exclusively in either the surface or the bottom net as seen in Table 4.9-19. B. tyrannus and C. harengus, although captured in both surface and bottom nets, were taken more often in the surface nets. The twelve most numerous fish species captured accounted for 95 percent of the gill net catches. These fish appeared well dispersed over the gill net sites (Table 4.9-20.)

The catch per unit-effort of each species at each site for both surface and bottom sets is shown in Table 4.9-21. The yearly catch per set was calculated and is shown in Figure 4.9-8. The highest catch per set was at Jordan Cove and the lowest was in the surface net at Bartlett Reef.

Each net site for the period January, 1975 through December, 1975 was compared using a square root transformation to stabilize the variance in each location. However, large seasonal variances coupled with the lack of monthly replicates resulted in such large variations that no significant difference could be found among net locations (Table 4.9-20).

Species diversity (Figure 4.9-9) showed a marked seasonal pattern; increasing in the warmer months when resident and migratory species were in the area, and decreasing in the winter when the samples were dominated by large catches of Atlantic herring. In general, species richness and evenness (Figure 4.9-9) followed the same pattern as diversity except for periods where there may have been an increase or decrease in the number of species from one sample to the next but the catch was dominated by one particular species, or when there was no particular domination by any species. For example, from June to September, 1972, there was an increase from six to nine species, but the September catch was dominated by scup (Stenotomus chrysops). Consequently, diversity and evenness dropped, but species richness increased. From July to September, 1973, the species number dropped from 12 to 7. The July catch was dominated by northern searobins (Prionotus carolinus) but there was a more even distribution of individuals among the seven species taken in September. Diversity and richness dropped, but the evenness index increased.

A list of the top eleven species as ranked by percent composition of the fish caught in the Bay Point gill net and impinged upon the intake screens at Unit No. 1 was compiled (Table 4.9-22). The top eleven species of the Bay Point gill net accounted for almost 99 percent of the fish taken at that site during 1975, yet only three species overlapped with the top eleven impinged at Unit No. 1 during the same period. The family Clupeidae comprised 84 percent of the Bay Point gill net catch, and only 5 percent of the impinged fish.

Discussion

The Millstone Point area supports a relatively diverse pelagic fish community dominated by representatives of the family Clupeidae, with menhaden being present year-round and Atlantic herring on a seasonal basis. The largest catches were in Jordan Cove, probably because that area is a nursery and year-round residence area for many of the small fish that provide food for the pelagic species. The low catches near Bartlett Reef were not necessarily indicative of few fish in that area, but rather of the difficulty in setting nets where there were strong currents and extensive kelp beds.

Gill net sampling did not indicate that there was any difference in the kinds and numbers of fish found in the thermal plume compared to anywhere else around Millstone Point, except for Jordan Cove; nor was there any indication that any particular species was in the thermal plume beyond the seasonal period when they would be expected in the area.

Comparisons between Bay Point (the station closest to the intakes) gill net catches and impingement data for Unit No. 1 for 1975 seem to indicate that gill net catches may not be representative of fish that will be impinged from a specific area. The intake would tend to show a greater percentage of rock dwellers (i.e., *T. onitis*, *T. adspersus*) due to its location on-shore, while the Bay Point gill net was set over a muddy bottom off-shore from the intake structure.

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4.9.3 Otter Trawl Studies

Introduction

An otter trawl program was introduced on a quarterly basis in December, 1971, to provide a list of fish species present in the deeper waters around Millstone Point. In April, 1973, the program was expanded to biweekly sampling to provide information on the occurrence and distribution of epibenthic and near-bottom dwelling fish. In addition, it was expected that the trawls would also capture fish that had been tagged as part of a population estimate program which also begain early in 1973.

Additional trawling was also done on a limited basis in Jordan Cove during 1974 and 1975 to determine whether the number of juvenile winter flounder caught would indicate if this species used Jordan Cove as a spawning and nursery area.

In February, 1975, surface trawling was initiated to obtain information on the distribution of pelagic schooling fish in the Millstone Point area.

Stomach contents of a representative number of each species collected in the 1973 and 1974 trawls were examined and the data reported earlier (William F. Clapp Laboratories' Annual Report to Northeast Utilities Service Company, February 15, 1975).

The information discussed here was developed from the program as it was carried out from April, 1973, through December, 1975.

Materials and Methods

Collection

Beginning in April, 1973, sampling was carried out every other week at Stations 1, 4, 6, 7, 8, 9, and 10. Station 11 was added to the program in September, 1974, and Station 5 was added in February, 1975. In June, 1975, Station 2 was added to increase the recapture of tagged winter flounder. Figure 4.9-10 shows the sites sampled by otter trawl during 1975.

A single tow was made at each station each sampling period until June, 1974, when the tows were augmented by duplicating the sampling at one randomly selected station each sampling period. In August, the random replication of tows was increased to three at one station each sampling period. Beginning September, 1974, tows at Stations 8, 10, and 11 were also duplicated. Beginning in February, 1975, the sampling effort called for duplicate surface and bottom tows at Stations 5, 8, 10, and 11 and for the remainder of the stations, at each sampling period, there was a single tow made with one random duplication.

For bottom trawls, a 30-foot Wilcox biological sampling otter trawl with a 1/4-inch cod-end liner was towed at each station at 1 1/2 knots to 2 knots for 15 minutes. A five-to-one ratio of steel cable length to depth was used to insure that the net was dragged along the bottom.

Surface trawls were made with a converted 30-foot otter trawl with floating doors. The net was towed in a zigzag pattern for 15 minutes at a speed of three to five knots at a distance of 250 feet from the stern of the boat.

The catch from each tow was placed in a live box with flowing seawater, and the fish were identified and measured (total length to the nearest millimeter). Until February, 1975, all fish were also weighed. All fish were released alive following the sample processing.

Analysis

The actual number of each species captured per month at each trawl site was determined. A monthly catch per 15-minute tow at each station was calculated for the most abundant species and for all species combined.

The relative abundance of each species was determined using the technique of Warfel and Merriman (1944).

Catches at each station were compared with a two-factor analysis of variance using monthly average catch per unit-effort for each station and by a Tukey test using log transformation of monthly average for pairwise comparisons of the stations. The catch per unit-effort for Stations 1, 4, 6, 7, 8, 9, and 10 for 1974 and 1975 and for Stations 1, 4, 5, 6, 7, 8, 9, 10, and 11 for 1975 was calculated. Cluster analyses (Anderberg, 1973) of similarity coefficients were accomplished using monthly average catch per unit-effort per species per station. A Mann-Whitney rank test of monthly average catch per unit-effort for winter flounder per station was also carried out.

In order to determine the average instantaneous populations of all species of fish and the five most abundant species caught in trawls during April, 1973, through December, 1975, for the Millstone sampling areas, the sampling area was divided into station areas (Figure 4.9-11). The individual station areas were then combined by similar bottom types and depths into four station areas. These were: river stations - Stations 1 and 2; inner stations - Stations 4, 5, 6, and 11; No. 1 outer station - Station 7; No. 2 outer stations - Stations 8, 9, and 10.

The average tow area was determined from boat tow speed and the width of the net being towed. The width of the net was determined to be approximately 30 feet.

The area of each station combination was divided by the area covered by each tow to determine the number of tow areas in each station area. The average catch per unit-effort for each station area was multiplied by the number of tow areas in each station to obtain the average instantaneous population for each station area. The average populations of all station areas were added together to obtain an estimate of the instantaneous population for the total Millstone sampling area.

The estimated monthly instantaneous population of the Millstone sampling area was also determined for winter flounder (*Pseudopleuronectes americanus*) by that method.

Results

A total of 30,605 fish representing at least 63 species were collected in the regular otter trawl program since April, 1973. Table 4.9-23 lists the number of each species, ranked by actual abundance, captured during the 33-month program. Included in Table 4.9-23 is the number of relative points accumulated by each species and the stations at which the fish were captured.

Winter flounder (Pseudopleuronectes americanus), the most abundant species with 13,176 individuals, accounted for 43 percent of all fish captured. Scup (Stenotomus chrysops) were the second most abundant fish in the samples with 5,493 individuals comprising 18 percent of the total. Windowpane (Scophthalmus aquosus), skates, (Raja spp.), and cunner (Tautogolabrus adspersus) accounted for 9, 7, and 5 percent of the total, respectively; and the five species together comprised 83 percent of all fish taken during the trawl studies.

Of the five most abundant species, only the skates were not captured at every station, and the only station at which they were not taken was at Station 1, the station furthest up in the Niantic River.

The greatest number of species at any one station for the 33-month study period was 43 at Station 8. For stations sampled over the entire 33-month period, Station 1 had the highest yearly average of 88.2 fish per tow during 1975.

Tables 4.9-24 through 4.9-26 show the number of fish collected during the last nine months of 1973 and all of 1974 and 1975, respectively. Winter flounder comprised 61 percent of the fish taken during 1973 and 50 percent of all fish captured in 1974. In 1975, however, they accounted for only 34 percent of the total catch, even though over 1,500 more flounder were taken in 1975 than in 1974.

In 1973, most of the winter flounder were taken at Stations 9 and 10 (Figure 4.9-12). However, in 1974 and 1975, the greatest numbers of winter flounder were taken in the Niantic River Stations 1 and 2 (Figure 4.9-12). The results of a Mann-Whitney rank test of abundance indicated that catches of winter flounder were highest at Station 1 and lowest at Station 7. Two major peaks of abundance occurred each year (Figure 4.9-13). The first and longest occurred between March and June, probably related to the February through March spawning season. The second peak occurred in the late fall and early winter.

Because of large seasonal catches in the Summer of 1975, scup (S. chrysops) were the second most abundant fish taken in the trawls (Table 4.9-23). They were fifth, however, in relative abundance. Nearly one-fifth of all scup taken during the study were captured in a single 15-minute tow at Station 5 in August, 1975. Scup accounted for 29 percent of all fish taken in 1975, most of which were taken at Stations 4 and 5 (Figure 4.9-12). Most of the scup taken were juveniles ranging from 30 to 60 millimeters in length.

The windowpane (S. aquosus) was third in actual abundance for all years combined, but second in terms of relative abundance each year and for the 33-month study period. They were generally most numerous at Stations 9 and 10 (Figure 4.9-12).

Two species of skates, Raja ocellata and R. erinacea, occur in the Millstone Point area. Differentiation in the field is often difficult without sacrificing the fish. For this reason, skates taken in the trawls, since they were to be released alive, were only classified to genus. The two species combined accounted for seven percent of all fish taken during the study. Most skates were taken outside the Niantic River area at Stations 4, 8, 9, and 10. No skates were collected at Station 1.

Catches of skates were year-round with seasonal peaks occurring in April and May, July and August, and November and December (Figure 4.9-13).

Cunner (T. adspersus) ranked fifth in actual abundance and fourth in relative abundance (Table 4.9-23). Catches of cunner were generally highest at Station 7 (Figure 4.9-12) and were higher during the summer months.

Juvenile cunners were caught at Station 1 in relatively large numbers from September, 1974, through March, 1975, indicating that the Niantic River might also be a nursery area for this species.

An analysis of variance indicated that there was a significant difference between stations in the numbers of fish collected ($F = 3.666$; $p = .001$). The results of the Tukey test for differences (Table 4.9-27) indicate that Stations 1 and 7 are least similar to one another in terms of abundance of fish. This indicates that Station 7 (lowest average catch per unit-effort) and Station 1 (highest average catch per unit-effort) differed from more stations than any other station.

Stations were clustered by monthly similarity coefficients (Figures 4.9-14 through 4.9-16) for 1973, 1974, and 1975. Similarity coefficients were generally highest in the summer and lowest in the winter. The similarity coefficients were also arranged by yearly and total averages per station (Figures 4.9-17 through 4.9-26). The greatest similarity occurred between the Niantic Bay Stations, 4 and 5. The next most similar stations were Stations 8, 9, 10, and 11 which were followed closely by Stations 6 and 7. The Niantic River stations (Stations 1 and 2) were the least similar to any other station. Similarity coefficients ranged from 71.7 between Stations 4 and 5 in June, 1975, to zero between Station 7 and all other stations in February, 1974, (no fish were caught on Station 7 during this month). The highest average similarity between each Station was as follows: Station 1 to Station 2, Station 2 to Station 11, Station 4 to Station 5, Station 5 to Station 4, Station 6 to Station 11, Station 7 to Station 9, Station 8 to Station 11, Station 9 to Station 5, Station 10 to Station 8, and Station 11 to Station 8. The highest monthly similarities between each station were as follows: Station 1 to Station 4, Station 2 to Station 11, Station 4 to Station 5, Station 5 to Station 4, Station 6 to Station 10, Station 7 to Station 9, Station 8 to Station 9, Station 9 to Station 10, Station 10 to Station 9, and Station 11 to Station 5.

Using the tow area data in Table 4.9-28, the average instantaneous population for April, 1973, through December, 1975, was determined to be 98,136 for winter flounder, with a range of 13,318 to 247,934 (see Table 4.9-29), 37,419 scup, 22,313 windowpane, 17,751 skates, 13,328 cunner, and 226,001 of all species (see Table 4.9-30).

If the turnover rate for winter founder in the total Millstone area is the same as the turnover rate for the Niantic River (26 percent average weekly turnover during 1974 and 1975), the maximum number of flounder that would enter the Millstone sampling area would be approximately 1.3 million flounder.

When the 1974 monthly catch per unit-effort of winter flounder in the Millstone Point is compared with the catch per unit-effort in the nearby Thames River over the same time period (Figure 4.9-27), the same seasonal patterns were evident except that the late spring and early summer peak in the Thames River was higher and somewhat later.

Surface trawls resulted in the capture of 1,454 fish, with catches being extremely sporadic. Butterfish (Peprilus triacanthus) accounted for 77 percent of the catch (Table 4.9-31). They were only caught during the jellyfish bloom in August and September. The Atlantic silverside (Menidia menidia) was ranked second in actual abundance and comprised 20 percent of the surface catch.

The Atlantic silverside ranked second in actual abundance, comprising 20 percent of the surface catch. All of the silversides and threespine sticklebacks (Gasterosteus aculeatus) were taken in December, and 93 percent of the silversides were captured at Station 11.

With the exception of a fourspine stickleback (Apeltes quadracus) and a bluefish (Pomatomus saltatrix) taken in June, all fish captured in surface trawls at Station 11 were captured in December.

Discussion

The Millstone Point area supports a large variety of fish species. The relatively large numbers of winter flounder are the base of a sizeable sport fishery in the area. Generally, winter flounder populations are larger in the Niantic River than at the other sampling sites.

There are some indications of exchanges of winter flounder populations between the Niantic River and Niantic Bay, and possibly between the bay and the deeper waters outside the sampling area. In December, 1973, there was a sharp decrease in numbers of winter flounder taken in the river and an increase in numbers in the bay and outer stations. In January, 1974, there were small catches at all stations, which might have indicated that the winter flounder moved to the deeper waters outside the sampling area.

This type of areal fluctuation with flounder decreasing in the Niantic River and increasing in Niantic Bay also occurred each May during the study.

The yearly average catch per unit-effort for winter flounder during 1973, 1974, and 1975 indicates a decrease in winter flounder over these three years. This is misleading because the catch per unit-effort for 1973 is based on nine months. If the catch per unit-effort for the same nine months during 1974 and 1975 are considered, the highest catch per unit-effort occurred during 1974, followed by 1973, and 1975 having the lowest catch per unit-effort.

If the number of fish in the total Millstone sampling area is compared with trawl catches and impingement catches, only a small percent (less than 1 percent) is ever caught or removed from the population.

No statistical differences between stations, except Station 7 and 1, exist in terms of numbers caught. Comparing the station areas that conceivably could be considered for offshore intakes, (5, 8, 9, and 10) with Station 11, at the present intake, Station 8 had the lowest overall catch per unit-effort. However, Station 8 has a rocky bottom, thus making the catch efficiency lower than at Station 5, 9, and 11 (a portion of Station 10 has a rocky bottom).

Although similarity coefficients were low, the highest coefficients occurred among the areas which might be considered as offshore intake locations and the present intake area.

Comparing winter flounder catches in the Millstone Point area to the Thames River area during 1974 indicated that the Millstone Point area was not a unique part of Long Island Sound in terms of flounder population dynamics.

Surface trawls provided little information on the distribution of pelagic fish in the area. Usually, the surface trawls were not too successful, possibly because of the ability of the adult fish to avoid the slow-moving net. The species caught in the surface trawls around Millstone Point are considered relatively slow swimmers.

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4.9.4 Winter Flounder Population Estimates

Introduction

An indigenous population of winter flounder (Pseudopleuronectes americanus) utilizes the Niantic River and near-shore areas. Large numbers of flounder enter the river during winter and spring for spawning and/or feeding, making the river the focus of an extensive sport fishery during these seasons, while the general Millstone area attracts flounder anglers for the remainder of the year.

Flounders from the Niantic River range over a large area of Long Island Sound in the summer and fall; however, the specific contribution of the Niantic River population of flounder to the commercial fishery of Long Island Sound is unknown.

The Millstone Nuclear Power Station is located on the eastern shore of Niantic Bay, about 1,850 yards (two kilometers) south of the mouth of the Niantic River. The power plant, acting as a predator of adults and larvae, may stress the populations of flounder spawning in the area. The potential entrainment of flounder larvae originating in the Niantic River is heightened by the current patterns of Niantic Bay. On an ebb tide, for example, the outfall of the Niantic River flows along the eastern shore of Niantic Bay, passing the intake structures of the Millstone Station (see Sections 2.2 and 4.2).

Estimates of the population of winter flounder were deemed necessary to provide baseline data for a mathematical prediction of the effects from once-through cooling on the flounder population over the life of the power plant, and to monitor fluctuations in this population.

Initial efforts to quantify the population of winter flounder entering the Niantic River estuary began in 1973 with a limited tagging program of adult winter flounder caught both in the river and in the general Millstone area. Tagging efforts in 1974 were increased over the previous year and focused on those fish in the Niantic River and Jordan Cove. Recaptures of tagged flounder were too few and sporadic for an accurate population estimate (see Summary Report Ecological and Hydrographic Studies, May, 1966, through December, 1974, Section 2.13). Tag loss, tag-induced mortality, and an insufficient number of tagged flounder were judged to be the limiting factors in obtaining recaptures of tagged flounder.

The mark-and-recapture study carried out in 1975 was designed to eliminate the faults of the previous studies. Flounder were marked by clipping one pectoral and/or one ventral fin; a unique clip for each week's effort.

The 1976 mark-and-recapture study was similar to the 1975 study, except it was carried out for a longer period of time.

Differences and similarities between 1974, 1975, and 1976 in the apparent number of winter flounder, their gonadal development, and time of peak abundance in the river were noted.

Materials and Methods

Winter flounder taken in trawls during 1973 and 1974 were tagged with a Floy anchor tag (FD68-B) lateral to the posterior third of the dorsal fin. Trawling techniques were the same as those of 1975 (refer to Summary Report Ecological and Hydrographic Studies, May, 1966, through December, 1974, Section 2.13).

During 1973 and 1974, only Stations 2, 6, and 7 (see Figure 4.9-28) were sampled for tagging purposes; no tows were made over the shallows out of the channel. The minimum size of the fish tagged was 250 millimeters.

The design of the 1975 winter flounder population study was originally based on the requirements for the Triple-Catch Trellis method (Ricker, 1958) for estimating population, survival, and recruitment.

The Niantic River was divided into nonsampling (shallow or weedy) areas and sampling areas. Eleven sampling stations were established in the sampling areas; Stations 1 through 5 were located in the channel, and Stations 6 through 11 were outside the channel (Figure 4.9-28).

A monitoring program of test trawls to determine the abundance of winter flounder in the Niantic River began at selected stations during the second week of February, 1975, and continued through the week of March 24 through March 28.

Winter flounder were considered to be numerous enough to begin marking during the week of March 31 through April 4. Mark-and-recapture sampling was conducted for a nine to ten-hour period on Monday and Tuesday of each week for six weeks over a seven-week period (the sixth week was a monitoring week). Two boats were used for trawling, each of which towed a 30-foot Wilcox biological otter trawl with a one-fourth inch cod-end liner.

Trawls were taken primarily at Stations 1 through 7 during weeks 1 and 2, with some sampling at Stations 8 through 11 on week 2. During weeks 3 through 7, trawls were taken at most of the sampling stations. The majority of the tows were taken at the station of best-catch-per-tow and were approximately five minutes in duration. The duration of tow varied according to conditions such as the size of the area to be towed, the expected catch, or the amount of clogging of the nets with eel grass and algae.

After each trawl, winter flounder were counted and categorized into one of three size groups: Group 1, total length less than 150 millimeters; Group 2, total length 150 millimeters to 300 millimeters; and Group 3, total length greater than 300 millimeters. All Group 2 and Group 3 fish in good condition were marked by clipping a pectoral and/or ventral fin (Figure 4.9-29). The clipping schedule was as follows: week 1, lower pectoral; week 2, upper pectoral; week 3, lower ventral; week 4, upper ventral; and week 5, lower pectoral and lower ventral. No fish were clipped on week 7, which was strictly a recapture week. The fins were clipped with pruning shears close to the base of the fin, leaving a small section of rays to enable the fins to regenerate.

All recaptured fish were recorded by length group, and clip. During week 2, all recaptures clipped during week 1 were given a second clip on the anterior portion of the dorsal fin. Since none of these double-clipped fish were recaptured in subsequent samples, the double clip was not used for weeks 3 through 7.

After the seventh week of sampling, monitoring trawls were done until the week of June 23, 1975, at which time the study was terminated.

During the first week of sampling, an attempt was made to determine the degree of gonad development of each winter flounder caught. Less than 25 percent of the fish could be quickly classified as ripe or spent, so this portion of the study was deleted.

Each week, approximately 100 to 200 fish were measured to the nearest millimeter of total length. The measurements were used to calculate the overall average weekly lengths and the average lengths in each of the three length groups.

A study to determine the mortality rate of clipped flounder was done in Duxbury from March 21 to June 15, 1975. Three tanks were used in the study, each containing 60 winter flounder. One tank contained fish with a lower pectoral fin clip, another contained fish with an upper pectoral fin clip, and the control tank contained fish with no clips.

Similar studes to determine the mortality rate of Floy-tagged flounder were attempted in 1973 and 1974 at the Millstone Environmental Laboratory. These studies were plagued with water-supply problems and were generally inconclusive.

Two population estimate methods, Triple-Catch Trellis (Ricker, 1958) and Jolly (1965) (programmed by Davies), were used to analyze the mark-and-recapture data. Total population estimates were obtained by starting with an estimate of the initial population and then adding the total number of fish that were recruited during subsequent weeks.

The mark-and-recapture data obtained did not fit all requirements for the Jolly method. To use this method, it was assumed that no fish were recaptured more than once. In order to estimate the effect of multiple recaptures, data simulating an expected multi-recapture were analyzed. A ratio of recaptured fish to tagged fish was used to determine the simulated multiple recaptured. The data were analyzed by computer using the program outlined by Davies (1971) with a modification: the Do loop, where R(I) was defined, was changed so that the initial I value was 1 instead of 2.

The 1976 study was similar to the 1975 program except for certain specific additions or revisions.

First, the protocol was developed for the Jolly (1965) method of analysis. All fish were fin-clipped upon first capture and tagged with a spaghetti tag when recaptured the first time. This eliminated the problem of having to assume that no fish were recaptured more than once, since it was obvious when a fish bearing a spaghetti tag was recaptured. Recaptured fish possessing a spaghetti tag did not receive any additional markings.

For the 1976 study, what were Stations 3, 4, and 5 in 1975 were combined to form Station 4; and what were Stations 6 and 7 in 1975 became Station 5. The 1976 stations are shown are shown in Figure 4.9-30.

Monitoring trawls started in January, with fin-clipping trawls beginning during the first week of March. Fin-clipping was performed until the week of May 3. Monitoring trawls continued from the week of May 10 through the week of June 14. The fin-clip pattern used in 1976 was different from that used in 1975 so that the returns from each year's clipping could be distinguished from one another (Table 4.9-32).

Four length categories were established rather than the three of the previous year. They were: Group 1 - less than 150 millimeters; Group 2 - 150 millimeters to 199 millimeters; Group 3 - 200 millimeters to 299 millimeters; and Group 4 - 300 millimeters and greater. Only the flounders in Groups 2, 3, and 4 were fin-clipped.

Where possible, the sex of each fish was determined, and a portion of each week's catch over 150 millimeters was examined to determine the state of gonad development.

During the first half of the study, sampling was primarily at Stations 1 and 2. During the second half, sampling was centered on Station 6. The weekly sampling period was shortened to seven to eight hours, and did not always occur on Monday and Tuesday, as it did in 1975. However, at least four nonsampling days were allowed to elapse between each sampling period.

Two stations in Niantic Bay, 9 and 10 (Figure 4.9-30), were sampled to monitor any spawning activity that might have occurred in the northern portion of the bay.

Two fin-clip mortality studies were attempted with a group of multiple fin-clipped winter flounder, half of which were also tagged with spaghetti tags, and a control group of unclipped fish; but they failed because of mechanical or handling problems and could not be reattempted before the marking phase expired.

Results

Approximately 1,000 flounder were tagged and released in the Niantic River during February and March, 1973. An additional 1,000 were tagged and released in the greater Millstone area (but outside of the Niantic River) during April, May, and June, 1973.

Approximately 2,300 flounder were tagged and released in the Niantic River during February, March, and April, 1974. An additional 300 flounder were tagged and released from the surrounding area by July, 1974.

Estimates (Jolly method) of the instantaneous population of winter flounder in the Niantic River during the 1974 study ranged from 4,834 to over 250,000 fish (Table 4.9-33 (see Summary Report of Ecological and Hydrographic Studies, May, 1966, through December, 1974, Section 2.13).

From March 31, 1975, through the week of May 12, 1975, 10,633 winter flounder were clipped (approximately six percent to seven percent of the total population) and of those clipped, 547 (5.1 percent) fish were recaptured (Table 4.9-34).

Estimates of the instantaneous weekly populations during 1975 ranged from 33,304 to 135,122 (Tables 4.9-35 and 4.9-37). The total population of winter flounder over 150 millimeters in length in the Niantic River during the study period was over 160,000 (Tables 4.9-35 through 4.9-37 and Figure 4.9-31).

One flounder with an upper pectoral clip died after 50 days in the 1975 clip-induced mortality study. However, the wound caused by clipping was healed over and probable cause of death was starvation. All other flounder, 60 lower-pectorally clipped, 59 upper-pectorally clipped, and 60 unclipped, were alive 94 days after capture and clipping. All wounds appeared to be healed. The study was terminated after the 94th day due to water supply problems.

From the week of March 1, 1976, through the week of May 4, 1976, 10,693 winter flounder were clipped (approximately 10 percent of the total population); and of those clipped, 674 (6.3 percent) fish were recaptured (Table 4.9-38).

Estimates of instantaneous weekly populations during 1976 ranged from 23,827 to 51,381 (Table 4.9-39 and Figure 4.9-31). The total population of winter flounder over 150 millimeters in size in the Niantic River during the study period was approximately 91,394 (Table 4.9-39). The total population for the same period sampled during 1975 was approximately 63,769 or 39.8 percent of the 1975 population estimate.

The average catch per five-minute tow for the Niantic River during 1974, 1975, and 1976 showed large differences in numbers caught, but the peaks of abundance occurred at approximately the same time each year (Figure 4.9-32). The 1976 average catch per five-minute tow was compared with the average catch during 1974 and 1975 for Station 2 (1976) (Figure 4.9-33) and Station 5 (1976) (Figure 4.9-34) and during 1975 for 6, 7 and 8 (1976) (Figure 4.9-35). Stations 1 and 2 (1976) had the greatest abundance of fish during the first half of the study (spawning period); and during the second half, the upper portion of the Niantic River had the greatest abundance of fish (Figure 4.9-36). Station 6 (1976) was the major area where flounder were caught in 1976, and Station 7 (1976) was the major area in 1975. The average catch figures, other than those taken during weeks of major sampling, may be misleading since they are based on only a few tows. However, the general trends of the flounder population are probably represented.

The average size and percent composition of each size group for 1975 differed only slightly from that of 1976 (Table 4.9-40).

The sex ratio of winter flounder in 1976 was determined (Table 4.9-41). The ratio for the total study period was 1.7 (63 percent) females to each male, and the ratio for the spawning period of fish over 250 millimeters was 1.9 (66 percent) females to each male. The size range of ripe females was not determined, but it was noted that most ripe or near-ripe females were over 250 millimeters in length, which represents only 36 percent of the population.

During 1976, approximately 50,000 to 60,000 flounder were in the Niantic River during the spawning period; thus, there were approximately 12,000 to 14,000 females that spawned in the river. During 1975, approximately the same number of females spawned in or near the Niantic River.

Juvenile flounder less than 30 millimeters were found at Station 6 (1976) on May 27, 1976 and at Stations 5, 6, 7, and 8 (1976) on June 16, 1976.

Few flounder were caught on Station 9 (1976) and 10 (1976) in the Niantic Bay. An average of 2.2 fish per five-minute tow was caught over the total study period. Two peaks occurred, once during the week of March 22, 1976, (10.5 fish per five-minute tow) and once during the week of April 19, 1976, (6.5 per five-minute tow).

Discussion

Population and immigration estimates based on 1975 and 1976 mark-and-recapture data had acceptable standard errors (Tables 4.9-35, 4.9-36, and 4.9-37). The success of the 1975 study was mainly due to the large numbers of flounders examined and marked in a very short period of time. Fin-clipping and size grouping of the flounders was much more efficient than measuring, weighing, and tagging.

There were some similarities between all of the years sampled which indicated that a small amount of spawning occurred in the lower Niantic River during February.

The second cyclic peak, as demonstrated by otter trawl catches, occurred during the weeks of March 4 and March 11, 1974 (Table 4.9-33 and Figures 4.9-29 through 4.9-34, the week of March 10, 1975, (Figures 4.9-35, and the week of March 8, 1976, (Table 4.9-39 and Figures 4.9-31 through 4.9-35).

The principal spawning for 1975 and 1976 occurred in the lower Niantic River during the week of March 10, 1975, and March 8, 1976. The 1975 Niantic River spawning was preceded by spawning which occurred in the northern section of the Niantic Bay (Station 9 and 10 - 1976).

The next peak of abundance occurred during the week of April 22, 1974, (Figure 4.9-34), the week of April 21, 1975, (Tables 4.9-35 through 4.9-37 and Figures 4.9-31 through 4.9-35), and the week of April 19, 1976 (Table 4.9-39 and Figures 4.9-31 through 4.9-35). There was very little spawning in April of all three years indicating that the April peak of abundance was probably a population of feeding flounder.

During April when the feeding population was in the river, the majority of fish were caught in the shallow areas of the river (Station 3, 6, 7, and 8 - 1976). The largest April peak occurred in 1975. It may have been due to a high availability of food during that year. During 1976, the bottom areas where most of the flounder were found were covered with a thick growth of filamentous algae which may have made much of the bottom food unavailable to the flounder.

The spawning population was largest in 1974, as shown by unit-effort data in Figures 4.9-33 and 4.9-34 and population data in Table 4.9-33. The spawning population during 1975 and 1976 was very similar, as shown by the unit-effort data in Figures 4.9-32 through 4.9-34. The 1975 spawning population was slightly smaller, but this may have been due to the spawning which occurred in Niantic Bay. Niantic Bay spawning was not evident in 1976. A very small percentage of all of the fish that enter the Millstone bight are females that spawn in the Niantic River, approximately two to eight percent during 1976.

The months of the spawning period (January, February, and March) are the major periods when fish are impinged by the Millstone Nuclear Power Plant. From 1973 to 1975, 71 percent to 55 percent of the yearly totals of all impinged flounder were taken during January, February, and March. However, the effect on the spawning flounder population is probably minimal, since most of the impinged fish are less than 150 millimeters and immature. Also, during this same period the percentage of immature flounder (less than 150 millimeters) taken by otter trawls was at its highest.

Sufficient data have not been obtained to determine any annual population trend. If the size of the spawning population is cyclic, there may be another major spawning year, similar to 1974 in 1977 or 1978. The feeding population appears to be random in size and may be dependent on water temperature, food species, and vegetation present.

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4.10 Impingement Studies

4.10.1 Impingement Monitoring

Introduction

Efforts to monitor the fish and invertebrates impinged on the intake screens of Millstone Unit No. 1 began on an irregular basis in May, 1971, but were not carried out on any quantitative basis until January, 1972.

From January 1 through December 31, 1972, each organism impinged was measured separately. From January 1, 1973, through April 30, 1975, the organisms were placed in one of three length categories, but the individual measurements were not recorded. Beginning in May, 1975, the fish were all measured except when more than fifty individuals of any one species were collected. Then, only fifty were measured, but all were counted and distributed through the length catagories.

Studies of day/night differences began on July 26, 1973, when the screens began to be monitored on a 12-hour basis every Tuesday, Thursday, and Saturday. Collections on Monday, Wednesday, Friday, and Sunday were on a 24-hour basis. The day/night studies were carried out for a year, ending on July 31, 1974.

In April, 1974, counts of live organisms were begun. Daily counts of organisms impinged on the Unit No. 2 screen began in September, 1975, when that unit began operation of the circulating water pumps.

Methods and Materials

For the periods described above, all organisms washed from the Units No. 1 and 2 traveling intake screens were collected and identified. Identifications, counts and, where specified, measurements were made on a daily basis. All organisms were sorted into three length catagories: (1) 0 to 2.9 inches; (2) 3 to 5.9 inches, and (3) six inches and greater. Lobsters were grouped by carapace length, crabs by carapace width. The numbers of each species that were still alive were determined, and all organisms that were alive were released to Long Island Sound.

Results

Abundance

To date, at least 76 species of fish and 12 invertebrate species have been collected from the intake screens at the Millstone Point Nuclear Generating Station since January, 1972. Tables 4.10-1 through 4.10-4 show the numbers of each fish species impinged monthly from 1972 through 1975, respectively. Tables 4.10-5 through 4.10-8 give the same kind of information for the invertebrates over that same time period. Also shown on Tables 4.10-1 through 4.10-8 are the various length categories into which the impinged organisms were placed. Table 4.10-9 shows the total list of impinged fish species arranged in descending order of abundance for the 1972 through 1975 period, and the percent of the total made up by each species. It also shows the annual total abundance of each species from 1972 through 1975 and the number of fish impinged per day. Similar information for the invertebrates is provided in Table 4.10-10.

The species impinged most frequently over the four-year period was the winter flounder, (Pseudopleuronectes americanus). Through 1975, a total of 14,712 winter flounder were collected from the intake screens, accounting for approximately 28 percent of the 52,667 fish impinged since 1972.

Only 16 species made up 90 percent of all fish impinged since 1972. The second most abundant species was the threespine stickleback (Gasterosteus aculeatus) accounting for about seven and one-half percent of the total. The grubby (Myoxocephalus aenaeus) and the silversides, Menidia spp., each accounted for about seven percent. Four species each totaled about five percent. They were the windowpane (Scophthalmus aquosus); the cunner (Tautogolabrus adspersus); the white perch (Morone americana); and the menhaden (Brevoortia tyrannus). Tautogs (Tautoga onitis); and blueback herring (Alosa aestivalis) were ranked ninth and tenth, each accounting for about four percent. The eleventh ranked species, Merluccius bilinearis, the silver hake, accounting for about three percent of the total, was taken primarily in December, 1975.

During the four years of impingement collections, about 40,000 invertebrates were taken, with the squid, Loligo sp., accounting for about 33 percent of them (Table 4.10-10). The lady crab (Ovalipes ocellatus) was the second most abundant species, totalling 25 percent of all invertebrates. Third and fourth, each about 11 percent of the total, were the lobster, (Homarus americanus) and the blue crab (Callinectes sapidus).

Day Versus Night Differences

The numbers of fish and invertebrates taken off the screens during the day were compared to figures from night collections for a year beginning in late July, 1973. The results of the day/night collections of fish are shown in Table 4.10-11 and for invertebrates in Table 4.10-12. In both cases, the night collections were significantly higher than the day collections.

When the ratios of the day to night collections were plotted (Figure 4.10-1), no seasonal differences were seen for fish except that the collections were most similar in October, 1973, and least similar in May, 1974. Invertebrates, on the other hand, seemed to show a seasonal pattern, with day and night collections being most similar in the winter, especially in February, 1974. As with the fish, the collections of invertebrates differed most in May, 1974.

Seasonality of Impingement

The patterns of impingement of the five most abundant fish species were plotted in Figure 4.10-2, along with the pattern for menhaden. In most cases there were indications of seasonal variation. Winter flounder are impinged more in the winter than in the summer. This is also true of the sticklebacks (G. aculeatus) which were rarely impinged in the summer. Grubbies (M. aenaeus) also showed winter peaks of impingement, with the fewest usually being taken in the late summer and early fall. Silversides, Menidia spp., were interesting in that they were impinged at about the same levels for most of the year, showing sharp depressions in the numbers collected in later summer and early fall. The windowpane (S. aquosus) showed no apparent seasonality, with only a few exceptions where none were collected. Menhaden (B. tyrannus) were usually impinged least during the spring and summer, except for the summer of 1973, when the greatest number were collected.

Figure 4.10-3 shows the impingement patterns of lobsters (H. americanus) and blue crabs (C. sapidus). Fewer lobsters were impinged in January and February than at other times of the year. Blue crabs showed marked seasonality, with none being impinged in the coldest months.

Seasonality of Survival

When the numbers of live individuals released at the time of the daily monitoring counts were compared to the total number of individuals of each species impinged, there were some interesting results. Table 4.10-13 shows the monthly number of survivors of each of the five most abundant fish species impinged on the Unit No. 1 intake screen during 1975, and Table 4.10-14 gives the similar information for the invertebrates.

In general, invertebrates survived much better than the fish. There were relatively few deaths among the crabs, and slightly less survival among the lobsters. The squid, Loligo sp., the most abundant invertebrate, showed relatively poor survival.

In contrast to the good invertebrate survival, fish did not survive well. Of the five most abundant fish species impinged on the Unit No. 1 intake screen in 1975, the winter flounder (P. americanus) had the best survival rate, and the silversides, Menidia spp., the worst.

When the proportion of survivors to total impinged winter flounder was plotted, a seasonality to survival was evident.

Figure 4.10-4, the observed and fitted patterns of winter flounder survival, indicates that survival is least in the warmer summer months.

The pattern of survival is not as clear with the lobster (H. americanus). Figure 4.10-5 shows the pattern of survival of lobsters impinged on the Unit No. 1 intake screen during 1975. It would appear as if there is no definite seasonality; however, when confidence intervals were constructed to compare the differences between two pairs of seasonal (viz., spring, summer, winter, fall) proportions using a normal approximation to the binomial, the 95 percent confidence interval indicated that survival was significantly greater in the spring and fall than in the summer and winter.

Relationship of Numbers Impinged to Area Populations

Winter flounder

Estimates of the standing population of winter flounder in the greater Millstone Point area were made for each month from April, 1973, through December, 1975, and were reported in Section 4.9.3 (Otter Trawl Studies). These estimates were compared with the actual number of winter flounder impinged during each of the months, and the results of the comparison are shown in Table 4.10-15. Only three times did the number impinged exceed one percent of the estimated area population--in April, 1973, and January and February, 1974. The mean monthly percentage never reached one percent being 0.7 percent in 1973, 0.9 percent in 1974, and 0.3 percent in 1975 when both intake units were operational for the final four months of the year.

Lobster

Estimates of lobster populations for the months of May, 1974 through May, 1975, and October through December, 1975, were made in Section 4.6 (Lobster Population Studies). These estimates are compared in Table 4.10-16 with the actual number of lobsters impinged during those same months. Because of a change in the mark-and-recapture program, no estimates of the lobster populations are available for June through September; however, it is felt that the estimates for October through December are more reliable than earlier estimates. It should be pointed out that those figures represent estimates of only those lobsters with a carapace length of 55 millimeters or greater.

The results of the comparisons show an average of 10 percent of the estimated population of lobsters over 55 millimeters carapace length was impinged in 1974 and an average of 4.8 percent in 1975. The 1974 average is inflated somewhat by the May and June percentages based on estimated populations of 520 and 846 lobsters in the greater Millstone Point area during those months, respectively. The estimates were the first two made from the original mark-and-recapture method and were considered to be too low.

Relationship of Impinged Species to Commercial Catch

Not enough data were available to compare fish impinged from 1972 through 1975 with Long Island Sound commercial landings during that period since Connecticut stopped supplying these data to the National Marine Fisheries Service in 1972. The Connecticut Department of Environmental Protection was able to supply some figures for commercial fish landings in eastern Long Island Sound for 1972 and 1973, and lobster landings for 1972 through 1975. Table 4.10-17 shows the poundage of selected species landed during 1972 and 1973 compared with the numbers impinged during those years. In 1972, only 5 commercial fish species were impinged; and in 1973, 10 commercial species were collected from the intake screens. Only winter flounder and menhaden were impinged in any sizable amount either year.

The number of lobsters impinged each year from 1972 through 1975 was compared with the landings in pounds from eastern Long Island Sound for those years (Table 4.10-18). The number of pounds landed increased considerably from 1972 through 1975, whereas the number of lobsters impinged fluctuated. The fewest number were impinged in 1975, the year with the largest commercial landings.

Discussion

Except for winter flounder, the fish species most frequently impinged appear to be those of a rocky shore-zone community. Sticklebacks, grubbies, silversides, cunners, tautogs, toadfish, pipefish, and young anchovies made up 37 percent of the total community impinged since 1972. Winter flounder and windowpane comprised 33 percent; white perch, menhaden, and blueback herring represented about 14 percent.

Approximately 65 other species comprised the additional 16 percent of the total fish impinged. Many of the 65 species are common to the area, and are collected frequently in other sampling programs. It would appear, therefore, that the intakes are not necessarily impacting on the general fish community around Millstone Point.

Young squid and lady crabs totalled 58 percent of all invertebrate species collected from the intake screens since 1972. Lobsters and blue crabs together comprised 22 percent of the invertebrate total.

From the studies conducted in 1973 and 1974, it would appear that most of the organisms impinged were trapped at night. The reasons for this are not clear. There were lights in the intake area, and perhaps those attracted some species, with others coming in to feed on them. It is also possible that the lights were not sufficient to illuminate the area enough for the organisms to see and avoid the intake structures.

As expected, impingement for most species was seasonal, with greater numbers being impinged when the organisms are most abundant in the area. The silversides were somewhat of an exception in that they, being year-round residents, were impinged at about the same level year-round except for sharp drops in numbers impinged in the late summer or early fall. The period of hiatus did not last long, however, and impingement levels rose sharply following it.

In general, invertebrates survived impingement better than the fish, with most of the arthropods being almost totally unharmed. Lobsters showed a definite seasonality in their survival patterns, more surviving in the spring and fall then in the summer and winter. Summer deaths could be attributed to weakened or vulnerable conditions following molting.

Winter flounder also showed marked seasonal patterns of survival with least surviving in the summer.

A small percentage of commercial species are impinged. Winter flounder and menhaden were the most abundant commercial fish and blue crabs and lobsters the most abundant commercial shellfish impinged. There were not sufficient data on the commercial fish landings to make good comparisons of impingement to commercial catches. Lobster impingement, however, was not correlated with commercial landings, which showed an increase over the four-year study period. The fewest lobsters were impinged in 1975, with a two-unit operation for one-third of the year, while that was the year of the greatest landings.

4.10.2 Deterrent Devices

Introduction

During the last few years there has been a great deal of effort devoted to impingement/entrapment studies. Such investigations have centered on the behavioral responses of impinged organisms as well as the design and operational features of thermal power plants. Most recently documentation of impingement studies has been provided by Jensen (1974) and Sonnichsen et al., (1975). Concepts being investigated as means to reduce impingement losses include intake location, approach velocities, variations to conventional traveling screens, physical barriers, attractive or avoidance stimuli and fish handling devices.

Sonnichsen et al., conclude the various designs being constructed and tested today rely primarily upon the use of physical screens of one form or another to reduce impingement. Two screens presently being developed which show promise are: 1) the continuously rotating vertical screen with a dual wash system, and 2) the horizontal traveling screen. The continuously rotating vertical screen has been incorporated into the design for Millstone Unit 3. Added features which include modified screen fish buckets and fish handling facilities are described in Section 3.

Throughout the design, construction and operation of Millstone Nuclear Power Station consideration has been given to impact on marine organisms that results from impingement (Section 3). While it is felt the intake structures in service at Units 1 and 2 along with the intake being constructed for Unit 3 represent the best available technology for minimizing environmental impact, additional measures have been undertaken in an attempt to further reduce impingement losses. This section details these efforts.

Surface Fish Diversion Device

In late August 1971, an estimated 50 million juvenile menhaden and blueback herring were impinged and/or entrained at Millstone Unit 1. Subsequent analysis of catch information from shore-zone seines indicates the abnormal impingement loss was associated with a corresponding abundance in Long Island Sound during that year (Section 4.9.1). In order to help preclude a recurrence of this event a floating surface fish diversion device was installed in 1972.

Several designs were evaluated before settling on a modified oil slick boom. This device is made of heavy rubber and extends from the surface where it is buoyed to a depth of approximately four and one-half feet. The boom is attached to each end of the intake structure face with the center of the boom extending out from the intake about 100 feet forming an isosoles triangle.

Effectiveness of the surface fish diversion device was to be evaluated by comparing year-to-year abundance of juvenile mehaden in shore-zone seine catches with impingement losses during the same period (1971-1975, Table 4.10-19). However, these data are not easily interpreted because of the extreme variations. More than anything else the data do indicate the randomness of impingement. In 1972, 179 juvenile menhaden were seined and none were impinged. In 1973, none were seined and 1,229 were impinged. Given this randomness one would have expected more impingement than has occurred since installation of the surface barrier. Additional operating experience will be required to adequately support such a conclusion.

One notable observation which should be made from the data given in Table 4.10-19 is the relative impact of impingement since installation of the surface barrier. In 1970, a total of 1275 junevile menhaden were caught in the seine hauls taken at Bay Point at one sampling. The maximum number impinged in any one year was 1229 in 1973.

Fish Deterring Net Panels

Since the utility of the surface fish diversion device is still under investigation, an additional scheme was developed which would be employed in the event of an occurrence similar to that in 1971 when the abnormally large number of juvenile menhaden and blueback herring were impinged.

Nylon net panels twenty feet wide by thirty feet deep were fabricated from 1/4" - square mesh seine material. These were outfitted with snap hooks along the top which is supported by polypropalene rope. Chain is tied along the bottom for weight. During an emergency these panels would be strung along a taut steel cable outboard of the intake structures to provide an impenetrable barrier to fish. As nets become clogged, they will be payed along the cable and removed as clean panels are attached on the opposite end of the cable.

It is not felt that these net panels would be appropriate during normal power plant operation since the rate of clogging even during routine conditions would require that the nets receive constant cleaning and replacement.

Benthic Fish Diversion Device

The use of a barrier as a means of diverting species that move along or near the bottom is presently being investigated at Millstone Unit 1. The design is similar to the surface fish diversion device also installed at Unit 1. It consists of a rubber curtain wall anchored to the bottom and supported in a vertical position by floatation along with verticle pipes anchored in concrete (Figure 4.10-6). Continuity of the barrier is maintained along the side slopes with fence material.

It is anticipated that the benthic fish diversion device will be evaluated by comparing numbers of bottom oriented organisms impinged at Unit 1 with those impinged at Unit 2 over the year 1976. Analyses will key on certain benthic species such as winter flounder and american lobster which are important commercially and recreationally and which constitute a large relative percentage of the impinged organisms.

Electric Fish Screen

In 1973 a study was initiated at the University of Rhode Island to evaluate the feasibility of an electrified guidance device that could be used in the marine environment and would prevent fish and crustaceans from being entrapped.

Studies were conducted in continuously flowing once-through electrified maze tanks in which both lobster and winter flounder could be studied. Preliminary results indicated that some lobsters respond to rectified alternating current. A comprehensive program was continued using several types of waveforms and bottom electrode configurations to determine the comparative threshold level and blocking effectiveness of various electrical combinations. Conclusions drawn from these laboratory studies indicated that different electrical parameters would be required for fish than for crustacea and would complicated overall barrier design.

The final field design included large continuous duty equipment and consisted of nine vertical electrodes mounted in front of the existing discharge racks in two rows to create a rotating field of quarter wave pulses supplied by a bank of four three-phase transformers and 12 silicon controlled rectifiers. The electrode configuration would concentrate the field well in front of the gratings.

An evaluation was made on the safety aspects of such an installation and it was concluded that hazardous voltages appear at all points within the electrode array. These voltages could be lethal in the event of human contact. Calculations indicate that maximum (peak) voltages would be 170 volts between any pair of electrodes and 680 volts across the whole structure.

Because of power requirements and associated safety hazard it was concluded that such an electrical device in salt water is not feasible.

Acoustic Stimuli

Use of acoustic stimuli has been suggested as a method to reduce fish impingement at the intake structures of operating power plants. This section examines the available literature on use of sound to deter fish and reports the results of tests made at Millstone where an electric sparker was used.

Much of the literature on response of fish to accoustic stimuli deals with salmonids and only one report documents the use of sound to deter fish at a thermal power plant. Burner and Moore (1962) exposed rainbow and brown trout to low frequency sounds between 67 cycles per second (C.P.S. = hertz (hz)) and 70,000 c.p.s. at intensities up to 82 db re one microbar. Moore and Newman (1958) exposed juvenile salmonids to frequencies between 50 c.p.s. and 20,000 c.p.s. at intensities up to 7,200 dynes/cm^2. The authors concluded there was no significant response to sound, except for an initial "start" reaction at the lower frequencies.

Vanderwalker (1967) attempted to guide steelhead trout migrating downstream by using a sound barrier. The study was conducted in an eastern Oregon irrigation canal. Using air-driven vibrators mounted vertically and parallel to the flow of water and driven at 270 c.p.s., fish were successfully guided into a bypass. It was not clear, however, whether the fishes' response was to pressure waves, low frequency sound, or related phenomenon such as water displacement. Following the field study, several laboratory studies were conducted to determine the frequency ranges in which juvenile chinook salmon would respond and to describe the characteristics of the response. In Phase I studies, Vanderwalker observed two types of responses. In the first response type, fish showed a loss of equilibrium at frequencies of 30, 60 and 180 c.p.s. with a 3 g acceleration. Loss of equilibrium was interrupted by short period of erratic swimming. The second type of response was described an an escape action, characterized by rapid swimming around the tank. This response was most pronounced at 70 and 88 c.p.s., at an acceleration of 3 to 5 g.

In Vanderwalker's Phase II studies, fish were exposed to a range of sound up to 280 c.p.s. Fish responded to the sound source by moving away from it. The greatest distance they moved away from the source was 2 ft., indicating a near-field displacement. Fish remained out of the evacuated areas for up to 60 seconds. Fish did not become less sensitive to repeated exposune to the reference frequencies.

Stober (1969) tested the response of cutthroat trout to low frequency sound, using both conditioned and unconditioned responses. Like Vanderwalker, he found that fish respond without conditioning to low frequencies (a natural startle reaction); but, unlike Vanderwalker, Stober found that the salmonids became less sensitive (habituated) with repeated exposure to the sound source.

Schuler and Larson (1974) explored the use of sound to repel fish at the Long Beach Generating Station. Black perch, shiner perch, kelp surfperch, queenfish, and northern anchovy living in the forebay were exposed to rock music, a killer whale tape, and a range of frequencies from 20-15,000 c.p.s. No fear reaction was observed. Fish also did not respond to a tape playback of the sound of a car horn, metal, or the striking of a mallet on wooden planks.

An underwater pneumatic impact device (popper) which creates an underwater shock wave was tested and found to elicit a fear reaction in fish under certain conditions (Schuler and Larson, 1974). When the popper was cycled continuously, most fish avoided the immediate vicinity by at least 10 ft. Fish in open areas reacted more dramatically than did fish in the forebay, where the popper was located. Generally, they fled open areas and hovered closed to underwater structures.

The popper was also tested at the Redondo Beach Generating Station intake structure. The popper was placed at the opening of the structure, midway between the velocity cap and top of the riser bowl. Upon activation, all fish located within approximately 12 ft. left the immediate vicinity. Those located on the other three sides of the structure showed no reaction. After approximately 3 hr., with the device operating continuously, a few surfperches were observed 5-8 ft. from the device. No fish were observed swimming in the opening in which the popper was operating. Further testing is planned to determine the effectiveness of the popper under continuous operation.

A number of researchers have attempted to attract fish using sound. Richards (1968) tested the effectiveness of pulsed low-frequency acoustic signals for attracting fish. The acoustic signals were contrived to simulate the hydrodynamically generated disturbances normally associated with active predation. Demersal predatory fishes were successfully attracted, although they habituated rapidly to the acoustic stimulus. Members of the families Serranidae (grouper), Lutjanidae (snapper), and

Pomadasyidae (margate, grunts) were particularly well represented among the fishes attracted. Sharks were also attracted in large numbers. Herbivorous reef fishes were not attracted.

Maniwa (1970) successfully lured fish schools of various species using recorded sounds. It was determined that fish are attracted to the sounds of their own species eating bait. Sound was successful in luring carp, yellowtails, mackerel, and jack mackerel. In addition, recorded sounds of dolphins successfully drove barracuda, mackerel, and jack markerel into a stationary net.

Conclusions based on results of the above research are equivocal. In a few studies, fish have been deterred, guided, or attracted by acoustic signals. Unfortunately, fish have not responded consistently to acoustic stimuli. Under field conditions, no conclusive avoidance response to sound has been observed. Schuler and Larson's experiments with the popper, although demonstrating future potential, are qualitative and incomplete.

At Millstone a sparker type of geophysical sounding device was tested. Initially the sparker was energized in the Millstone Quary in order to determine its acoustical characteristics. The power source was a truck mounted capacitor discharge system connected to a 220 volt outside power source. A hydrophone was placed in the water at a set distance so that sound pressure and dB levels could be determined at various power levels. Measurements indicated the noise level produced by a maximum sound input of 2000 volts to the sparker was 130 dB.

Behavioral response of winter flounder to the sparker was observed by placing 35 individuals varying in length from 6 to 15 inches in a net coverage cage and energizing the sparker at distances of 15 feet and less. Flounder were allowed to acclimate in the cage for several days prior to the test.

Results indicate that regardless of power level or distance thar was no visible response. Based upon these results no future experimentation has been planned.

<u>Underwater Lights</u>

Response of organisms to light is a well known phenomena. Organisms may be photopositive or photonegative or either depending upon their accustomed day-night cycle. It was felt in the case of Millstone Nuclear Power Station that perhaps the increased rate of impingement during the dark hours results from the lack of visual cues fish and shellfish would otherwise use in avoiding the intake structure. Illumination of the Unit 1 intake as a means of deterring fish was therefore considered.

Ten 1,000 watt lights were mounted on the Unit 1 trash racks approximately four feet from the ocean bottom, with two lights per intake bay. The lights were positioned to illuminate the bottom area immediately in front of the trash racks.

Starting August 1, the lights were operated on a two-day-on, two-day-off schedule from 6 p.m. to 6 a.m. The experiment was terminated on August 29. In the absence of a control location (which Millstone Unit 2 will provide when in operation), contiguous days were partitioned into four day periods for analysis purposes as follows:

Period	Day in August
1	1-4
2	5-8
3	9-12
4	13-16
5	17-20
6	21-24
7	25-28

On each sampling date the following information was recorded: time period, water temperature at the intake at 8 a.m., lights on or off, and the number of organisms impinged by species.

The following model was used to analyze the data:

$$Y_{ijk} = \mu + \pi_i + \lambda_j + \alpha\tau_a + \beta\tau_b + p + \varepsilon_{ijk}$$

where:

Y_{ijk} = number of impinged organisms in i-th period exposed to j-th light level and k-th level of residual effect

μ = overall average response

π_i = i-th period effect, i = 1, ..., 7

λ_j = effect of j-th level of light, j = 1, 2

τ_a = water temperature morning after sample

τ_b = water temperature morning after sample

ρ_k = residual effect of k-th level of light, k = 1, 2

ε_{ijk} = normally distributed random error with zero mean and unknown standard deviation. Errors are assumed to be uncorrelated.

α = unknown parameters allowing for linear effects of water temperature covariates.

In an attempt to stabilize the variances of the ε's the y's were transformed using the following transformations:

Transformation 1: $y^* = 10g\ (y + 1)$

Transformation 2: $y^* = (y + 1)^{1/2}$

Separate analyses were performed for each set of transformed observations. The hypotehsis tested in each instance was that of no light effect, i.e., $H. : \lambda_j = \rho_k = 0$; j=1, 2; k=1,2. Blue crabs, lady crabs, and squid were the only species abundant enough during the sampling period to permit meaningful analysis. Using the above model with transformed y's, an analysis of covariance was performed separately for each species. The results of these analyses are presented below.

Species	Transformation	F-value	Prob. of greater F under H
Blue crabs	1	0.21	0.81
	2	0.41	0.67
Lady crabs	1	0.92	0.41
	2	0.54	0.59
Squid	1	0.15	0.86
	2	0.05	0.95

The results indicate no significant light effect for these three species under conditions the experiment was performed under. The lights may be effective under different conditions (e.g., season, temperature) and for other species during periods when they are in greater abundance in the Millstone Bight. Further experimentation will be conducted under varying conditions with Millstone Unit 2 as a control site in an attempt to more thoroughly assess the effectiveness of underwater lights.

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4.11 Entrainment Studies

4.11.1 Introduction

Studies of entrained planktonic organisms in the cooling waters of operating units at Millstone have been carried out continuously since 1970. These have been reported in seven semi-annual and one summary report by Carpenter of Woods Hole Oceanographic Institution and in one annual report by Normandeau Associates, Inc. (Fontneau, 1976). Since phytoplankton, zooplankton, and ichthyoplankton can be assumed to be entrained in proportion to their abundance in the cooling water source area, namely Niantic Bay and adjacent waters, entrainment data provide important population information concerning species composition, temporal and spatial abundance and the normal fluctuations of abundance from year to year (Figure 4.11-1). Numerical estimates of phytoplankton, zooplankton, and ichthyoplankton entrained and some discussion of the impact of entrainment to the local ecosystem have been made and will be presented in a subsequent section (5.3).

The mortality caused by passage through the Millstone plant has been examined by collecting samples at the intake, discharge, and quarry cut (Figure 4.11-2). The effect of chlorination and temperature rise on the productivity of entrained phytoplankton was studied and chlorination was found to be a major source of phytoplankton mortality (Carpenter, Peck and Anderson, 1972). The survival of entrained copepods was investigated at different points on passage through the plant using visual live-dead experiments and a neutral red vital stain technique; only 30% survived entrainment (Carpenter, Peck and Anderson, 1974). Carpenter (1975) has presented preliminary results on the temperature tolerance and aspects of the initial and latent mortality of fish larvae after entrainment, showing mortalities approaching 100% due to combined mechanical chlorination and temperature effects. In addition to these entrainment studies, there have been extensive ecological monitoring programs carried out by Clapp-Battelle Laboratories described fully in Section 4.8 and computer simulation model of the impact of entrainment of winter flounder larvae on the Niantic River winter flounder population (Hess, Sissenwine and Saila, 1975).

To compare the entrained plankton community at Millstone to that of wider areas of Long Island Sound, data from several investigators at Millstone and other local sources will be discussed. In these comparisons, species composition, temporal abundance, and spatial abundance will be examined. The extent of the source area for entrained plankton could be an important consideration in evaluating entrainment impact.

Because evaluation of the location of intake structures, designation of important and representative species of entrained holoplankton and meroplankton, and demonstration of their ability to perpetuate local populations require local or site specific data, the following section will report on the species abundance of phytoplankton over almost two years, of zooplankton for over three years, and of ichthyoplankton for almost three years. For phytoplankton, zooplankton, and ichthyoplankton, the major features of annual cycles of selected species will be summarized and some aspects of their distribution and population behavior examined. This same data base will be used to make simple volumetric estimates of the numbers of phytoplankton, zooplankton, and ichthyoplankton entrained. Some of the functional relationships of these trophic groups as they pertain to the potential population response to entrainment losses will also be discussed.

4.11.2 Materials and Methods

Phytoplankton

From September 1970 through July 1971, one-liter water bottle samples were collected from the surface, seaward of Unit 1 Intake (Carpenter, 1971; Carpenter et al., 1971). Each biweekly sample was preserved in Lugol's Iodine solution which avoids damage to flagellates and fragile nannoplankton. After settling the raw sample and concentrating to a volume of ten ml, the Utermöhl inverted microscope -- settling chamber technique (Utermöhl, 1958) was used to subsample, count and identify phytoplankton species. A minimum of 200 cells were counted and identified to lowest practical taxon.

From late April 1975 through May 1975, two-liter water samples were collected weekly from the surface at Unit 1 or 2 Discharge alternately. April, May, and June samples were preserved in 4% formalin buffered with sodium borate. After July 1975 phytoplankton samples were preserved initially with Lugol's Iodine, allowed to settle at least 48 hours, reduced to a final volume of 33 ml, and represerved in 4% formalin buffered with hexamine. It was found that subsampling using a 0.1 ml Palmer-Maloney counting cell (Palmer and Maloney, 1954) at 400x was not sufficient to characterize the numbers for rarer taxa, especially of the larger-sized phytoplankton. So in addition, two replicate 1.0 ml fillings of a Sedgewick-Rafter counting chamber were examined at 125x and phytoplankton cells were counted and identified. Depending on the abundance of each taxon, a different subsampling area was examined according to the scheme presented by Jackson and Williams (1962).

Zooplankton (excluding fish eggs and larvae)

The first zooplankton samples at Millstone were collected biweekly using a 0.5 m diameter 333μm mesh net. One daytime and one night sample was taken on each date. The net was lowered by a pulley system into the slight intake current (10 to 15 cm/sec) at the approach of the Unit 1 Intake (Figure 4.11-2). The volume filtered through this plankton net was estimated from revolutions of a TSK flowmeter. The performance of this flowmeter was judged better than a General Oceanics Model 2030 flowmeter although varying by as much as 40% at these low intake current velocities (Sissenwine et al., 1974). Each day or night zooplankton sample was preserved in 6% formalin buffered to neutrality with sodium borate. In the laboratory, these samples were subsampled with a Folsom-type plankton splitter and zooplankters in that fraction identified to lowest practical taxon. These methods were used from November 1970 to November 1971 (Carpenter, 1971; Carpenter et al., 1971).

In November 1973, the zooplankton field collection methods were modified and a second annual cycle was investigated (Carpenter et al., 1973; Carpenter, 1974). During this program, a 0.5 m diameter, 202μm mesh net was paired with the existing 333μm mesh net. Day and night samples were collected biweekly at the intake of Unit 1 until July 1975. In the period from about January 15, 1974 through October 15, 1974, a General Oceanics Model 2030 or GO flowmeter was substituted for the standard TSK flowmeter. Because these GO flowmeters were found to respond sluggishly at current velocities below 63 cm/sec (Sissenwine et al., 1974), the zooplankton data for the intake (with flows 10-15 cm/sec) during this period was probably overestimated. The GO flowmeter may have underestimated the volume filtered and resulted in an overestimate of plankton abundance. Laboratory processing of these zooplankton samples included splitting to practical aliquot size and species identification and counts as described earlier. Since most of the previous and ongoing zooplankton samples were gathered with a 333μm mesh net and there had been slightly more zooplankton caught at night (Carpenter et al., 1972b), the remaining WHOI 333μm mesh night samples for alternate weeks were chosen for analysis rather than the remainder of the day 333μm and the day or night 202μm samples (Fontneau, 1976).

In order to avoid some of the potential zooplankton sampling problems at the intake, namely, net avoidance, net clogging, inaccuracy of volume measurements, and small-scale patchy distribution of plankton, zooplankton samples after July 1, 1975 have been collected with larger, 1.0 m diameter, 333μm mesh nets positioned at the discharges of either Unit 1 or 2. The discharge weir was judged to present a more representative and quantitative estimate of the numbers and types of zooplankton entrained than a single subsurface sample at the intake (Fontneau, 1976). Also, the response of TSK and GO flowmeters would be considerably better with the increased velocities (up to about 200 cm/sec) at the discharges. Any potential problem of active avoidance such as that observed by Clutter and Anraku (1968) or Singarajah (1969) would be virtually eliminated with the larger net and approach velocity.

As part of a new ichthyoplankton sampling program, 18 weekly zooplankton samples during July and August 1975 were collected alongside of the Unit 1 discharge with the 1m diameter, 333μm mesh net and TSK flowmeter. Of these eighteen, one day and one night sample were chosen for analysis of zooplankton abundance and dry weight biomass. Abundance estimates and identification were accomplished from subsamples with a minimum of 300 zooplankters examined. Dry weight biomass estimates were made on one-half aliquots of the selected zooplankton samples. After several washings with distilled water, the zooplankton were filtered off and placed into preweighed vessels, dried at 60°C for 24 hours and the contents weighed to the nearest milligram.

In an attempt to increase the accuracy of measurements of volume filtered and to examine any effect of net clogging, NAI designed an alternative sampling gear for the discharge consisting of plankton nets fitted with modified Bendix Q-series ducted current meter sensors inside and outside and gantry deployment frame to position these nets directly in the area of greatest flow (Figure 4.11-3). An electronic readout box was constructed which gave instantaneous velocity (m/sec) for both inside and outside meters. Another circuit converted velocity signals over time directly to predicted volume filtered (m^3) versus time for both meters on a dual-channel Rustrak recorder. Clogging would be observed if present as a change in slope of the trace of volume accumulated in time given by the inside meter. A change in the average velocity field would change both the inside and outside slopes proportionally. Detailed specifications and calibrations of this zooplankton sampling gear were described in Fontneau (1976). Besides offering instantaneous volume measurements in the field, any effect of net clogging on the quality of the tow could be observed and corrective actions taken while on station.

Although the nets used for July and August 1975 zooplankton samples at the discharge were identical (1.0 meter diameter, 333μm mesh net, 3.6 m long) to those used for this alternative sampling gear, a study between the two methods were conducted in September 1975 to establish whether both abundance estimates at the discharge were comparable. On each of three day and three nights each week, triplicate sequential tows were taken at the discharge of Unit 1 using the new gantry system (Figure 4.11-3) and the 1 m diameter net. Ultimately all 18 weekly samples for each method would be processed for ichthyoplankton. One day and one night replicate for each date sampled was aliquoted for zooplankton counts, identification, and dry weight biomass.

Zooplankton samples have been collected using the NAI alternative sampling gear since September 1975 (Fontneau, 1976). Zooplankton abundance and dry weight biomass were estimated each week using one day and one night replicate and alternating when possible from the Unit 1 to the Unit 2 discharge. Aliquots for enumeration, identifications and dry weight biomass were processed as described earlier after each sample had been sorted for fish eggs and larvae.

Ichthyoplankton

All fish larvae and eggs prior to March 1973 were sorted from the 0.5 m, 333μm mesh net tows used to estimate the abundance of larger zooplankton. Because of the low approach velocities (10-15 cm/sec) in front of the Unit 1 intake and the small diameter of this net, avoidance was judged to be a problem in any comparison of the resulting data (Sissenwine et al., 1974; Fontneau, 1976). These data will not be included in the present report but are available in Carpenter et al., (1972a; 1972b).

New sampling methodology was introduced in April 1973 to reduce potential avoidance (Carpenter, 1973). An unbridled, 1.0 m diameter, 333μm mesh net, 3.6 m long was deployed from a pulley system about four meters outside the coarse bar racks of Unit 1 intake. This net was used to obtain passive tows at depths of 1, 3 and 5 meters in the intake current (Figure 4.11-2). Samples were also collected at a depth of one meter on the edge of the discharge from Unit 1 and in the turbulent flow seaward of the fish barrier at the quarry cut. Three day and three night replicates were collected weekly from April 3, 1973 until July 1, 1975 at each of the five stations (Intake 1, 3 and 5 meters, Discharge, and Quarry Cut). A TSK flowmeter was used to estimate volume filtered except in the period from January 22, 1974 through October 7, 1974 when a GO flowmeter was used. Volume measurements using GO flowmeters at the intake stations were probably underestimated because of poor response at low approach velocities (Fontneau, 1976).

Ichthyoplankton samples were preserved in 6% formalin neutralized with sodium borate. Samples were then presorted to remove large macroalgae and debris. Channelled clear plastic trays were used to sort fish eggs and larvae from the zooplankton manually under the dissecting microscope. Tentative egg identifications were made through July 1974 using the sparse existing literature and original observations (S.J. Anderson). Larvae were identified by experienced personnel using either separate taxonomic papers or compiled keys like Colton and Marak (1969), Bigelow and Schroeder (1953), Scotton et al. (1973) and Lippson and Moran (1974). An extensive comparability study on ichthyoplankton sorting techniques used by WHOI and Clapp-Battelle at Millstone has shown that the methodology of these two groups was comparable (Sissenwine et al., 1974).

In July 1975 ichthyoplankton sampling frequency was increased to three day and three night replicate tows for each of three days a week. Also, the location for the most representative sample of the number of zooplankton and ichthyoplankton entrained was changed to the discharge. During July and August 1975, the 1 m diameter, 333μm mesh sampling nets and raft were used to collect the 18 samples per week for ichthyoplankton. One day and one night replicate of these was chosen for zooplankton and dry weight analysis.

The alternative sampling method using the plankton net with current meter sensors (Figure 4.11-3) was compared with the 1 m diameter, 333μm mesh net method in September 1975. Since several statistical tests could not detect a significant difference between abundance of eggs or larvae estimated by the two methods, the results obtained from discharge samples taken during past ichthyoplankton programs were considered to be comparable with those of the continuing study (Fontneau, 1976).

Eighteen samples each week have been collected at the discharge since September 1975. Samples were preserved in 6% formalin neutralized with sodium borate. Samples were then sorted whole or in aliquots containing a minimum of 100 larvae and 150-200 eggs. Since the same personnel have processed these ichthyoplankton samples, continuity of identification procedures has been assured. More difficult larval identifications were sent to outside experts for confirmation. Under the NAI quality control program a minimum of 5% of all ichthyoplankton samples were resorted and identified. Sample and data accountability were assured through use of field card number, sample control log, identification sheets and final computer coding forms.

4.11-3 Results and Discussion

Phytoplankton

Table 4.11-1 shows the total phytoplankton species list found by Carpenter (1971), Carpenter et al. (1971) and the present program. Of the 128 taxa, 40 are new additions to the list. Diatoms dominate the list with 88 taxa, 36 of which were added in the period from April 1975 through May 1976. Dinoflagellates (with 16 taxa) are of minor importance on this list as are green algae (6 species) and cryptomonads (5 species). Nuzzi (1973) at Shoreham, Long Island, found a total of 130 species, including 72 diatoms, very similar to those found at Millstone. He also found that dinoflagellates tended to be more abundant in summer in the western basin of Long Island Sound while diatoms were dominant in the eastern narrows. In New Haven Harbor, 67 out of a total 105 species were diatoms; these accounted for 77% of the annual average abundance while dinoflagellates accounted for only 1.6% (NAI, 1976). Carpenter et al. (1971) also found a diatom-dominated phytoplankton community at Millstone Unit 1 intake, with 35 diatoms of 53 total species. He found that dinoflagellates were numerically unimportant in intake samples. Since Marshall and Wheeler (1965) had found very high densities of dinoflagellates and chrysophyceans combined in the Niantic River rather than the ubiquitous diatom flora found in Niantic Bay and Long Island Sound, Carpenter et al. (1971) concluded that little of the Niantic River estuary water reached the intake structure. Although this shallow estuary probably has the retentional and growth characteristics to allow significant dinoflagellate and chrysophycean blooms, the dominance of dinoflagellates plus chrysophyceans found by Marshall and Wheeler (1965) may be partially an artifact of different sampling or choice of data category, including dominant chrysophyceans with the dinoflagellates.

Figure 4.11-4 shows the variation found in phytoplankton abundance biweekly from April 30, 1975 to April 28, 1976 and from September 15, 1970 through June 7, 1971. Although it appears that for the months where comparison can be made, Carpenter (1971) found higher concentrations of phytoplankton, this difference may be a consequence of different station location or different year. The earlier study collected surface samples at the intake while the present study sampled phytoplankton at the discharge. Since phytoplankton are frequently present in a vertical gradient with a maximum near the surface and since the intake may draw from the entire water column, any near-surface maximum abundance of phytoplankton would be diluted by bottom water as the cooling waters are mixed and passed through the plant to the discharge.

Perhaps because of the formalin representation step, NAI did not find the two cryptomonad flagellates, Rhodomonas minuta and R. amphioxeia which were numerically dominant in autumn or early winter in 1971 (Carpenter, 1971). Normal year to year fluctuations in abundance or difference in counting chamber techniques may also account for some of the observed difference which is especially apparent during the winter months. The summer maximum phytoplankton abundance of about 2.5×10^6 cells/liter found by Carpenter et al (1971) in early June 1971 agrees favorably with the present study where density was $2-3 \times 10^6$ cells/liter in July.

The seasonal phytoplankton cycle showed two major peaks of abundance (Figure 4.11-4). A strong July peak of as many as 3×10^6 cells/liter was the most important bloom of the annual cycle. Except for a mid-September peak of about 4×10^5 cells/liter, phytoplankton abundance was below 10^5 cells/liter from October through December 1976. A long winter-spring bloom of between 1 and 2×10^5 cells/liter occurred from late January through mid April.

This seasonal cycle is representative of the temperate coastal waters in this region although the levels of abundance reached in each peak can vary regionally (Smayda, 1973). The two major bloom periods and annual cycle observed in the present NAI survey are quite comparable to the scheme proposed by Riley (1952) for adjacent Block Island Sound; a mid-winter minimum, February to March spring bloom up to 1.5×10^6 cells/liter and a moderately high late summer population.

The major difference between phytoplankton cycles observed from Block Island Sound by Riley (1952) and for the central basin of Long Island Sound by Riley (1955) was in the relative abundance of phytoplankton in the winter-spring and summer blooms. Riley and Conover (1956) and Riley (1959) postulated a two-layer transport system which favors retention or enrichment of nutrients in Long Island Sound relative to adjacent waters. Concentrations of both phosphate and nitrate, important nutrients promoting phytoplankton growth, decreased from the western basin through the central basin and to the poorer eastern end of Long Island Sound. Largely because of this nutrient gradient, the seasonal phytoplankton cycle for the central basin was intermediate between the more nutrient-rich western end and the less eutrophic eastern end (Riley, 1959; Conover, 1956; Riley and Conover, 1967). Typical major blooms for the central basin occurred between January and March, followed by several irregular minor blooms during the spring and summer. These smaller blooms appear to vary in density due to temperature, light, and local availability of nutrients.

The major summer (July 1975) peak of as many as 3×10^6 cells/liter at Millstone probably resulted from favorable inshore nutrient, temperature and light conditions (Figure 4.11-4). The phytoplankton abundance in New Haven Harbor during July 1975 exceeded 2×10^7 cells/liter and had secondary peaks in April, May, June, and September (NAI, 1976). This annual cycle was somewhat similar in timing to that observed at Millstone except that considerably higher densities of phytoplankton were found. This suggests the consequences of the nutrient gradient which generally leaves eastern Long Island Sound and Block Island Sound reduced in nutrients and phytoplankton cells compared to the central basin (Riley and Conover, 1956). Nuzzi (1973) at Shoreham, opposite New Haven on Long Island, found that the winter-spring bloom emphasized by earlier investigators was also considerably lower in total phytoplankton density than summer blooms. He found a winter-spring bloom in March up to only 8.8×10^4 cells/liter, a May-June bloom up to 1.4×10^6 cells/liter, and a second major summer bloom in July up to 6.4×10^6 cells/liter. A smaller October increase up to 4.1×10^6 cells/liter occurred in the central basin of Long Island Sound while the October density at Shoreham was only 1.4×10^6 cells/liter. In the twenty or more years that have passed since early studies of Riley (1952), Riley and Conover (1956) and Conover (1956) among others, the importance of phytoplankton blooms during the summer in coastal Long Island Sound appears to have increased or to have been overlooked previously.

Although the abundance and timing of some of the major summer peaks of phytoplankton appear to be dependent on local factors of water column stability, nutrients, temperature and light, it is very clear that the dominant species comprising these seasonal blooms are similar over wide areas of Long Island Sound. Table 4.11-2 shows that *Skeletonema costatum* (now *Stephanopyxis costata*) makes up between 71 and 87% of the total cells in the July 1975 bloom. This neritic or coastal centric diatom species had similar numerical dominance in July 1973 at Shoreham opposite New Haven on Long Island (Nuzzi, 1973) and in July 1975 in New Haven Harbor where it accounted for 47% of the total phytoplankton cells for the year (NAI, 1976). *Skeletonema costatum* at Millstone, Shoreham, and New Haven is the most important and ubiquitous species over a large portion of the annual cycle, including early winter, late spring and blooms throughout the summer. *Asterionella japonica* is a pennate diatom normally found in association, either preceding or following blooms of *Skeletonema* (Mulligan, 1974). In the winter months of December, January, and February, *Skeletonema costatum*, *Asterionella japonica*, *Thalassiosira nordenskioldii* and *Thalassionema nitzschoides* made up a large portion of the total phytoplankton cells. This was similar to the communities described by Riley (1956). *Thalassiosira nordenskioldii* the most dominant species in March to early April 1976 when two species of *Chaetoceros* also became important. Unidentified microflagellates and *Navicula* spp. were important categories in late spring and throughout the fall when chain-forming diatoms were reduced in abundance. *Rhizosolenia delicatula* was occasionally important in late spring. *Distephanus speculum* was found in late May as it was in studies of Conover (1956) and Carpenter *et al.* (1971). No dinoflagellate species was numerically abundant (over 5% of the total cells counted) throughout the annual cycle. This observation agreed with the results from New Haven Harbor (NAI, 1976), Shoreham (Nuzzi, 1973), and Millstone (Carpenter, 1971; Carpenter *et al.*, 1971) and contrasted sharply with the relative abundance of dinoflagellates found during the summer in earlier studies in central Long Island Sound (Conover, 1956; Riley and Conover, 1967).

With the exception of the dinoflagellates, most of the dominant species or taxa in Table 4.11-2 are included in the 40 species which Conover (1956) lists as major constituents of Long Island Sound phytoplankton.

Nuzzi (1973) at Shoreham found similar timing and species associations in the major blooms for the central basin as have been found for Millstone (Table 4.11-2). At Shoreham Skeletonema costatum, Thalassiosira nordenskioldii and several other species bloom in February and March, thus making up the late-winter-early spring bloom. In May, Thalassionema nitzschoides, Navicula spp. and others were dominant. Asterionella japonica was abundant in June. In July, Skeletonema comprised over 90% of the summer phytoplankton bloom which attained densities of up to 6.4 x 10^6 cells/liter. Thalassiosira pseudonana (formerly Cyclotella nana) was more abundant than Skeletonema in both August and September. In October, Skeletonema costatum, Nitzschia seriata, Asterionella japonica and a suite of Chaetoceros species dominated a minor fall bloom which declined gradually through November and December. In December, Thalassionema nitzschoides and Thalassiosira subtilis were dominant. Schroederella delicatula was important in January at Shoreham although Riley and Conover (1967) had found Skeletonema costatum, Asterionella japonica, Thalassionema nitzschoides to be dominants in January for the central basin off New Haven.

Summary

Although in comparing one location or year with another, some variation is found in the dominant species by week or month, there appears to be an annual cycle of phytoplankton which characterizes a wide area of Long Island Sound from the eastern narrows near Millstone through the central basin around New Haven and Shoreham. This phytoplankton community is dominated by small, chain-forming diatoms like Skeletonema costatum, Thalassiosira nordenskioldii, Thalassionema nitzschoides and Asterionella japonica. Major blooms of Skeletonema and Asterionella occur in July. A longer, less dense winter-spring bloom occurs from late January through mid April when the same four species of diatoms that are the most dominant over the year make up most of the total species composition. The influence of other species of centric and pennate diatoms, cryptomonads, chrysophyceans, green algae, and dinoflagellates is secondary to the phytoplankton community structure formed by these few abundant diatoms species.

Zooplankton (excluding fish eggs and larvae)

In order to determine whether the abundance and species of zooplankton which are entrained in the cooling waters at Millstone are similar to the zooplankton found in the Battelle ecological monitoring program in the Greater Millstone Bight (Figure 4.11-1) or at several more distant locations in Long Island Sound the following types of data have been examined: (1) total species lists; (2) percent species composition by season or location; (3) time of maximum abundance of species over several annual cycles; (4) abundance of total zooplankton compared across several stations in the Millstone and adjacent Long Island Sound areas.

Table 4.11-3 shows the species list covering all entrainment zooplankton programs from November 1970 through December 1975. The dominant larger zooplankton caught in the 333μm mesh nets are adults and copepodites of calanoid and harpacticoid copepods. These copepods form the majority of the holoplanktonic species, those species who spend their complete life cycle drifting in the water column. Larval stages of many phyla of benthic invertebrates form a second large group of species or types which comprise the meroplankton, or temporary plankton whose planktonic larval stages metamorphose and assume the habit of the adult. Comparing this species list with that provided by Battelle (Table 4.18-1) the number of species in each phyletic group for Greater Millstone Bight is generally similar, in particular for the calanoid copepods and meroplanktonic larval stages. Small differences are evident. For instance, more harpacticoid copepod, amphipod and coelenterate species have been identified from the entrainment studies while the Battelle program has attempted more specific identifications of bivalve larvae. Consideration of the percent species composition of zooplankton found in entrainment studies and from Battelle offshore programs should help determine whether the zooplankton community passing through the intake is different from that found offshore.

Table 4.11-4 shows the percent species composition of zooplankton taken from samples at the intake of Unit 1 from November 8, 1973 through 1 July 1975. The seven most abundant species entrained and ranked by percent species composition were all calanoid copepods. Acartia tonsa, Acartia clausi, Temora longicornis, Pseudocalanus minutus and Centropages hamatus, Acartia spp copepodites and Eurytemora americana in descending order of percent species composition accounted for 73% of the total zooplankton for the period. The top six species ranked by percent composition found by Battelle (Figure 4.8-3) were also copepods and, with the exception of anomalous importance of the carnivorous copepod Tortanus discaudatus which made up 6% compared to about 0.2% from entrainment collections, the top five species on this list were identical to those found in the entrainment studies. Acartia tonsa at 41% appeared to be more important in the Battelle offshore monitoring samples than the 19% found in the entrainment studies. However, this may be partially an artifact or bias of the different months of the annual cycles compared. Acartia tonsa and its congener Acartia clausi have been observed to alternate seasonally as the most numerically abundant copepod. Acartia tonsa was abundant for late summer and early winter while A. clausi was most abundant in mid winter to early summer (Deevey, 1952a, b; Deevey, 1956; Conover, 1956). Paracalanus parvus was also found to be more important in offshore monitoring samples than for entrainment samples. The less abundant copepods were more difficult to compare because of differences in identification techniques and perhaps because of a difference in species distribution found from comparing day oblique tows offshore with pooled day and night data from entrainment studies.

Meroplanktonic larvae of benthic invertebrates, in particular, cirripede larvae, Littorina eggs, polychaete and gastropod larvae were, along with the five dominant copepods, very similar in numerical importance in both offshore and entrainment programs as well as in earlier studies by Deevey (1956). These five most dominant copepods and barnacle (cirripede) cyprids have been chosen for more detailed analysis and comparison concerning their seasonal abundance over three annual zooplankton cycles.

1971 Study Year

In the intake samples for the period November, 1970 to November, 1971, the same group of dominant copepods, meroplanktonic larvae and amphipods abundant over the entire program make up over 90% of the total species composition (Table 4.11-5). Because there would be some year to year differences in the percent species composition, small changes in relative abundance within this group would be expected. The relative abundance of Acartia clausi and A. tonsa was reversed, Acartia clausi being more important over this time period, compared to the overall species rank list (Table 4.11-6). The two congeners made up 42% of the total species abundance found, while Pseudocalanus minutus and Temora longicornis together comprised another 12%. Barnacle nauplii and cyprids (9%) and Littorina eggs (10%) were the most dominant meroplankton. Bivalve and gastropod veliger larvae made up only 1.4% of the total.

The abundance of total zooplankton in the period from November 10, 1970 to November 14, 1971 was a maximum of $6455/m^3$ in April with several lesser peaks occurring, especially in night samples in late February, late May, July and late September (Figure 4.11-5). After transformation of these data by $\log_e(N+1)$, a two-way analysis of variance was conducted. Total zooplankton varied significantly ($p < 0.1$) by date and by day versus night. Tukey's procedure (Guenther, 1964) for all possible pairwise comparisons showed that the trend toward higher abundance of zooplankton at night was not concentrated at one particular time of year. The winter minimum for zooplankton occurs in November and December. The considerable variety of peaks of zooplankton abundance observed in other seasons reflected perhaps the peaks of successful broods of dominant copepods or other associated species as well as secondary pulses of meroplanktonic larvae. The abundance figures for the total zooplankton (using a 333μm net) agreed fairly well with those of Deevey (1956) for her No. 2 net samples (342μm); poorly for her No. 10 (150μm) samples. Deevey pointed out, however, that the larger net selected for the adult and copepodite stages of copepods as well as more mature meroplanktonic larvae. Smaller mesh size would tend to capture naupliar stages of copepods and increase abundance figures by up to an order of magnitude (Deevey, 1956). Also, according to Riley (1956) a two-fold variation in total zooplankton abundance in Long Island Sound from year to year could be expected normally.

The alternation of Acartia clausi, an omnivorous winter-spring dominant copepod of estuaries, and Acartia tonsa, a herbivorous summer-fall estuarine and marine dominant (Jeffries and Johnson, 1973) was a persistent characteristic of the Millstone area zooplankton cycle. Figure 4.11-6 shows that Acartia clausi reached an abundance of $3492/m^3$ in April and was important (above $10/m^3$) from January through August. Acartia tonsa peaked in August ($791/m^3$) and was more abundant than A. clausi in the period from August through December. Conover (1956) and Deevey (1956) found a similar alternation of abundance for these two species except that A. tonsa was dominant July through January and A. clausi from February to June. The figure clearly showed a succession: A. clausi was at a peak while A. tonsa was at a minimum. As A. clausi declined, A. tonsa increased and reached maximum densities while A. clausi was at a minimum. Figure 4.11-7 shows the surface temperature for the same period. The general correspondence of A. clausi to the ascending portion of the annual temperature cycle and A. tonsa to the descending side suggested that temperature was an important factor in this succession. Acartia tonsa has been found to be able to adapt to a wider range and higher absolute temperature than A. clausi (Gonzalez, 1974). This partly accounted for the minimum of A. clausi and maximum of A. tonsa at the maximum annual temperature of 20°C in August. Both species were at low and similar abundance during the annual temperature minimum in February. Both Acartia tonsa and A. clausi had clear tendency for higher abundance at night. Whether this was due to reduced net avoidance or increased activity or migration in the water column could not be determined from this data.

Figure 4.11-8 shows the day and night density of Pseudocalanus minutus and Temora longicornis over the 1971 annual cycle. Pseudocalanus minutus (=elongatus) is a herbivorous euryhaline marine calanoid copepod which was normally abundant in spring to late summer (Jeffries and Johnson, 1973). Although Deevey (1956) observed these two species to follow the same abundance pattern as A. clausi, Figures 4.11-6 and 4.11-8 suggested a succession of peaks from early spring to early fall with Acartia clausi, P. minutus, T. longicornis and finally Acartia tonsa blooming in that order. Pseudocalanus minutus peaked in April-May ($612/m^3$) and again in July. These peaks were considerably lower than the $3000/m^3$ peaks for this species which Deevey (1956) reported from the central basin of Long Island Sound. Although present over the entire year, P. minutus was abundant (i.e., over $10/m^3$) only from January through August. The bimodal peaks found for P. minutus suggest two broods occur as were found by Carter (1965). Corkett and Urry (1968) found that P. elongatus (=minutus) had its best survival and growth in the temperature range from 10 to 17.5°C. In addition, McLaren (1965) found that in Long Island Sound the eggs of P. minutus could not survive incubation temperatures above 18°C. Temperature could have been one important factor causing the population decrease through August 1971 (Figure 4.11-7).

Temora longicornis peaked in June with densities up to $444/m^3$ following the peak of P. minutus (Figure 4.11-8). It was above a density of $10/m^3$ only from February through August for this annual cycle. Berner (1962) found that T. longicornis fed on chains of Skeletonema costatum in preference to a variety of other size phytoplankton. The abundance of

T. longicornis from February to August may be directly related to the abundance of its preferred prey Skeletonema costatum.

Figure 4.11-9 shows the day and night seasonal abundance of Centropages hamatus, another spring-summer dominant copepod which tends to be more estuarine than its congener C. typicus (Jeffries and Johnson, 1973). C. hamatus has peaks of abundance in February ($65/m^3$), June-July ($307/m^3$) and September ($20/m^3$) which may correspond to the maximum adult abundance for each of three annual broods (Fish, 1925).

The bimodal abundance of cirripede cyprids is also illustrated in Figure 4.11-9 as an example of the annual cycle of meroplanktonic larvae of benthic invertebrates. These cyprids (probably larvae of barnacles) are most abundant primarily in February through May, reaching a peak of $788/m^3$. A secondary period of abundance is apparent in late summer and fall but densities in this period are only about $10/m^3$. The late winter-spring peak of abundance is most representative of many species of benthic invertebrates, including decapods, polychaetes, gastropods and many others. Bivalve larvae tend to be present in late spring through the summer but the very low densities of these veliger larvae are obscured by the much more abundant holoplanktonic copepods.

When compared together Figure 4.11-6, 4.11-8 and 4.11-9 showed that there usually was only one dominant species at a time. Barnacle cyprids peaked first in March, then A. clausi in April, P. minutus in May, C. hamatus in June, T. longicornis in July and A. tonsa in August.

Day or night variations in vulnerability to collection may have an important effect on species composition of entrained zooplankton. Figures 4.11-10 and 4.11-11 show the percent species composition of the 23 most dominant (over 5% of the total community) species or types of zooplankton over the 1971 cycle for day or night samples independently. The significant increase in abundance of night zooplankton found in this annual cycle is probably caused by the obvious increase in species composition of Acartia tonsa first and second of A. clausi at night. Pseudodiaptomus coronatus, polychaete larvae, bivalve and gastropod veliger larvae also appear to be more important to the species composition at night. Several species are more important to the zooplankton community during the day, however. These include cirripede cyprids, Centropages hamatus, Pseudocalanus minutus, Eurytemora americana, Temora longicornis and the cladocerans Evadne spp. and Podon spp. Meroplanktonic Littorina eggs, copepod nauplii and the medusa Rathkea octopunctata are about equally important to the zooplankton community. These two figures summarize the species and types of dominant holoplankton and meroplankton in near surface zooplankton samples at the intake of Unit 1 and illustrate the considerable variation that can occur between day and night zooplankton communities. This variation may be related to net avoidance or an activity cycle of zooplankton species that migrate, tending to be associated with the bottom during the day and dispersed throughout the water column at night.

1974 Study Year

Figure 4.11-2 shows the day and night abundance of total zooplankton at the intake near surface for both 333μm and 202μm net tows. Both mesh sizes show at least three seasonal peaks of total zooplankton. The 333μm net samples show total zooplankton to peak in March, May, June-July and September (with a maximum of 250,000/m^3). The 202μm net samples analyzed only from February through August showed total zooplankton to peak in March, May, June-July (up to a maximum of 244,000/m^3) as well. It is important to note that the 202μm net did not always capture very many more zooplankton than the 333μm net normally used even though Deevey (1956) had found use of a smaller net increased the abundance from 3 to 10 times due to capture of more copepod nauplii. The low approach velocities (10-15 cm/sec) may account for this occasional similarity of 202 and 333μm samples if many active zooplankters can avoid both nets. There was no significant ($\alpha = 0.05$) difference between day and night abundance of total zooplankton for either 202μm or 333μm net samples. The maximum abundance of total zooplankton was considerably higher than for the 1971 annual cycle. Also, the maximum abundance of zooplankton in September and the relative minimum in April appear unique to this year. Between about January 15, 1974 and October 15, 1974, a GO flowmeter was used in the 333μm and 202μm samples to estimate volume filtered. Because this flowmeter performed poorly in the low current velocities at the intake compared to the TSK used for all other zooplankton samples, the volume filtered for these tows was considerably underestimated and, hence, the abundance of zooplankton was overestimated (Fontneau, 1976). With this caution stated clearly, the 1971 and 1974 cycles will be compared further with respect to timing of peaks for dominant copepod species and for overall species composition rather than abundance.

Figure 4.11-13 shows the relative abundance of _Acartia tonsa_ and _A. clausi_ during 1974. _A. clausi_ was abundant over a longer period (January through July) than in 1971 when it was abundant only from March through June (Figure 4.11-6). _A. tonsa_ was more abundant in August and September than _A. clausi_ was during the entire year, accounting perhaps for the increased dominance of _A. tonsa_ in 1974 compared to 1971. _A. tonsa_ was the dominant copepod between late July and late December for both 1971 and 1974. Battelle (1976) showed (in text Figure E-1) that over the same time period the cycle of the two congeners in offshore waters at Millstone was very similar.

Figure 4.11-14 shows _Pseudocalanus minutus_ and _Temora longicornis_ for 1974 day and night. Both species were most abundant in June and there was no consistent difference in day versus night abundance. The period of maximum abundance (April to June) was not as long for both species in the 1971 cycle (December to June). For the 1974 cycle then, the _P. minutus_ abundance peak did not precede that of _A. clausi_ but followed after it. _Temora longicornis_ reached maximum abundance in June 1974 as it did in 1971. Both species were absent or insignificant in the fall of 1974, while in 1971 there was a minor fall peak. Battelle (1976) showed (in text Figure E-2) similar periods of abundance for these species in Niantic Bay and waters adjacent to Millstone, including as seen for A. clausi, the precipitous decrease in abundance through the month of July.

Figure 4.11-15 shows the abundance of the holoplanktonic copepod Centropages hamatus and the meroplanktonic cirripede cyprid. C. hamatus peaked in June while cyprids peaked in March. In the 1974 cycle, C. hamatus reached higher abundances than the cyprids while in the 1971 cycle the reverse was true. Also, cyprids had a February 1971 maximum compared to the maximum in March 1974. The timing of release of meroplanktonic larvae to coincide with the availability of phytoplankton or the reduced activities of predators would be very important to the annual success of benthic invertebrates and other meroplankton. Although timing of reproduction would be an adaptive phenomenon over many generations, the seasonal abundance or composition of phytoplankton and related physical factors like temperature, light intensity or day length might provide a proximal stimulus for the reproducing adult. Perhaps this shift in maximum abundance of cirripede cyprids of only one month to March 1974 had some causal relationship to the reduced spring peak and complete lack of a minor fall peak observed in 1971.

The general seasonal patterns of zooplankton abundance among the six taxa considered was similar for 1971 and 1974. Perhaps because of the difficulty with volume measurements, the 1974 data appeared to be more variable and any zooplankton successional pattern was somewhat obscured, especially during spring and summer. In 1971, only one species of this group was very dominant at one time. In 1974, however, it appeared that the zooplankton cycle was slightly compressed with A. clausi, T. longicornis, P. minutus and C. hamatus all very abundant in June, cyprids in March, and A. tonsa in September. The one month difference in abundance of cyprids in 1974 compared to 1971, and the general time compression of the major peaks for all copepods except A. clausi suggested perhaps that winter minimum temperatures extended through March in 1974 and only through February in 1971. A. clausi, the winter-spring dominant, would have the observed longer period of high abundance under these conditions.

Because analysis of 1974 day zooplankton samples was only partially completed, the species composition and its variation over the year was presented for night samples only (Figure 4.11-16). As in the night 1971 samples, two of the apparently nocturnally active copepods Acartia tonsa and Pseudodiaptomus coronatus were very dominant in July through December. In January, Acartia clausi, Centropages hamatus, Pseudocalanus minutus as well as meroplanktonic Littorina eggs became important contributors to zooplankton species composition. In February, veliger larvae and Eurytemora americana were added to those important in January. In March, several meroplanktonic types including polychaete larvae, cirripede nauplii and cyprids became important against a background of holoplanktonic copepods. In early April, a marked increase in abundance of cirripede nauplii and cyprids occurs. Later in April, the former complement of copepods returned to dominance with T. longicornis and E. affinis also present in abundance. In May, Temora longicornis was codominant with Acartia clausi and Pseudocalanus minutus; also, the cladocerans Evadne and Podon appeared in the plankton. In the month of June where zooplankton was at at maximum, C. hamatus became codominant over the other common copepods A. clausi, P. minutus and T. longicornis. July appeared to be a month of transition with the two common June copepods, T. longicornis and A. clausi, replaced by Acartia tonsa and Pseudodiaptomus coronatus.

The 1971 and 1974 zooplankton cycles were overall very similar in species composition by month. Day oblique tows from 1974 averaged over stations and dates in the Battelle zooplankton sampling program gave the following percentages by species: A. clausi (30%); A. tonsa (26%), T. longicornis (16%), cirripede (6%), P. elongatus (=minutus) (5%); and C. hamatus (5%). The zooplankton cycle was dominated by similar species of calanoid copepods and transient meroplanktonic larvae.

1975 Study Year

Comparison of zooplankton samples taken in 1975 with earlier years was particularly important becuase of a major transition in sampling location which occurred in July of the 1975 annual cycle. January through June 1975 zooplankton samples were taken with a 0.5 m diameter, 333μm mesh net at a depth of one meter at the Unit 1 intake. From July through the present this same net type has been used for collecting samples at the discharges (see Methods; Figure 4.11-3). Correspondence of this 1975 zooplankton cycle with those earlier should partly answer the questions of comparability of methods and provide further information concerning actual entrainment effect.

Figure 4.11-17 shows the percent species composition of species comprising more than 5% of the total zooplankton population for night samples only. Comparable day samples were not analyzed for the first four months of 1975. Percent species composition by month during 1975 was very similar to that found in 1974 with the exception that Temora longicornis was more abundant and was present over a longer period. In January, A. clausi was dominant followed by A. tonsa, P. coronatus and polychaete larvae. In February, A. clausi was again the most abundant followed by C. hamatus, P. minutus, gastropod eggs, cirripede cyprids, and polychaete larvae. In March, P. minutus was the most abundant copepod followed by A. clausi, several meroplanktonic larvae and T. longicornis. In April, T. longicornis was the overall dominant followed by P. minutus, A. clausi and gastropod eggs. Temora longicornis, A. clausi and P. minutus were codominants in May. In June, T. longicornis and P. minutus were most abundant followed by A. clausi and C. hamatus. In July, A. clausi was dominant along with T. longicornis, C. hamatus and a new competitor, A. tonsa. In the period from August through November, A. tonsa dominated the zooplankton community followed by Acartia spp. copepodites and P. coronatus. Some P. minutus and Paracalanus parvus were added to the major fall species (A. tonsa, P. coronatus) in December. Not only was this annual cycle of abundant copepods like that of

1971 and 1974 but most characteristics of it were observed by Deevey (1956) and Riley and Conover (1956) for central Long Island Sound.

For the majority of dominant zooplankton species, the percent species composition from entrainment studies in 1974 and 1975 was quite similar. However, the zooplankton species composition from 1975 day oblique 333μm bongo tows in the Millstone offshore area reported by Battelle was somewhat anomalous. *Acartia tonsa* represented 54% of the total zooplankton taken with the offshore sampling program (Section 4.8.3) while *Acartia clausi* was only 9% of the total. Comparison of these figures with the results of entrainment programs and earlier Battelle programs (Table 4.11-4) suggested that these two alternating dominant copepod species each contributed about 16 to 30% of the total annual species composition. Battelle found (Section 4.8.3) an unusually high abundance (15%) of the carnivorous copepod *Tortanus discaudatus* during 1975, which in previous years of offshore monitoring reports and entrainment studies represented up to only 1% and often considerably less. *T. discaudatus* had its maximum period of abundance in adjacent Block Island Sound from late February through July with a peak of abundance up to $373/m^3$ (Deevey, 1952a, b). However, Deevey (1956) and these entrainment studies (Table 4.11-4) have both found this species to be relatively scarce in Long Island Sound. *Centropages hamatus* was also present with less (2%) than normal dominance while its more neritic and oceanic congener *C. typicus* accounted for an unusual 1%. *Eurytemora herdmani* and chaetognaths characteristic of neritic rather than estuarine waters were also more important for the 1975 Battelle offshore zooplankton sampling program. Entrainment studies for this period (Figure 4.11-17) did not find the same dramatic changes.

Figure 4.11-18 shows the abundance of total zooplankton for available day and night weekly samples. Similar to earlier zooplankton cycles, there was an April peak ($10,000/m^3$), an unusually high June peak ($30,000/m^3$) and a September peak ($6,000/m^3$). There was no significant difference (α = 0.05) in abundance between day and night samples in the period from May through July when the location of samples changed from the intake to the discharge. The relative abundance of the three major zooplankton peaks was similar to both earlier annual cycles, especially that of 1971 (Figure 4.11-5) where the spring peak was larger than the late summer peak. The timing of the 1975 zooplankton cycle with peaks in mid April, early June, early July and early September was somewhat more similar to the 1974 annual cycle. Overall there was little change in the zooplankton cycle observed in 1975 compared to those of other years that might have been related to the major change in entrainment sampling location occurring in July 1975.

Figure 4.11-19 shows the dry weight biomass (mg/m^3) from the same samples used for estimating total zooplankton abundance (Figure 4.11-18). Dry weight biomass of zooplankton ranged from less than 1 mg/m^3 up to 115 mg/m^3 for one week in early June 1975. The peaks of dry weight biomass corresponded well to the peaks of total zooplankton abundance occurring in April (66 mg/m^3), early June (115 mg/m^3), early July (70 mg/m^3), early September (93 mg/m^3) and early December (30 mg/m^3). Since adult copepod and copepodites comprised most of this biomass, these peaks may indicate the passage of different reproductive broods of zooplankton or relative brood strength of zooplankton over the annual cycle.

Table 4.11-6 shows the dry weight biomass and total zooplankton abundance for nearly simultaneous day and night tows using both sampling methods during the September 1975 comparability study. This data showed great variability in both dry weight and total zooplankton abundance between all combinations of net type, day versus night and sampling date. Both sets of data were transformed and the significance of variability due to different factors was tested using a 3-way mixed model analysis of variance (Guenther, 1964). For both biomass and abundance, no significant ($p < 0.10$) differences were found between net type or between day and night.

Figure 4.11-20 shows the abundance of Acartia tonsa and A. clausi for 1975. A. clausi was present from December through August with a maximum abundance (8,768/m^3) in early June. A. tonsa was present from July through February with maximum abundance (4,800/m^3) in late August. The periods of abundance for these two most dominant copepods were similar in 1974 and 1975 and about one month earlier than in 1971. The absolute abundance of each species was intermediate between that observed in 1971 and that in 1974 where abundance was overestimated by difficulties in volume measurement. 1971 and 1975 zooplankton abundance varied by about a factor of two. Riley (1956) found that this factor was a normal year to year variance in total zooplankton abundance of Long Island Sound.

Figure 4.11-21 shows the abundance of P. minutus and T. longicornis over the same period as the two Acartia congeners. P. minutus had peaks of abundance in late April (600/m^3), in late May (1,500/m^3), and in early July (500/m^3). T. longicornis had peaks in late April, late May and early July that were very similar in abundance and followed the same timing as P. minutus. Both species appeared to reach peak abundance somewhat after Acartia clausi. Pseudocalanus minutus essentially disappeared from collections during mid summer and fall, a full two months before the August peak of Acartia tonsa. The dramatic decline of P. minutus in the summer and fall may be accounted for by reduction in survivorship of adults or viability of eggs at temperatures above 18°C which were characteristic of Long Island Sound in summer (Landry, 1965). Both P. minutus and Temora longicornis showed a minor fall resurgence perhaps correlated to the declining temperatures. This minor fall peak was observed in 1971 and was absent in 1974.

Regional Abundance of Zooplankton

Abundance of total zooplankton from the Battelle offshore plankton sampling programs at Millstone (Section 4.8.3) was examined statistically. Weekly day samples for total zooplankton for two periods (October 29, 1974 to December 19, 1975 and June 7, 1974 to October 22,

1974) were tabulated for both entrainment and offshore plankton studies. The first group of data did not have the complication of potential volume underestimate while this factor may have produced abundance overestimate for entrainment samples only in the second group of data. The entrainment data was then compared with weekly 333μm day oblique bongo tows at five selected stations (2, 3 ebb, 5, 10 and 11) one at a time from the offshore monitoring program (Figure 4.11-1). A Friedman two-way analysis of variance by ranks (Guenther, 1964) was used, and only dates where all six stations (including intake or discharge) were sampled were considered in the analysis. There were no significant ($p > 0.1$) differences found between the abundance of total zooplankton in entrainment samples and in those from any of the five stations located in Niantic River, Niantic Bay and almost two miles offshore (Figure 4.11-1). Given the inherent variability of zooplankton data, missing data, and lack of an estimate for true sampling error, this analysis was the most representative approach possible.

In order to examine whether the abundance or composition of zooplankton was unique or typical of larger areas of Long Island Sound, Table 4.11-7 was prepared for maximum abundance and month for total zooplankton and selected species for Shoreham and New Haven, on opposite sides of the central basin, offshore Stations 5 and 11, and Millstone entrainment studies. The probable overestimation of zooplankton during the 1974 study was evident when comparing the entrainment data with Station 5 and 11. There was an increased zooplankton abundance in New Haven Harbor which was partially due to the sampling method using smaller mesh nets that capture many more copepod nauplii (NAI, 1976). The time when total zooplankton reached a maximum abundance was generally the spring or summer as observed at Millstone.

Acartia tonsa and *A. clausi* reached a maximum for all locations in about the same months, indicating that these two copepods were important regional and annual zooplankton indicators. *P. minutus* and *T. longicornis* showed considerable variability in both timing and strength of their peak abundance from site to site and from year to year. Similar variability was evident for these species after comparing three years of entrainment data (Figures 4.11-8, 4.11-14, and 4.11-21). With the two exceptions noted, namely New Haven sampling method and overestimated 1974 entrainment data and considering the variability inherent in zooplankton data, there was good general correspondence between total and selected zooplankton species over the immediate Millstone area and over wider areas of Long Island Sound.

Summary

Zooplankton entrained at Millstone and in the adjacent offshore waters in the Greater Millstone Bight were dominated first by a ubiquitous group of estuarine and marine calanoid copepods (including *Acartia tonsa*, *Acartia clausi*, *Pseudocalanus minutus*, *Temora longicornis*, *Centropages hamatus* and several others) and, second, by various meroplanktonic larvae of benthic invertebrates. *A. clausi*, *P. minutus*, *T.*

longicornis and C. hamatus as well as several meroplanktonic species dominated the zooplankton from January through July. Their peaks of abundance as well as their associations varied from year to year. In the period from August through December, Acartia tonsa and Pseudodiaptomus coronatus were the abundant copepods while the other most common holoplankton were present in reduced populations. Overall, it appeared that the major features of the annual cycle of zooplankton abundance and species composition were similar and repeatable from year to year at Millstone (both entrainment and offshore programs), at Shoreham (Austin and Caplan, 1974), in New Haven (NAI, 1976) and from earlier Long Island Sound studies (Deevey, 1956; Riley and Conover, 1956).

Ichthyoplankton

The ichthyoplankton community in the Millstone area and in other regions of Long Island Sound was examined and compared on the basis of species list, percent species composition of seasonal dominants, and species abundance.

The scientific and common names of those species of groups whose eggs or larvae have been found in entrainment programs are shown in Table 4.11-8. When this list is compared with the offshore species list (Figure 4.8-2), some major differences are apparent. However, many of these differences are artificial and taxonomic. For instance, the offshore species list contains categories like Engraulidae, which includes all the anchovy larvae (Anchoa spp., Anchoa mitchilli, Anchoa hepsetus) and Clupeidae, which includes the herrings (Alosa spp., A. aestivalis, A. pseudoharengus, Brevoortia tyrannus, and Clupea harengus). The entrainment programs have historically distinguished the herrings and anchovies to genus and species where possible. From several years of observation and extrapolation of larval populations, it is clear that the Battelle category, Engraulidae, is mostly composed of Anchoa spp. while the category Clupeidae is mostly composed of B. tyrannus. Another less important taxonomic difference between the two parallel programs centers on Battelle usage of the species identification Lumpenus lumpretaeformis in place of Ulvaria subbifurcata used by NAI in entrainment studies. The primary key for identification of fish larvae at Millstone is Colton and Marak (1969). Colton (1973, personal communication) identifies the larva pictured as L. lumpretaeformis now, as Ulvaria subbifurcata, and NAI has adopted this convention. There are three species differences in distribution that appear real between the two programs. Conger oceanicus has been found only in entrainment samples while Lophius americanus and representatives of the family Gerreidae have been reported only from offshore monitoring samples. Due to the extreme rarity of these forms, there is little important difference in the total species list.

There are also some taxonomic level differences in the manner in which fish eggs have been identified by Battelle and by entrainment studies. Because of considerable uncertainties in differentiation of eggs of the cunner (Tautogolabrus adspersus), the tautog (Tautoga onitis) and yellow-tail flounder (Limanda ferruginea) which could make up 50 to 75% of the total eggs identified over an annual cycle, and between the eggs of the cod (Gadus morhua) and haddock (Melanogrammus aeglefinus), these groups have been combined by Battelle. Under a previous WHOI entrainment program, these egg species were distinguished by S.J. Anderson based on size frequencies and indirectly on subsequent larval abundance. Since the eggs of these species can make up 70 to 80% of the annual total found in the entrainment studies as well and because of the lack of confirmatory literature, the present entrainment program does not attempt to separate the common labrid and other fish eggs.

The percent species composition for fish eggs found between April 1973 and May 1975 at all five entrainment stations is given in Table 4.11-9. The most abundant eggs found were of the labrids, the cunner and tautog. Cunner (80%) and tautog (10%) alone represented almost 90% of the total eggs although the extrapolation of compositional data from one period (April 1973 to July 1974) to the whole program (April 1973 to May 1975) may have inflated these figures somewhat. Scomber scombrus, the mackerel; Prionotus spp., the searobin; Scophthalmus aquosus, the windowpane flounder; and Limanda ferruginea, the yellowtail flounder; each make up at least an additional 1% of the species composition for the entire period.

Any dependence of egg distribution on water taken from different depths can be determined by comparing the percent species composition of fish eggs at the three intake depths and the discharge. Table 4.11-10 compares the results of collections from the three intake depths with the results from the discharge in order to determine the relative importance of each egg species there. The period April 3, 1973 to January 15, 1974 was chosen because it avoids the period where a GO flowmeter probably overestimated the abundance of fish eggs. An important order, Clupeiformes, was collected at the 3m intake depth and not at the discharge. These eggs may have been more susceptible to mechanical damage upon passage through the plant or the discharge station was not positioned to optimize their capture. Buoyant and semi-buoyant fish eggs were found mostly in the upper 3 m at Millstone (Carpenter, 1973) or in the upper 5 m in Long Island Sound (Williams, 1968). Those species with high relative abundance in Table 4.11-10 showed no large differences in fish egg composition among the three intake depths and discharge. Egg species with low relative abundance in the lower half of the table did not compare well among stations, probably because of reduced chance of detection. The agreement among the intake and discharge stations indicated that cooling water was probably drawn from all depths below one meter.

Table 4.11-11 shows the percent species composition of the most important egg types for 1973 compared to 1974. Identifications were accomplished through July 1974. The relative abundances found in 1973 were applied to 1974 egg data to extrapolate composition for the entire year. Some of the mid-late summer spawners, i.e., anchovies, menhaden, or Clupeiformes were no doubt underestimated in this table. Cunner, tautog, and mackerel, with maximum spawning periods in June-July, July, or

May, respectively (Fontneau, 1976) were quite similar in relative abundance.

A comparison of the percent species composition or relative abundance between entrainment and offshore monitoring studies suggested some important differences. Fontneau (1976) reported that of the larvae entrained between April 1973 and May 1975, Pseudopleuronectes americanus (the winter flounder) made up 30% and Anchoa spp. (primarily the bay anchovy, Anchoa mitchilli) made up 15% of the total species composition. Battelle (1976) found almost the reverse trend in species composition (Figure 4.8-3) over all stations during a similar time period. The species composition from the offshore program was composed of 33% Engraulidae (probably primarily Anchoa spp.) and 13% winter flounder. There were several other differences in relative abundance of species cumulatively making up 95% of the total. Pholis gunnellus (rock gunnel), Anguilla rostrata (American eel) and Liparis spp. (sea snail) did not appear as subdominants from the offshore programs but comprised 2.59, 1.26 and 0.9% respectively of those larvae entrained in cooling waters. The dominant species from entrainment studies like those listed above and Ammodytes spp. (sand lance) or Myoxocephalus aeneus (grubby sculpin) included the larvae whose parents assume an epibenthic habitat near shore. On the other hand, the more offshore ichthyoplankton sampling program included as dominants more cosmopolitan, migratory species and offshore spawners who have pelagic eggs almost exclusively (Battelle, 1976). These differences in relative abundance suggested that the effects of short epidemic spawns of larvae, like the bay anchovy and mackerel could temporarily obscure the importance of the larvae of winter flounder, cunner, tautog and other bottom or shore oriented fishes that were less abundant and had a prolonged larval period.

The relative abundance of fish larvae at the discharge was compared to three depths at the intake to examine whether the discharge station was more influenced by any one depth (Table 4.11-12 and Table 4.11-13). Two periods, one, April 3, 1973 to January 15, 1974, and the other October 15, 1974 to May 27, 1975, were chosen to avoid a period of probable overestimation of intake abundance (Fontneau, 1976). Table 4.11-12 shows that cunner larvae were more abundant for 3 m and 5 m at the intake than at the discharge or intake 1 m. Clupeiformes were more abundant at intake 1 m than at discharge or the other intake depths. These differences may be due to larval behavior patterns or activity cycles rather than a function of passive flow into the intake. In the period from April to mid-January, most of the sand lance collected at the discharge were large (at least 10-12 mm); these larger larvae may have been able to avoid nets forward of the intake but not the intake structure itself. Very small, less motile larvae of a species may be sampled effectively by intake nets but be damaged at the discharge. The problem of finding the most representative portion of the cooling system to sample for accurate estimates of entrainment was thus made very complex. Mackerel larvae appeared to be distributed differently between the discharge (2.4%) and the intake 1m (5.15%) and 3 m (6.42%); discharge and intake 5 m were similar. Mackerel are normally offshore spawners whose eggs and larvae are carried inshore by surface currents (Bigelow and Schroeder, 1953); this offshore tendency was reflected in its increased percent composition in waters adjacent to Millstone (Battelle, 1976) compared to entrainment studies (Fontneau, 1976).

The relative abundance of fish larvae at the discharge compared with three intake depths is shown for a second time period in Table 4.11-13. Winter flounder were fairly well represented by the composition observed in the intake 1 and 3 m samples. The sand lance were again more abundant in the discharge than the intake. A similar pattern was observed for the grubby sculpin and the rock gunnel. Because of potential net avoidance or sampling bias in comparing three intake depths with a mixed discharge sample, the question of whether one depth at the intake was more important or representative for estimates of numbers entrained could not be completely answered.

Relative abundance of fish larvae from the entrainment and offshore monitoring programs is presented in Table 4.11-14. In general, species changes in relative abundance from year to year were detected by both programs. Anchoa spp. was less dominant in 1974 than other years although its decreased relative abundance in the Battelle 1975 versus NAI 1975 program might have been partially a function of less frequent sampling for the offshore program during the bay anchovy maximum in August 1975 (Battelle, 1976). Winter flounder was an important entrained species each year, while offshore it was only about one-third as important relative to the total. Mackerel were unusually abundant in the 1975 entrainment studies while both 1973 and 1974 offshore ichthyoplankton programs found it to be considerably less abundant. Cunner larvae from both programs were relatively less important in 1975 than in 1974, but this was partly a distortion caused by the overwhelming dominance of anchovies and mackerel on the 1975 ichthyoplankton. Windowpane flounder was much more dominant for offshore programs in 1975 than entrainment studies, while in 1974 this species was about equally abundant in both programs. This table illustrated the normal year to year and geographical variation that might be expected in studying the life cycle of fishes. This variation may, in fact, be used to estimate successful or unsuccessful year classes of fish since the strength of the year-class often may be determined by the number or survivorship of the spawned eggs or larvae. Resident species like the winter flounder, sand lance, grubby sculpin, cunner and tautog also appear to be more stable elements of the ichthyoplankton cycle from year to year than the bay anchovy, mackerel, and menhaden.

To compare day and night collections and to examine whether differences in vulnerability to capture in plankton nets might be important in interpreting annual variations in ichthyoplankton relative abundance, Table 4.11-15 was prepared. The bay anchovy was consistently more abundant in night samples versus the day. This suggested that these larvae were able to avoid nets to some extent during day sampling or they may be more abundant in the water column at night samples. None of the other species listed showed the same consistency over the three year period. However, the cunner, windowpane, and fourbeard rockling had a tendency to be less important in night samples. This suggested that the day or night dominance of larvae was not a simple size, motility or sight-dependent function of net avoidance.

1975 Ichthyoplankton Cycle

Seasonal distribution and abundance of ichthyoplankton during 1973 and 1974 have been described in detail elsewhere (Fontneau, 1976). Weekly species composition for day and night samples illustrate some of the features of the annual ichthyoplankton cycle at Millstone (Figure 4.11-22; 4.11-23). There were two periods of low species diversity: early winter (January) and late summer (August and September). The most diverse ichthyoplankton community occurred in June and early July. February through May and October through December were periods of intermediate diversity. The rock gunnel was the single dominant during January. In February and March, the sand lance and grubby sculpin were abundant. In April and May, the larvae of the winter flounder were most abundant. In the June-early July period of highest diversity, no single species was dominant. Mackerel, winter flounder, menhaden, windowpane, tautog, cunner, and bay anchovy all were important during this short summer period. This year was unusual, primarily because of the increased abundance of mackerel in June. Bay anchovies comprised 60 to over 90% of the total species composition in the second period of low diversity from mid July through September. The bay anchovy, menhaden, windowpane, and Clupeiformes were dominant in October. Menhaden, sand lance, bay anchovy, Gobiidae, and Clupeidae were abundant from November through December. The relative abundance for day and night fish larvae samples was similar in 1975 with two important exceptions. The bay anchovy and mackerel larvae were somewhat more abundant at night during 1975.

The 1975 weekly percent species composition at Battelle Station 11 near the intakes at Millstone and at the Unit 1 or 2 discharge was compared for a few selected dominant species. Similar seasonal patterns were found. Winter flounder dominated (35-45%) Battelle Station 11 ichthyoplankton samples in April and comprised as high as 80% of the abundance at the discharges in April through mid-May. Winter flounder were generally more abundant at night for both entrainment and offshore monitoring samples (Battelle, 1976). Increased net avoidance, especially for more motile, older larvae during the day, or differences in day/night location in the water column were perhaps indicated. Engraulidae (the bay anchovy) were abundant (33-74%) from July through September offshore while in entrainment samples they comprised 30-95% of the species composition from July through September and into November. The maximum abundance of sand lance (50%) and windowpane flounder (67%) at Station 11 offshore occurred at the same time and with a higher percent species composition than at the discharge (Figures 4.11-22, 4.11-23). In November, Clupeidae (the menhaden) comprised 99% of the total species abundance at Station 11 while menhaden made up only about 25% of the species composition at the discharges. The differences in distribution found in comparing Battelle Station 11 and the discharges were similar to those found when the ichthyoplankton abundance at all stations was considered (Table 4.11-9).

An examination of absolute abundance rather than percent species composition during the 1975 ichthyoplankton cycle provides further information concerning day/night and station to station differences. The abundance of fish eggs from day and night samples at the discharges ranged from less than $0.001/m^3$ up to a maximum of $66/m^3$ in late May (Figure 4.11-24). There was no significant difference between night and day abundance of total fish eggs over the annual cycle. This seasonal pattern of fish egg abundance agreed well with the results of investigators from Long Island Sound and Block Island Sound (Merriman and Schlar, 1956; Wheatland, 1956; Richards, 1959).

Abundance of total fish larvae in 1975 day and night samples ranged from a minimum in January of less than $0.001/m^3$ to a maximum of about $12/m^3$ in early June when an unusual density of mackerel larvae occurred. The maximum abundance of larvae in June 1975 was an order of magnitude higher than that observed in April 1974, illustrating the marked effect of one or two species. In general, larvae were more abundant in 1975 than in other years. For example, mackerel had been found prior to 1975 in densities as high as $0.077/m^3$ compared to $18/m^3$ in 1975. Bay anchovies had been found in densities as high as $1.526/m^3$ in earlier years, while in 1975, densities of over $4/m^3$ were found during late July and August. Winter flounder had been found in densities as high as $0.690/m^3$ earlier, and in 1975 were found in densities as high as $1.048/m^3$ (Fontneau, 1976). Sand lance were found in densities as high as $0.462/m^3$ in 1975 compared to $0.236/m^3$ earlier years.

Monthly peaks on Figure 4.11-25 were made up by the rock gunnel in January, the sand lance and grubby sculpin in February and March, the winter flounder in April, the mackerel in June, the bay anchovy in August and menhaden in November. Differences in day/night abundance showed species trends described earlier. For example, either because of net avoidance or increased vulnerability to entrainment, more bay anchovy and mackerel were collected at night. Differences in abundance of total fish larvae between day and night samples were not significant ($p < 0.05$) over the annual cycle.

Several representative Battelle offshore monitoring stations were chosen to investigate the question of whether there was any significant difference in the abundance of total fish larvae or eggs between the discharge of Unit 1 or 2 and any one Battelle station. Figure 4.11-1 shows the location of Station 2 in the middle of Niantic River, of Station 3 (ebb tide) in the gut between Niantic River and Bay, of Station 5 in the middle of Niantic Bay, of Station 11 a few hundred yards west of Unit 1 Intake near Bay Point, and of Station 10 about one mile east, offshore from Millstone Point. A non-parametric test (Friedman Two-Way Analysis of Variance by Ranks) was chosen for comparison because many tows were not accomplished on the same sampling day and were not replicated (Hollander and Douglas, 1973). For 59 dates between June 8, 1974 and December 19, 1975, total egg abundance was significantly ($\alpha = 0.05$) greater at the discharge of Units 1 or 2 than at the inshore Stations 2 and 3. No other paired comparisons were significant.

For 60 dates between June 8, 1974 and December 19, 1975, abundance of total fish larvae at the discharge was compared to the results from each of the five Battelle stations above. The discharge station had significantly ($\alpha = 0.05$) more larvae than only Station 3 (ebb). No other Niantic River, inshore or offshore station had a significant difference in abundance of total larvae compared to the discharge. Battelle (Section 4.8.3) found that the greatest overall densities of fish larvae were found at outer stations, lowest in Niantic River and intermediate in Niantic Bay.

On the basis of total species list and species composition, several differences over a typical annual cycle between entrained ichthyoplankton and Battelle offshore ichthyoplankton surveys were found. For instance, the reverse patterns in the importance of Engraulids and winter flounder larvae for Battelle and the entrainment studies suggested some onshore/offshore difference in ichthyoplankton composition. Battelle (Section 4.8.3) found that the mean concentration of anchovies, mackerel, windowpane, and clupeids (menhaden) appeared higher in their offshore stations than either Niantic Bay or Niantic River. Tautog mean concentration appeared higher in offshore and Niantic Bay stations than in Niantic River. Niantic Bay had a higher mean concentration of cunner than offshore or river stations. Winter flounder larvae mean concentrations appeared highest in the Niantic River stations during February and March 1975, intermediate in Niantic Bay and lowest in offshore stations. In April 1975, Niantic Bay mean concentrations of winter flounder larvae were highest, while offshore stations had the highest mean concentrations in May and June. Battelle has found then a higher abundance of migrant and some resident fish species in their offshore stations. Location of highest mean concentration of winter flounder larvae varied over the 1975 season.

To examine whether these onshore/offshore patterns were significant for the winter flounder larvae, larval abundance from discharge samples on twenty-two dates (June 8, 1974 to June 20, 1975) were compared with each of five representative Battelle stations. Winter flounder was chosen because this species spawns in inshore coastal waters or estuaries (Pearcy, 1962) and because it was the most abundant resident fish over the year (Battelle, 1976). There was no significant ($\alpha = 0.05$) difference between the abundance of winter flounder larvae at the discharge and any of the five Battelle monitoring stations. Winter flounder larvae were distributed evenly through Niantic Bay and Niantic River when compared to the discharge.

The timing and abundance of total larvae or those of selected species have been compared in recent ichthyoplankton studies at Millstone and several other adjacent estuaries in Long Island Sound (Table 4.11-16). The abundance of total larvae, total eggs, and most selected species in the area offshore at Millstone showed a trend for increased abundance except for the unusual summer of 1975. Year to year fluctuations in abundance and the month of maximum abundance showed similar patterns for entrainment studies and Battelle offshore ichthyoplankton programs. For instance, the maximum abundance of winter flounder has been increasing steadily in both programs from 1973 through 1975. The bay anchovy and menhaden had low abundance in 1974, increased in 1975 and intermediate in 1973. Maximum abundance for the cunner larvae has generally decreased from 1973 through 1975, while the mackerel has increased dramatically in this period.

Maximum abundance of total larvae or eggs and that for selected larval species (especially those of endemic fish species) were broadly comparable from Northport in western Long Island Sound through the Millstone area and further east to Charlestown (Block Island Sound) and Narragansett Bay (Table 4.11-16). Species maxima were somewhat different reflecting perhaps as a result of local adult abundance. Considerable variability among sites was present especially for the larvae of migratory species like menhaden or offshore spawners like mackerel.

The bay anchovy appeared to be a very important summer species distributed over the entire Long Island Sound area (Table 4.11-16). However, the bay anchovy had sporadic episodes of maximum abundance. For example, the unusually high abundance at Shoreham in June-July 1973 or the high maximum abundance in entrainment samples in 1975. The timing of the bay anchovy maximum was similar throughout Long Island Sound. Because of the patchy distribution found regionally and year to year, the bay anchovy was probably not as good an indicator of entrainment impact as more localized species, e.g., winter flounder, cunner and tautog. Migratory or offshore species like menhaden or mackerel were also sufficiently different and widespread from year to year and site to site as to be poor candidates for study of entrainment impact.

Summary

Although there were some differences in distribution and abundance from site to site across Long Island Sound, especially in the larval abundance of offshore or migratory summer species and of resident species, the overall species composition, abundance and other major features of the annual cycle of ichthyoplankton were quite similar. For instance, the rock gunnel was the single dominant species in January. In February and March, the grubby sculpin and sand lance were important. In April and May, the larvae of winter flounder usually comprised the major portion of the spring-early summer maximum of total ichthyoplankton which had been observed in the nearby Mystic River Estuary by Pearcy and Richards (1962) or over several years at Millstone by Fontneau (1976). Typically June and early July ichthyoplankton collections were made up of an abundance of menhaden, mackerel, windowpane, tautog, cunner, and, to a lesser extent, winter flounder in varying proportions. In 1975, the influence of an abnormal abundance of mackerel larvae during June may have interrupted this normal pattern. The more typical ichthyoplankton community returned by late June. Bay anchovies were very abundant and dominate almost exclusively from mid-July through September; this species was subject to considerable local and year to year fluctuations in abundance. The bay anchovy and a second group comprised of menhaden, windowpane and Clupeiformes were dominant in October. Menhaden, bay anchovies, Clupeidae, Gobiidae and sand lance were present in different proportions and with generally low abundance in the period from November through December. This general cycle of dominant ichthyoplankton has been observed in recent investigations (Austin <u>et al</u>., 1973, 1974; MRI, 1974, 1975; NAI, 1976; Battelle, 1976; Fontneau, 1976). The ichthyoplankton cycle described here was also very similar to that observed by investigators up to twenty years earlier (Merriman and Schlar, 1956; Wheatland, 1956; Richards, 1959).

In contrast to local populations of phytoplankton and zooplankton that appeared very similar across Long Island Sound, there were some distinct local and year to year differences in ichthyoplankton: first, for occasional and migrant summer dominants and, second, for larvae of fish species which reside the entire year in the waters adjacent to Millstone. Even though the overall annual abundance of larvae may be affected by extraordinary densities of a few summer larvae as with the bay anchovy and mackerel in 1975, the year to year and location variability of the transient summer group makes it difficult to extrapolate any local impact of entrainment of eggs or larvae. The resident fish species, for instance, winter flounder, cunner, and tautog, represent a somewhat more stable population with which to study the impact of entrainment.

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4.12 Siltation Studies

4.12.1 Introduction

A field survey program was initiated in March, 1975, to investigate the sediment transport phenomenon in the vicinity of the Unit 1 and Unit 2 intake structures and the proposed location for the Unit 3 intake structure. The primary goals are to delineate the possible causes and extent of the siltation phenomenon based on information extracted from the analysis of field data. The field data collected include bathymetry, beach profiles, sediment and water samples, and wave, current, and wind data.

4.12.2 Methods and Materials

Bathymetry and Beach Profiles

Bathymetry surveys have been made along transects T1 through T10 in an area bounded by grid lines W1100, W200, N250, and N1200 as shown in Figure 4.12-1. In addition, detailed bathymetric data were gathered in the area immediately in front of the Units 1 and 2 intake structures. Positions and depths along each transect were recorded electronically at 10-foot intervals and the depths corrected to mean low water. Transects which crossed the beach area were joined to topographical surveys of corresponding beach profiles.

Sediment and Water Samples

Bottom sediments were sampled within the study area. All samples were analyzed for composition and grain size distribution. In addition, higher order statistical parameters (skewness and kurtosis) were determined for selected samples. The determination of higher order moments is useful in identifying the source of the sedimentary materials. Water samples were taken from the cooling water of Unit 1 and the water column directly in front of the intake structure and in the middle of the survey area.

Current and Wave Data

Four ENDECO current meters were installed in locations as shown in Figure 4.12-1. Current speed and direction were sampled and recorded every 30 min. Additional nearshore current profiles were taken with a portable propeller-type current meter. There are four wave gages, arranged in an array, in each of two locations as shown in Figure 4.12-1. Wave heights were sampled and recorded every 1/4 sec. for 5 minutes every 8 hours. The arrangement of the gages was such that wave direction could be determined.

Wind Characteristics

Hourly average wind data, gathered at 33 feet above the ground at the meteorological tower, are used in a frequency-of-occurrence analysis of wind direction and speed.

Geologic Factors

The geology of the surrounding regions was sampled and analyzed. Samples were taken from Bay Point and along the beach area.

4.12.3 Data Analysis and Results

Bathymetry data were collected on four occasions during March to July 15, 1975. Using a contour-plotting program, these data were graphically displayed as bottom contour charts. Results indicate that significant deposition and erosion can occur along the beach area during storm conditions; however, little sediment movement is shown during the long periods of relatively calm site conditions.

Table 4.12-1 shows the results of deposition and erosion rate calculations for each of the surveys. It should be noted that significant deposition occurred during the period from March 24 to April 23, 1975. A plot of residual deposition for this period, Figure 4.12-2, shows that considerable deposition of material occurred immediately offshore in the area of the proposed Unit 3 intake structure. The discrepancies between net deposition and net erosion in the study area indicate that material is leaving or entering across the study area boundaries. This net mass transfer across the boundaries is mainly by the process of longshore transport.

From Figure 4.12-3, which shows a comparison of profiles along grid line T7, there appears to be erosion and deposition along the side slopes of the dredged channels in front of the Unit 1 and Unit 2 intake structures. However, there appears to be no significant amount of net filling in any of these areas.

Beach profiles were taken simultaneously with the bathymetry surveys. The distribution of material along the beach suggests that some of these materials come from Bay Point during storm conditions. Under storm conditions, large changes in beach profiles can be expected. During a long period of relative inactivity, small changes to the beach profiles occur but this appears to be a rearrangement of existing beach material rather than the transport of new material into or out of the beach area.

Important wave characteristics affecting sediment transport near the beach are wave height, period, and direction of the breakers. Wave height is significant in determining the quantity of material in motion, and wave direction is a major factor in determining longshore transport direction and rate. The wave data through August, 1975, have been analyzed using computer programs and the results plotted for wave amplitudes greater than 1/2 foot. Wave amplitude of 1/2 foot is considered to be the threshold for significant sediment movement. The wave gages were arranged so that wave direction and wave length could be calculated.

Current data through July, 1975, have been examined, and current speed and direction have been plotted. These data (wave, current, and wind) are used in the theoretical analysis of the sediment transport phenomenon. A mathematical model for the prediction of the longshore sand transport rate, based on wave, wind, and current parameters, is being developed. Before any conclusions can be reached, additional data will be required and are presently being gathered.

Bottom samples, taken to obtain information on the distribution, composition, and size characteristics of the bed load sediments, revealed almost no significant changes in the offshore distribution of sediments. However, the area parallel to the beach appears to undergo considerable change. Water samples indicate that extremely low and uniform concentrations of suspended load exist around the Unit 1 intake and in the middle of the survey area. Other samples were taken at several locations and the results are shown in Figure 4.12-4.

The frequency-of-occurrence analysis of wind direction and speed indicated that the annual dominant wind is from the WSW direction, with an average wind speed of 11 mph.

The geology of beach area is very complex. The main rock type observed at the site is the Monson Gneiss. The outcrop on Bay Point is mainly Monson Gneiss. The sand on the intake beach area has fragments of garnet and mica. The possibility of the micaceous portions of the sand coming from the adjacent outcrop at Bay Point exists; however, it is more likely to be due to the erosion of the Brimfield Schist. This schist outcrops along the Niantic River, Black Point and a few small islands south of Millstone Point.

Based on comparisons of data from bathymetry, beach profiles, and sediment samples, the dominant sediment transport mode, during March to July, 1975, appears to be longshore movement. The transport rate can vary substantially, depending on wave height, period and angle, current speed, and direction.

It is believed that a zone exists where net sediment movement is zero. Bathymetry and sediment samples substantiate that an area exists, 100 feet offshore, where virtually no significant bottom configuration change occurred during the survey period.

Current data indicate that a low-velocity counterclockwise circulation pattern may exist in the study area approximately 75 percent of the time. The wave climate was characterized by long periods of calm water and small wave heights.

Continuing studies (July, 1975, through December, 1976) are presently being conducted. These studies are designed to provide continuing wave and current data to be used in the mathematical transport model. The primary goals are to investigate the effects of the Unit 3 cofferdam, as a structure, on sediment movement along the beach area, and to provide additional bathymetry and sediment sample data to be used in calculation of actual transport rates.

4.12.4 Theoretical Analysis and Results

Wave Refraction

A wave refraction study was performed to obtain information on the change of wave height and direction as waves travel from deep water approaching a shoreline. Wave directions from the northwest, west, southwest and south with three different wave periods (4, 6 and 8 sec.) were used in the study. All wave refraction patterns show a concentration of wave energy at Bay Point and a dissipation of wave energy along the beach. The results also indicate, the generation of longshore current, which is believed to be the major cause of the sediment transport along the beach. The direction of this current depends upon the angle of the approaching waves.

Longshore Transport

A mathematical model for the prediction of the longshore sand transport rate from wave and current parameters is being developed. The model, proposed by Komar, relates the rate of sediment transport to the longshore component of the flux of wave energy arriving at the beach. The longshore transport rate will be computed when a sufficient amount of field measured wave data has been analyzed.

Onshore-Offshore Transport

In dealing with onshore-offshore transport, the two most important parameters are the wave induced water particle velocity and the fall velocity of the sediment. The former is a function of water depth, wave period, and wave height, and is used to determine the motion of a given sediment size. The latter can be used to predict whether the transport is onshore or offshore.

According to Dean, the sand is placed into suspension by the action of breaking waves. After the suspension phase and during the return of the particle to the bottom, the direction of net horizontal displacement depends on whether the particle is acted upon by an onshore velocity field or an offshore velocity field. If the fall time is short relative to the wave period, the particle will be effected by onshore velocities. If the fall time is long compared to the wave period, then the particle is directed offshore.

Initial calculations using field data indicate that the onshore-offshore transport rate is insignificant when compared to the longshore transport rate.

SECTION 5

IMPACTS OF THREE-UNIT OPERATION

5.1 Introduction

This section presents the most probable predictions of the impact of 3 unit operation on the marine communities in the area of Millstone Nuclear Power Station. The basis for these predictions is the information collected in the ecological monitoring studies reported in Section 4.

Based on the information collected to date the operation of Millstone Unit 1 has not significantly impacted the marine community around Millstone Point. This demonstration provides extrapolations for the operation of 3 units based on the estimated effect from the operation of Unit 1. The assessment also utilizes certain mathematical models for the prediction of impact due to entrainment and impingement for winter flounder and Atlantic menhaden.

The characterization of the biological community for the purposes of this assessment considers the important and/or most abundant species which have been entrained and/or impinged during the operation of Unit 1. The assessment generally involves the comparison of the number of individuals of a species predicted to be entrained or impinged to estimates of the number of individuals in their respective populations. The prediction of the number of each species impinged or entrained by three operating units has been determined by calculating the mean number of the species collected by year and multiplying that number by four since the three units are expected to pump about four times the volume of water pumped by Unit 1 alone. For the evaluation of impact to the phytoplankton and zooplankton communities a trophic approach is also used.

Consideration is also given to anticipated impact relative to intake location. Distributional comparisons drawn from data presented in Section 4 are made for selected species to determine if the intakes are located in an area of disproportionate abundance of each species.

5.2 Characterization of the Impacted Community

Impinged Species

At least 76 species of fish and 12 invertebrate species were impinged from January, 1972, through December, 1975. Only 16 species made up about 90 percent of all fish impinged over that time period, and six invertebrate species comprised over 90 percent of all invertebrates. These species are listed in Table 5.2-1.

It would appear from the list of 90 percent of all fish impinged that the intakes are not impinging from the area as a whole, but rather from the rocky shore-zone community in which the intakes are located. One notable exception is the winter flounder which accounted for 28 percent of all fish impinged. This is not unreasonable since this species was also the most abundant in otter trawls. The trawl catch of winter flounder at Station 11 near the intakes (Figure 4.9-10) for example, represents about 24 percent of the Niantic Bay catch (Stations 4, 5, 8, 9 and 11).

The other 62 percent of the fish making up 90 percent are shore-zone or rocky area dwellers such as sticklebacks (Gasterosteus aculeatus), grubbies (Myoxocephalus aenaeus), silversides (Menidia spp.), cunner (Tautogolabrus adspersus), tautogs (Tautoga onitis), and tomcods (Microgadus tomcod). Young windowpanes (Scophthalmus aquosus) were also relatively common in the area and on the intake screens.

A number of the species impinged were from seasonally migrating schools. These include menhaden (Brevoortia tyrannus), smelt (Osmerus mordax), and anchovies (Anchoa spp.). Other rocky shore-zone inhabitants such as the pipefish (Syngnathus fuscus) and the toadfish (Opsanus tau) were also frequently impinged.

One of the 16 species most often impinged, the hake (Merluccius bilinearis) is relatively uncommon on the screens, but in December, 1975 a school of hake was impinged on the screens, resulting in about 1700 fish being impinged. This accounted for 96 percent of all hake impinged since 1972.

Since the Unit 1 intake appears to be impinging species which inhabit shore-zone, rocky or benthic habitat, distributional comparisons have been made to determine relative impacts that might result from placement of cooling water intake structures at other locations. In terms of shore-zone fish abundance it appears that the cooling water intakes are located such that impact to these populations is minimized relative to potential impacts at other shore-zone areas. For example, examination of the shore-zone seine catches since 1969 indicates catch-effort values are consistently higher at sampling stations protected from direct seaward exposure and which subsequently act as nursery areas (Section 4.9.1). Bay Point Beach on the other hand which is adjacent to the present intake locations has a direct southwest exposure and had the lowest catch-effort values of those stations sampled on a continuing basis since 1969, i.e., White Point, Jordon Cove, and Giants Neck (Table 4.9-10). Catch values at Bay Point were more similar to those at Cresent Beach and Seaside Point.

Based upon trawl and gill net data, location of intakes at off-shore areas would likely lead to some shifts in the dominant species impacted. Relative impact to winter flounder would remain unchanged. A comparison of catch per-unit-effort at the Bay Point otter trawl station with areas in Niantic Bay, Twotree Island Channel and further offshore suggests that fish abundance is similar.

When a Tukey test for station differences (Section 4.9.3) was applied to the trawl data, results suggest that in 1975, when all stations were sampled, there was no significant difference in catch-per-unit effort between Station 11 near the intake, Station 8 in Twotree Island Channel, Stations 4 and 5 in Niantic Bay and offshore at Stations 9 and 10 (Tables 4.9-23 and 4.9-27, Figure 4.9-10).

Similarity of trawl catches at various stations was also evaluated by calculating similarity coefficients (Figures 4.9-14 through 4.9-16). The greatest similarity occurred between Stations 4 and 5 in Niantic Bay (Figure 4.9-10). It is notable that the next most similar stations were 8, 9, 10 and 11 (Present intake location).

The trawl data also provide an indication of the likelihood of some fish species to be impinged in greater of lesser amounts depending upon intake location. For example, of the six top ranked species impinged, three are also among the top six caught in trawls, i.e., winter flounder (P. americanus), windowpane flounder (S. aquosus), and cunner (T. adspersus) (Tables 4.9-23 and 5.2-1). The catch-per-unit effort for winter flounder at each station over the period 1973-1975 shows that this species is evenly distributed over the Niantic Bay area both inshore and offshore. Relocation of the intakes would probably not substantially alter its impingement rate (Table 5.2-2).

Scup (S. chrysops) on the other hand which is also a recreationally important species was more abundant in Niantic Bay (Trawl Stations 4 and 5), than at intake trawl Station 11. Impingement of this species from an intake in Niantic Bay therefore is likely to increase. At present it constitutes only 0.2 percent of the fish impinged.

Based upon a ranking of the top 90 percent of fish impinged, the intakes in their present shoreline configuration, will impinge fewer pelagic species than near shore and benthic species. A ranking of the species caught in gill nets shows that the Atlantic herring (C. harengus) and Atlantic menhaden (Brevoortia tyrannus) contribute together 72 percent of the catch but represent at present less than six percent of the total impinged at the shoreline intakes.

Another factor in evaluating offshore intake locations is the possible increased impingement of other commercial species. Five of the top 90 percent of fish species collected by gill nets have commercial value. Those species are abundant around the greater Millstone area and would likely be impinged by an offshore intake. At present the only commercial species which contributes a large percentage of the Unit 1 impingement total is the winter flounder (Table 5.2-3).

The most abundant invertebrate impinged was the squid, Loligo sp., which accounted for 33 percent of all invertebrates collected from the screens. The remaining 90 percent of impinged invertebrates consists of four species of crabs and the lobster (Homarus americanus).

Survival following impingement is very high among the arthropod species. Mean percent survival ranged between a low of 77% for O. ocellatus in 1975 and a high of 98% for C. maenas. Blue Crab (C. sapidus) had an average survival of 97% (Table 5.2-4). While lobster survival was also high (average 79% in 1975), the regional economic and recreational significance of this species requires additional consideration be given relative to power plant impact.

Of the species impinged therefore, emphasis is placed on winter flounder (Section 5.4) and lobsters (Section 5.6). For the most part the other species are also very common in the area but in some cases more have been collected during sampling than have been impinged over the last four years. (Table 5.2-5).

Special consideration is also given to the Atlantic menhaden. Impingement on the Unit 1 traveling screens since daily monitoring began in 1972 has been low. However, in late summer of 1971 an estimated 50 million juvenile menhaden and blueback herring were killed at the intake. In order to estimate the effect of this mortality on menhaden the information on menhaden population dynamics was synthesized and used to develop a life cycle model. Model development along with results predicting the effect of Millstone station are given in Section 5.5.

Entrained Species.

Phytoplankton, zooplankton and ichthyoplankton are not impinged. Because of their small size, they pass through the intake structure and condenser cooling system.

The phytoplankton entrained at Millstone were described in Section 4.11. The dominant phytoplankton species and their temporal abundance over an annual cycle do not appear unique to the Millstone area. A similar species composition seemed to be present over large areas of Long Island and Block Island Sounds. Because the potential for entrainment impact on a single species is low given the widespread distribution of phytoplankton occurring at Millstone, a more general analysis of entrainment impact is appropriate for this group.

The entrained zooplankton community excluding fish eggs and larvae has been described and compared with that in offshore areas adjacent to Millstone (Section 4.11). Entrained zooplankton was dominated by a group of common estuarine and marine copepods and, to a lesser extent, by various meroplanktonic larvae of benthic invertebrates. The species composition and seasonal abundance of these zooplankton were generally similar and repeatable from year to year for both entrainment and offshore studies at Millstone and for several other studies across Long Island Sound. Because the zooplankton community was not unique to the Millstone area, a more general approach to the assessment of entrainment impact was also taken focusing on the reproductive capacities of populations of dominant copepod species.

Unlike the phytoplankton and zooplankton, it was demonstrated in Section 4.11 that there were a few important year to year and region to region differences in abundance or composition of ichthyoplankton. This was especially true of the variable summer and migrant populations such as mackerel, menhaden and bay anchovy. Although the abundance of total eggs, total larvae and winter flounder larvae was not significantly different at several river, inshore, or offshore stations compared individually with the Unit 1 discharge (Section 4.11); the mean monthly abundance of grouped Niantic River, inshore, or offshore stations (Section 4.8.3) showed an apparent tendency for mackerel, menhaden and bay anchovy among other species to be more abundant at offshore stations. Their short epidemic spawnings temporarily obscured the more stable year to year resident ichthyoplankton which was relatively more important in the species composition of entrained samples and which consisted of bottom or inshore species such as cunner, tautog, and winter flounder (Table 4.11-12). Winter flounder, cunner, and tautog were selected therefore for further entrainment assessments. These larvae exhibited somewhat less variation in abundance or species composition over several years of ichthyoplankton studies (Table 4.11-14). Population parameters such as age structure, average fecundity and sex ratios could be obtained from the literature.

A monitoring study to estimate potential impact of ichthyoplankton entrainment should follow a species population over time in a defined area and attempt to demonstrate the relative health or stability of the population from year to year. Winter flounder was chosen above other important resident fish species such as cunner or tautog for comprehensive study because: (1) it represents the most abundant resident fish species year round in Greater Millstone Bight and Niantic River (Figure 4.11-1); (2) it spawns (laying demersal eggs) in inshore shoals and estuaries (Pearcy, 1962); (3) its meroplanktonic period is relatively long lasting (from February through June) when larvae may be subject to entrainment; (4) there is considerable information from Millstone and nearby areas concerning population parameters necessary to study dynamics of this species; and (5) there is an active recreational fishery to be protected in the areas adjacent to Millstone.

Battelle (1976) has reported on extensive population census studies for the Niantic River, a well-defined geographic area where annual spawnings of winter flounder take place over different weeks from late January to April. An analytical model based on hydrodynamic tidal flows has been developed to simulate the effect of power plant entrainment of larvae on the long term abundance of the winter flounder population of Niantic River (Sissenwine et al., 1974; Hess et al., 1975). Comparisons using the adult and larval population estimated for Niantic River and the larvae estimated entrained by three unit operation at Millstone from field data provide some information for evaluation of the impact of entrainment on an important resident population whose reproductive and larval behavior suggest that it has a relatively higher risk of entrainment (Section 5.4).

5.3 Entrained Plankton

Combined three unit operation at 100% power will require about 4350 cfs or about 1.066×10^7 m^3/day cooling water volume to be pumped from Niantic Bay. Since the average tidal exchange in Niantic Bay was about 100,000 cfs (see Section 3.2), three unit operation would be expected to entrain about 4% of the Niantic Bay tidal exchange. Several approaches have been examined to estimate the impact of entrainment on populations in the waters adjacent to Millstone. First, 100% mortality of entrained phytoplankton, zooplankton and ichthyoplankton has been assumed to give a conservative or worst-case numerical entrainment estimate. Second, based on the phytoplankton, zooplankton and ichthyoplankton data described in Section 4.11, simple volumetric estimates were prepared by calculating the numbers of each group that might be entrained by month or over an annual cycle. The basic approach for all three planktonic groups has been similar, namely, taking a point estimate of abundance (day or night, single value or arithmetic average of three replicates), multiplying by the number of full days in the interval preceding the point estimate and then multiplying this product by the daily cooling water volume (1.066×10^7 m^3/day) to calculate the number of organisms that might be entrained for specified intervals. In the case of zooplankton and ichthyoplankton, day and night abundance data has been used independently, thereby giving a maximum range for the total entrainment estimates. Third, for phytoplankton and holoplanktonic zooplankton (dominant copepods), reproductive capacity and its relationship to maintenance of a population was examined. Fourth, the number of reproductive adults equivalent to numbers of entrained ichthyoplankton were estimated and set into perspective for the species of fish whose larvae had a greater tendency to be entrained.

Before the individual potential impacts of entrainment on phytoplankton, zooplankton and ichthyoplankton can be judged, however, some of the factors leading to changes in abundance of different planktonic groups should be discussed. Millstone entrainment data has been shown to reflect the regional standing crop of phytoplankton, zooplankton and ichthyoplankton over an annual cycle (Section 4.11). Numerical estimates of monthly entrained phytoplankton (Table 5.3-1) were converted using conversion factors from the literature to equivalent carbon, dry weight and calories entrained (Table 5.3-2). Night zooplankton dry weight biomass samples were chosen as representative and the dry weight biomass of zooplankton entrained monthly was converted to carbon or calories using conversion factors from the literature (Table 5.3-3). Numerical estimates of monthly fish larvae entrained were made for 1975 as well (Table 5.3-4). Points corresponding to monthly entrained phytoplankton carbon, zooplankton carbon and numbers of fish larvae were graphed together as a schematic representation of the annual cycle of standing crop for these groups (Figure 5.3-1).

Peaks of zooplankton carbon standing crop in Figure 5.3-1 did not coincide exactly with those of phytoplankton. Biological factors such as grazing by zooplankton and renewal of nutrients as well as physical factors such as temperature, light intensity or photoperiod, winter mixing, summer retardation of nutrient renewal by vertical stratification, and retention time in areas favorable to growth or feeding probably were important factors accounting for the changing balance of phytoplankton and zooplankton. In

January through March and in the midsummer bloom, growth rate and abundance of phytoplankton was probably influenced more by physical factors and nutrient availability than by zooplankton grazing; the reverse was probably true in April, June-July and September when zooplankton biomass and grazing were at a maximum. Zooplankton standing crop was probably influenced by seasonal temperature, food availability, and density of predators. Peaks of biomass of zooplankton were followed closely by abundance of ctenophores (Section 4.11) whose feeding requirements could be as much as 5% of the zooplankton population per day (Bishop, 1968). Zooplankton standing crop variations coincided with the numbers of total fish larvae which may consume up to 10% of the zooplankton population each day (Thayer et al., 1974). The release in grazing pressure by reduced zooplankton populations in January through March or July and August combined with other conditions favorable to phytoplankton growth would lead perhaps to the elevated ratios of phytoplankton to zooplankton standing crop over these months (Table 5.3-3). Over the year the average of phytoplankton to zooplankton standing crop was 8.72 but the monthly figures for this ratio were considerably lower when zooplankton was abundant.

A delay or change in a biological or physical event important in the annual cycle of plankton communities can influence the relationships of one group to another or perhaps even the biomass attained by these groups. The increase of zooplankton and fish larvae population depends on the growth of phytoplankton as well as other physical or biological factors. If, as in Figure 5.3-1, zooplankton and fish larvae were offset (advanced) one month due to an abnormally cold winter, for instance, the summer bloom of phytoplankton may be reduced because of more complete utilization by zooplankton or other factors than predation limiting to growth. A higher zooplankton population in summer may support more fish larvae. Because of reduced grazing or less limiting nutrient or growth factors, phytoplankton may have, in this example, a more important late winter-early spring bloom than was observed in actual data. The timing of physically and biologically important events such as vernal temperature increase is in addition to predation (or the availability of food or nutrients) an important factor leading to some year to year variations in the typical biomass cycle of phytoplankton, zooplankton and fish larvae.

5.3.1 Phytoplankton

Simple volumetric estimates of the maximum number of phytoplankton cells entrained by month over an annual cycle have been made using the phytoplankton counts from April 30, 1975 through April 28, 1976 (Table 5.3-1). Of the total 1.51×10^{18} phytoplankton cells estimated to have been entrained over a year of three unit operation, most cells were of the dominant species comprising the late winter-early spring or the summer bloom, namely, Skeletonema costatum, Asterionella japonica, Thalassiosira nordenskioldii, and Thalassionema nitzschioides. The month of July when Skeletonema and Asterionella were abundant accounted for 40% of the total phytoplankton cells entrained for the year. The months of July, August and September combined accounted for almost 80% of the total.

The growth cycle of each phytoplankton species is a complex interaction of temperature, light intensity, photoperiod, stability of the water column, nutrients, competition and predation. However, there are available estimates of the generation times for all four of these dominants in the Millstone and Long Island Sound coastal areas. Smayda (1973) found that Skeletonema costatum had division rates of 0.20 per day at 2°C up to 4.0 divisions per day at 20°C. Riley (1952) found that Thalassionema nitzschoides could divide as fast as once every 19 hours. McAllister et al. (1961) found that Thalassiosira nordenskioldii could divide up to once in 30-38 hours. Teng (1976) found that Asterionella japonica divided between 0.43 divisions/day at 0°C linearly up to 2.87 divisions/day at 25°C.

These short generation times for dominant Millstone and Long Island Sound phytoplankton are important in setting the number of entrained phytoplankton cells into perspective. Since the Millstone plant withdraws only about 4% of the tidal exchange into Niantic Bay (Section 3.2) and since the remaining unaffected 96% of the phytoplankton could achieve much higher division rates as high as 1.0 per day as in spring and summer blooms (Smayda, 1973), it would likely require on the order of hours for phytoplankton reproduction to equal entrainment losses. Allowing for continuous dilution with unaffected Long Island Sound water which has been shown to contain similar abundance and species composition of phytoplankton (Section 4.11) and allowing for a modest growth rate, the numbers of entrained phytoplankton would rapidly be replaced.

The predicted numbers of phytoplankton entrained by month over an annual cycle (Table 5.3-1) has been converted to equivalent amounts of chlorophyll, carbon, dry weight or calories entrained (Table 5.3-2). For instance, about 453×10^6 g dry weight of phytoplankton was entrained over a year with the unit operation. Although 100% mortality of these phytoplankton cells has been assumed, the chemical and particulate form of these entrained cells has not been altered or made unavailable to the ecosystem by disintegration or by sinking in the quarry (Carpenter et al., 1971). The fact that these entrained amounts of chlorophyll, carbon, weight or calories in Table 5.3-2 are not lost to the ecosystem is important. For instance, the 453×10^6 g dry weight predicted entrained as phytoplankton over a year is equivalent to 195,855 pounds dry or about 979,275 pounds wet weight (assuming dry weight is about 20% of wet weight). At an assumed 10% ecological efficiency from one trophic level to the next, this 979,275 pounds wet weight would be equivalent to about 97,928 pounds of herbivorous zooplankton or about 9793 pounds of carnivorous fish over an entire year. Since protoplasm is not destroyed by entrainment, this energy and material remains available to support the ecosystem.

To set the numbers of phytoplankton entrained at Millstone into perspective, the volume of water cleared of phytoplankton each day by a single herbivore species could be compared to that pumped by three unit operation at Millstone. For example, menhaden have been found to clear up to 3.5×10^5 l/day (Durbin and Durbin, 1975). It would require as few as 2.8×10^4 or 28,000 menhaden to filter the daily cooling water volume of the Millstone plant.

The impact of three unit entrainment on the phytoplankton community around Millstone is judged to be minor because (1) the dominant phytoplankton species have short generation time and a high rate of reproduction; (2) there is a high potential for dilution by unaffected Long Island Sound phytoplankton which has a similar species composition; (3) many of the entrained phytoplankton cells remain capable of phytosynthesis and division after return to Long Island Sound (Carpenter et al., 1971); and (4) the entrained phytoplankton is not consumed by the plant but is still available to the ecosystem.

5.3.2 Zooplankton (excluding fish eggs and larvae)

Abundance data of total zooplankton in 1971, 1974 and 1975 has been treated in the same manner as the phytoplankton. Monthly or annual estimates of the total number of zooplankton entrained with three unit operation have been prepared (Tables 5.3-5; 5.3-6; 5.3-7). Since these estimates assume simple volumetric flow at the maximum cooling water volume, these monthly estimates closely follow the estimates for zooplankton abundance. Day and night estimates of total zooplankton entrained using 1971 data were 2.5 and 3.3 x 10^{12} respectively. The results from an incomplete day and a complete night sampling program for 1974 gives estimates of 3.0 and 9.9 x 10^{13} respectively. Night samples from the 1975 cycle estimate that 6.7 x 10^{12} zooplankton would be entrained per year with three unit operation. Because of a volume measurement problem discussed earlier with the 1974 data, the 9.9 x 10^{13} figure (Table 5.3-6) probably represents an overestimate by up to ten times. The 1971 and 1975 sampling programs result in an estimate ranging from 2.5 to 6.7 x 10^{12} zooplankton entrained each year. Most of the zooplankton were holoplanktonic calanoid copepods (such as Acartia tonsa, Acartia clausi, Temora longicornis and Pseudocalanus minutus) typical of the Millstone area, Long Island Sound and northern temperate coastal waters (see Section 4.11). Meroplanktonic larvae or eggs of common benthic invertebrates like barnacles, polychaetes, gastropods and bivalves as well as amphipods and ctenophores were entrained in fewer numbers than the dominant calanoid copepods.

The monthly and annual dry weight biomass of zooplankton estimated to be entrained in 1975 with three unit operation was shown in Table 5.3-3. Carbon and caloric equivalents of this amount of zooplankton dry weight have been extrapolated using conversions obtained from the literature. About 66 x 10^6 g carbon or 35 x 10^{10} calories of zooplankton organisms would have been entrained with three unit operation in 1975. In order to place these numbers or amounts into better perspective, namely, to the normal functioning of the planktonic community, some calculations were performed. Assuming a 10% conversion efficiency between herbivores (zooplankton) and primary carivores (small carnivorous fish), then the 66 x 10^6 g dry weight biomass of zooplankton entrained in 1975 might be equivalent to the wet weight biomass of 7474 pounds of fish over a year. In this calculation dry weight biomass was 40% of the wet weight (Beers, 1966) so that 66 x 10^6 g dry weight biomass was equivalent to 74,740 pounds of live zooplankton entrained per year.

Two observations are perhaps the most important in evaluating the impact of zooplankton entrainment to the Millstone area. First, Section 3.2 described the combined intake cooling water volume as about 4% of the tidal exchange in Niantic Bay across a line from Black Point to Millstone Point. Second, Section 4.11 showed that the abundance and species composition of holoplankton and meroplankton was not unique to waters adjacent to Millstone but rather was typical of Long Island and Block Island Sound waters. The small portion of the tidal exchange required for cooling combined with the ubiquitous composition of the zooplankton suggest that the impact of entrainment on zooplankton populations would be distributed widely by turbulent and diffusive tidal currents.

The estimated impact of zooplankton entrained might be judged further by consideration of the reproductive capacity of zooplankton which accounts for their ability to increase two orders of magnitude in a period of about two months (see Section 4.11). These reproductive factors include: 1) short generation time; 2) high fecundity; 3) high survivorship and 4) variation of population sex ratios.

Depending largely on the temperature and food availability, holoplanktonic zooplankton can be characterized as having short generation times compared, for instance, to meroplanktonic species which generally have only one opportunity each year to reproduce. Acartia tonsa had generation times (estimated from field measurements ranging from 6-8 weeks (Jeffries, 1962) while field and laboratory observations in the Patuxent River Estuary yielded estimates for generation time of 7 days (25.5°C), 9 days (22.4°C) and 13 days (15.5°C) (Heinle, 1970). The Patuxent River summer population of Acartia tonsa had a dry weight biomass turnover or doubling time of 2.2 to 2.5 days which was equivalent to a secondary production of 2.77 $mg/m^3/hr$ which suggested that this species alone consumed half of the estuary's primary production during the summer months. Acartia clausi had field generation times of 8-10 weeks (Jeffries, 1962) while laboratory populations of this species had generation times of 30 (20°C) to 60 (12°C) days (McLaren et al., 1969). Katona (1970) found laboratory generation times of 19 (15°C) to 73 (2°C) days for Eurytemora herdmani and 9 days (23.5°C) to 105 days (2°C) Eurytemora herdmani and 9 days (23.5°C) to 105 days (2°C) for Eurytemora affinis. Corkett and McLaren (1969) observed a field generation time of about two months for the two to four distinct broods of Pseudocalanus minutus.

High fecundity or high survivorship can be factors important in maintaining holoplanktonic zooplankton populations. Heinle (1970) observed in the laboratory that Eurytemora affinis was able to increase its birth rate under exploitation rates of 10-23% each day. Marshall (1967) found that Daphnia magna was also able to increase its birth rate with increasing levels of predation. Corkett and McLaren (1969) found that Pseudocalanus minutus females were highly fecund laying over 180 eggs for the average adult lifespan. Some relatively high survivorships have been observed from egg to adult for zooplankton species. Field observations have suggested that the chaetognath Sagitta elegans had a 17% survival (Sameoto, 1971) and that the small cyclopoid copepod Oithona similis had survival up to 8% (NAI, 1974). Laboratory experiments conducted without the influence of predation suggested that Calanus finmarchicus had up to 30% survival from egg to adult (Mullin and Brooks, 1971). Zooplankton populations are also able to change sex ratio in response to environmental factors such as temperature or in response to exploitation. Heinle (1966, 1970) found that eggs hatched from field populations had about a 1:1 ratio of females to males while under conditions of experimental exploitation this ratio was altered from unity to give a proportion of 58-71% female increasing directly with the level of daily exploitation. Eurytemora affinis in the same exploitation experiments increased the proportion of males in the population (Heinle, 1970). Although the carrying capacity of the environment ultimately regulates the population of zooplankton species, holoplankton in nature and in the laboratory have demonstrated very high reproductive potential. Many dominant holoplanktonic copepods typical of those found at Millstone may have relatively short generation time, multiple broods per year, varying fecundities, high potential survivorship, and changing population sex ratios.

Since the zooplankton species composition and abundance found at Millstone was typical of a larger geographic area, since the Millstone Plants would entrain only about 4% of the tidal exchange of tide dominated Niantic Bay, and since zooplankton may have density-dependent reproductive strategies to compensate for exploitation or dilution, the effect of entrainment on zooplankton in the immediate vicinity of Millstone will probably be small and difficult to detect over natural seasonal or year-to-year fluctuations.

5.3.3 Ichthyoplankton

As with phytoplankton and zooplankton, the abundance of total fish eggs and total fish larvae, as well as three species selected for more detailed study, has been used to estimate the total numbers of organisms that might have been entrained with three units operating at Millstone (Table 5.3-8). Day and night abundance estimates were used independently to calculate a range for total entrainment over three different years. Total fish eggs and larvae entrained in day or night samples were slightly underestimated in 1973 because only April through December were included in the sampling program. Total fish larvae entrained in 1975 was up to 4 to 10 times that of 1974. This dramatic year-to-year difference was largely due to increases in abundance of mackeral and bay anchovy found in June, July and August 1975 (Table 5.3-4). However, larvae of the cunner, tautog, and winter flounder were also considerably higher in abundance and, hence, more were entrained in 1975 than in 1974. Numbers of eggs and larvae of the cunner fluctuated from year-to-year following the general reduction of ichthyoplankton in 1974 compared to 1973 and 1975. Numbers of tautog larvae entrained were similar in 1973 and 1975 and reduced along with the general larval populations in 1974. Winter flounder larvae entrained showed an increase in abundance and numbers entrained from 1973 through 1975 (Fontneau, 1976).

Because there was no significant ($\alpha = 0.05$) difference (Friedman 2-way ANOVA by ranks, Guenther, 1964) in the abundance of total larvae, total eggs or winter flounder larvae between the intake and any of five other stations in Niantic Bay and Niantic River (see Section 4.11), these volumetric estimates of entrainment would not be changed substantially if the intake structures were at these locations.

Table 5.3-4 shows that virtually 80% of the total larvae entrained in 1975 were accounted for in the months of June, July and August. Largely because of increased night abundance of mackeral, bay anchovy, and menhaden over this period, the numbers of larvae estimated from night samples would represent the maximum number of larvae affected by three unit operation at Millstone about 2200×10^6 over one year.

An approach that can be used to put the numbers of entrained larvae into perspective consists of the extrapolation of entrained larvae to equivalent reproductive adults otherwise recruited to a population. Several simplifying assumptions are involved. First, a species pair will just replace itself for each larval generation, namely, a population which is neither increasing nor decreasing in size. Second, no compensatory reproduction or density-dependent mechanisms are assumed to be functioning in the population. Third, a sex ratio of unity is assumed; adjustments must be made to account for ratios of males to females different that 1:1. The following formula adapted from Horst (1975) can thus be used to estimate the reproductive adults equivalent to the larvae entrained:

$$\frac{2 \times (\text{Number of Entrained Larvae})}{(\text{Survivorship from egg to larvae}) \times (\text{Fecundity per generation})} = \text{Number of Equivalent Adults}$$

Although the life table information necessary to calculate the exact fecundity per generation of an isolated fish population is seldom available, the above estimate can be made roughly by using the average fecundity over the reproductive lifespan. For cunner, a four year reproductive life span and sex ratio of 2.2 males to 1 female was used for this type of calculation (Dew, 1976) along with a fecundity of about 100,000 eggs per female and a low 5% hatching success suggested by Williams et al., (1973). In 1975 the 12 to 31 million cunner larvae entrained with three unit operation is estimated to be the equivalent of 2723 to 6872 reproductive adults. In this calculation, a change in any of the four major factors could change the resultant estimate. For instance, changing only the sex ratio to unity would decrease the number of equivalent adults to between 1237 and 3124 cunner. Using a reproductive life span of about 10 years, fecundity of 90,000 eggs/female and a 10% hatching success (Chenoweth, 1963), the 21 to 31 million larvae entrained in 1975 (Table 5.3-8) would be equivalent to about 475 to 655 reproductive tautog. In comparison, the annual catch of tautog by fishermen in Gardiner's Island Sound and the Peconic Bays was between about 150,000 and 300,000 (Briggs, 1969); this area is about ten times that of Niantic Bay and approaches.

Thus, for the entrained larvae like cunner and tautog which are important prey and recreational fish species resident in the Millstone area several hundred to a few thousand reproductive adults appeared to be equivalent to the entrainment impact for each operating year. These estimates of entrainment impact are judged to be conservative because of the following assumptions: The well-flushed Niantic Bay may have other local sources for larvae of resident fish, and the fecundity per generation may vary in nature depending on the year-to-year density of resident fish stocks (Bagenal, 1973) or the abundance of food.

Winter flounder is another important resident fish species. In 1975, 209 to 274 million of its larvae were estimated to have been entrained with three unit operation (Table 5.3-8). Many more winter flounder larvae were entrained than cunner or tautog larvae. Because of the importance of the adult winter flounder spawning populations in the Niantic River and Niantic Bay (Battelle, 1976) and because of the number of entrained larvae, the following section will be devoted entirely to an assessment of the impact of both entrainment of larvae and impingement of adults by the Millstone plant on recruitment to and stability of a local winter flounder population.

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5.4 Winter Flounder Modeling

Background

Winter flounder (Pseudopleuronectes americanus) modeling combines hydrodynamic, concentration and population submodels as well as impingement data in a simulation of impact to the Niantic River winter flounder spawning population; impact which results from the operation of Millstone Units 1, 2 and 3. Results of the entrainment aspect of this effort directed by Dr. Saul Saila, of the University of Rhode Island are detailed in reports to Northeast Utilities and have been reported in the scientific literature as well (Sissenwine, et al. 1973, 1974, 1975, Vaughan, et al. 1976, Saila, 1976 and Hess, et al. 1975). The following is derived from that work:

Introduction

The winter flounder (blackback; Georges Bank flounder; lemon sole; flounder, sole; flatfish; rough flounder; mud dab; black flounder) is the object of an old and established trawl fishery in southern New England as well as being increasingly common in the catches of saltwater fishermen. Recent surveys of marine sport fishing indicate that the winter flounder is one of the most common fishes taken by coastal anglers in Southern New England. The winter flounder ranges geographically along the Atlantic coast from Labrador to Georgia. It is a typical shoal water fish throughout most of its range.

The breeding season of the winter flounder in New England waters extends from late winter to early spring. Shoal waters of estuaries and inlets are extensively utilized for spawning. The eggs are demersal and adhesive with a size range of about 0.74-0.85 mm in diameter. The eggs are usually deposited in clusters over a relatively sandy bottom. The fecundity of the species ranges to about 1.4 million eggs for a large female, but the average appears to be in the vicinity of 500,000 eggs.

The winter flounder is a hardy fish which appears to withstand relatively large environmental variations. They are often found in salt ponds within a large range of temperature and salinity. The diet of the winter flounder is varied, and includes worms, crustaceans and mollusks.

The rate of development of the eggs and larvae of winter flounder is variable according to temperature. Estimates of the periods of the various life history stages used for model calculations are provided later in this report. However, it is conservatively estimated that egg development requires about 15 days and that the total larval period prior to the benthic phases after metamorphosis lasts about 2 - 2-1/2 months.

Results of trawling surveys and results of winter flounder population estimates for the Niantic River (Section 4.9.4) indicate that mature fish are abundant there during their late winter and early spring spawning season. Information derived from the Niantic River winter flounder tag-recapture studies also demonstrates the ability of adults to return to the river in large numbers. The return of adult winter flounder to a specific breeding site has also been documented elsewhere (Saila, 1961). For the purposes of modeling power plant impacts, therefore, it was assumed that the Niantic River winter flounder population is reproductively isolated, although some exchange of larvae and adult fish with nearby populations certainly occurs.

Isolated populations are particularly sensitive to localized environmental stresses, since, for example, losses by entrainment of the Millstone Nuclear Power Station may not be offset by input from other populations. Entrainment of larvae decreases the number of individuals recruited to the benthic winter flounder population. The effect of entrainment considered here assumes organisms passing through the plant suffer 100 percent mortality. The effect of entrainment can be considered as a plant mortality acting in addition to the natural mortality, so that fewer winter flounder larvae survive to their benthic stage with the power plant in operation. In this study, the effects of natural and plant mortality are separated to simplify calculations. By considering the sources of mortality separately, the possibility of a decrease in natural mortality to compensate for entrainment losses is ignored. Thus the approach tends to overestimate the impact of entrainment and impingement when natural mortality is density dependent, otherwise the results are the same as when natural and plant mortality are considered together.

First, a hatch of organisms in the Niantic River and other possible breeding areas, and the movement of the larvae under the action of tidal currents around the river, the waters near Millstone Point and into Long Island Sound is simulated (without natural mortality). A comparison of the final number in the waters near Millstone Point at the end of the larval period, with and without the plant in operation, is used to estimate the entrainment mortality rate. The effect of impingement is estimated by considering the proportion of the Niantic River population represented in the impingement samples (see Section 4.10). This estimate is then extrapolated on the basis of flow to the operation of multiple units. This approach assumes that all flounder impinged breed in the Niantic River. These results were then employed in a compartmental model of the winter flounder population in order to simulate the impact of entrainment, impingement and the combination of entrainment and impingement after many years.

Local Dispersal of Winter Flounder Larvae

The transport of larvae around the Niantic Bay area is accomplished primarily be advection due to currents and secondarily by diffusion based on concentration gradients. Self-motion by the larvae is ignored because of their poor swimming ability. The net displacement per unit time of winter flounder larvae in laboratory chambers was measured. Using these results, the self-diffusion rate of the larvae was calculated, based on a random walk model, and found to be several order of magnitude lower than the turbulent diffusion rate. Of the prevailing circulation, the dominant component is that due to the tides in Long Island Sound. Wind-induced currents also produce short-term perturbations which are of only secondary importance in the total circulation. Gravitational, or density-driven, currents may exist only in the upper reaches of the Niantic River where noticeable salinity gradients result from brook discharge.

The currents in Niantic Bay sweep the larvae around Millstone Bight and past the cooling-water intake structures of the nuclear power station. The fate of larvae hatching in the Niantic River and other areas of the bight can be studied by using the currents as input to solve a convective-diffusive equation of mass conservation. The time-varying spatial concentration of organisms can be predicted, and the effect of the power plant assessed.

The tidal circulation in the bight is modeled numerically using a horizontal grid network consisting of 287 internal square grids 305 meters on a side (Figure 5.4-1). The time-dependent equations of flow and mass conservation in a fluid, assuming constant density and a hydrostatic vertical pressure relationship are employed. These equations are integrated over depth from the bottom to the water surface to give, for momentum,

$$\frac{\partial V}{\partial t} + U\frac{\partial V}{\partial x} + V\frac{\partial V}{\partial y} = - g\frac{\partial \eta}{\partial y} - fU + \frac{1}{\rho(h+\eta)} (\tau_{sy} - \tau_{by}) \qquad (5.4\text{-}1)$$

$$\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + V\frac{\partial V}{\partial y} = - g\frac{\partial \eta}{\partial x} + fV + \frac{1}{\rho(h+\eta)} (\tau_{sx} - \tau_{bx}) \qquad (5.4\text{-}2)$$

and for mass conservation

$$\frac{\partial \eta}{\partial t} + \frac{\partial}{\partial x} [(h+\eta)U] + \frac{\partial}{\partial y} [(h+\eta)V] = 0 , \qquad (5.4\text{-}3)$$

where η is the tide, U and V the vertically-average velocity components, and t_{ij} the surface and bottom stresses. These equations are solved in a time-stepping procedure by the computation scheme of Leendertse (1970) and new values of U, V, and η are obtained at each grid-square each 60 seconds. Local depths are used at each grid, and the water level at the three open boundaries are specified as a tide with both a progressive and standing wave component such as that occurring in Long Island Sound. The parameters were evaluated from data taken during two hydrographic surveys (Section 4.2.5).

Current vectors at flood and ebb are shown in Figures 5.4-2 and 5.4-3. At flood the flow is generally westward past Millstone Point, dividing into two streams, one moving up into the Niantic River, the other through the bay and exiting past Black Point. During the falling tide the flow is reversed, moving eastward through Twotree Island Channel. The Niantic River effluent hugs the shore line and passes close by Millstone Point.

The current vectors produced by the hydrodynamic model are then used in another conservation equation, this one for winter flounder larvae. The vertically-integrated equation, for average concentration C, is,

$$\frac{\partial}{\partial t}(h+\eta)C + \frac{\partial}{\partial x}(H+\eta)(AUC-D_x\frac{\partial C}{\partial x}) + \frac{\partial}{\partial y}(h+\eta)(AVC-D_y\frac{\partial C}{\partial y})=0 \qquad (5.4\text{-}4)$$

and it is modeled using a numerical scheme also developed by Leendertse (1970). The diffusion coefficients in Equation 5.4-4, D_x and D_y, are evaluated by the method described by Elder (1959).

Local concentrations of organisms vary over time by net changes in advection by the currents and turbulent diffusion process based on local concentration gradients. Diffusion is the lesser transport mechanism, accounting for only about one-twentieth of the total flux of larvae. Since organisms are assumed to be nonswimming, they move with the currents. The present model assumes a uniform vertical distribution of larvae in the column, although nonuniform configurations and vertical migration can be introduced with minor modification.

The effects of entrainment can be modeled by adding a sink at the grid boundary representing a river-like larvae loss at the Millstone Point location. Larvae crossing the outer boundaries of the modeled region are assumed to be lost from the system. This reflects the inhospitable conditions encountered there by the organisms. Likewise, no larvae are assumed to enter the region from the outside, so that the local population is the only one considered.

A series of simulations was carried out to model the fate of flounder larvae hatched in several areas of the greater Millstone Bight. The results indicate that the effects of entrainment on these organisms is small.

The first region of hatch extended from the mouth of the Niantic River north to the Sandy Point area. This region includes broad sandy bottoms which are favored by winter flounder for spawning. The lower river does not have this ideal bottom environment but it should reflect rapid larval loss and an earlier indication of larval dispersal in the Niantic Bay proper.

Another region likely to host hatching organisms is the upper arm of the Niantic River north of Sandy Point. In fact, many of the creatures from the first hatch are transported to this location (according to the results of the computer simulation), and remain there for a long period of time. This region appears to be the most favorable for the retention of larvae in the estuary. Although their loss rate is relatively low, their probable fate when entering Niantic Bay is virtually the same as for organisms hatched in other parts of the river, although it may occur several tidal cycles later.

Two bay hatch areas were also simulated. These were near the Niantic bar and in outer Jordan Cove. However, the larvae from these regions were rapidly transported out of the bight.

During the first several tidal cycles of the simulated river hatch there was rapid loss from the river. This loss is attributed to the fact that the lower river is not well suited to larval retention, and to the large gradient existing between river and bay, which promotes greater diffusion. Over one simulated tidal cycle, both with and without the effects of the power plant, about 72 percent of the larvae leaving the river at ebb return to the river on the following flood (Figure 5.4-4). The high probability of return may partially explain the strong larval retention characteristic of the estuary. Since there is little difference between the fraction returning with and without entrainment, it appears that potential entrainment mortality of organisms remaining in the river will be small.

The computer model of the Millstone Bight has been used to assess the effects of entrainment on constituents in the waterway by employing an outflow at one grid square representing the plant intakes. Since the circulation is rather crudely modeled in this region another model was developed to predict the local currents on a finer scale. A grid network consisting of 326 squares, 61 meters on a side, was developed for this purpose. Tidal currents in this network were computed using water levels from the larger model as boundary input.

The three intake structures are modeled separately, and results indicate that the total computed mass loss through the intakes from each model (305 and 61 meters grid size) is approximately equal. Thus the details of circulation in the intake region are realistically incorporated in the larger grid size model.

Larval dispersal over 20 tidal cycles for a Niantic River hatch area south of Sandy Point was simulated. The distribution of concentration is shown in Figure 5.4-5. The patterns show that most of the organisms leaving the river progress toward Millstone Point and continue out of the modeled area via Twotree Island Channel, where they are assumed lost from the system. Initially some larvae enter the outer Jordan Cove area, but in the model, they are rapidly flushed out. Thus there should be no build-up of organisms in this vicinity.

After several tidal cycles the rate of larval loss diminishes, and the fraction of larvae, out of the total remaining, which reside in the river, increases. This is indicative of the favorable retention characteristics of the river. It also indicates that the bay is freely flushed and planktonic organisms probably do not remain there for long.

The fraction of the initial organisms remaining at the end of each of the first 20 tidal cycles is shown in Figure 5.4-6. The loss is rapid for the first 12 cycles, but appears to lessen beyond that. There is an initial buildup in the cove, reaching a maximum after five cycles, then diminishing. Only 30 percent of the total organisms remain in the Millstone Bight after 20 cycles.

A direct comparison of those remaining both with and without the plant in operation is shown in Table 5.4-1. At the eleventh tidal cycle the percent difference in the two fractions is about 1.2 percent. At the twentieth cycle it has diminished to about 0.7 percent, and is decreasing. Therefore, for the 120 to 150 tidal cycles experienced by flounder larvae, projected plant mortality M_{pl} is probably less than 1 percent, based on the present results and model assumptions.

It has been shown that the Niantic River is ideally suited for a nursery area because it impedes larval loss by limiting the flushing rate. The dispersal model indicates that the total mass of larvae in the river decreases by only 4 percent per tidal cycle (after 20 cycles) and this fraction slowly becomes smaller. Assuming a 4 percent loss rate for a total of 150 tidal cycles (or 2-1/2 months), the model indicates that about 250 of 100,000 larvae hatched in the river remain in the system long enough to reach their benthic stage. This number is adequate to account for the apparent larval survival of the species. In contrast, the rest of the bay is flushed more rapidly.

A hatch area just south of the bar was simulated with the larval dispersal model (Figure 5.4-7). After just four cycles, only 27 percent of the initial mass is left. This compares with 80 percent for a river hatch. It is interesting to note that a sizable fraction of the remaining larvae are in the Niantic River. The distribution of concentration is similar to that after a river hatch, indicating that the primary loss path is through Twotree Island Channel. Another hatch area modeled was the outer Jordan Cove (Figure 5.4-8). The rate of loss is even more rapid. After a full tidal cycle only 19 percent of the initial mass was left. This indicates that the outer cove is well-flushed, and only the near-shore areas have a probability of retaining a larval population.

The results of present model studies indicate that larvae originating in the Niantic River remain in the Millstone Bight for long periods of time, and that mortality inflicted by the power plant on organisms in the river is minimal. Larvae escaping from the river suffer some damage from the plant, but they would likely be lost into Long Island Sound anyway. Organisms hatching in other areas of the bight are more rapidly flushed from the bay. Present results show that power plant operation during the winter flounder larval stage would result in a reduction in flounder entering year-class one of less than 1 percent.

<u>Winter Flounder Population Model</u>

The structure of the winter flounder population model is represented by Figure 5.4-9. YC_j for $j = 1,2,\ldots,12$ is the level (number or biomass) of the jth year-class. There is continuous loss from each year-class by natural and fishing mortality. The loss rates are proportional to the level of the particular year-class compartment with which they are associated. The loss of biomass due to fishing is added to the catch. At the beginning of each year, survivors of YC_j advance to YC_{j+1} and eggs are produced according to the mean fecundity of the year-classes. Recruitment to year-class 1 is a function of the number of eggs produced during the previous year multiplied by $1 - M_{p1}$, where M_{p1} is the reduction in recruitment resulting from entrainment.

Figure 5.4-9 describes a closed system where exchange with other populations is ignored. Accordingly, the model is conservative, since some of the reduction in recruitment from entrainment or impingement might be offset by immigration as local populations decrease.

Application of the model required specification of the initial conditions and parameters regulating the system. Values of the fishing and natural mortality rate, the mean weight and fecundity of each year-class and the sex ratio were based on the available literature. Both the Ricker (1954) function and a density independent function were used to define the relationship between egg production and recruitment.

According to Saila (1961):

$$\log(FEC) = 2.6712 + 1.1383 \log(W) \qquad (5.4\text{-}5)$$

where FEC and W are the fecundity (number of eggs per female) and weight in grams of winter flounder. The relationship between the length and weight of a winter flounder was reported by Lux (1969).

$$\log(W) = -5.239 + 3.138 \log(L) \qquad (5.4\text{-}6)$$

where L is in mm. The information in Table 5.4-2 was compiled based on the mean length of winter flounder by age and sex (Berry, et. al, 1965) a sex ratio of 7 females to 3 males (Saila, 1961), and Equations 5.4-5 and 5.4-6.

Initially there was no information available concerning the size of the resident winter flounder population in the Millstone Bight. Saila (1961) estimated the population density of yearling and older (age 2 and greater) winter flounder as 26.19 and 5.68 per $1000m^3$ for Charlestown and Green Hill Ponds, Rhode Island. Field studies to date have shown that winter flounder are concentrated in the Niantic River during the spawning season. Based on the area of the river ($3,196,800m^2$), an initial population size of 83,724 yearling and 18, 158 adult fish was assumed.

The mortality rate of adult winter flounder was assessed by Berry, et. al., (1965) and Poole (1969). Berry, et. al. (1965), estimated the instantaneous total mortality rate as 0.92 (60 percent per year) based on the age-class structure of fish from Charlestown Pond and Narragansett Bay. Poole (1969) considered tag and recapture data from Great South Bay, New York, and found an instantaneous total mortality rate of 1.38 (75 percent per year). Instantaneous fishing and natural mortality rates of 0.45 and 0.66 were therefore assumed for fish of year-class 2 and older; these values correspond to a total annual mortality rate of 67 percent per year and partitioning of mortality between source in a manner similar to the results reported by Poole (1969).

Pearcy (1968) estimated the survival from year-class 1 to 2 as about 40 percent. Pearcy's estimate was considered too high to be used in the model for the following reasons:

1. This survival rate is higher than Poole's estimate of the survival of adult fish.

2. This estimate would imply that the simulated population would be growing at an astronomical rate, more than tripling in the next year. Catch statistics for the Southern New England winter flounder do not indicate that the abundance of the species was increasing during the period when Saila (1961 a and b) and Pearcy (1968) conducted their pertinent research.

Therefore, the survival rate of yearling winter flounder was calculated so as to effect an equilibrium situation on the simulated population. Let

s_1 = annual survival of yearlings
s_2 = annual survival of fish 2 and greater
A = number of fish age 2 and greater

Then

$$
\begin{aligned}
YC(2) &= s_1 \cdot YC(1) \\
YC(3) &= s_2 \cdot YC(2) = s_2 s_1 \cdot YC(1) \\
YC(4) &= s_2 \cdot YC(3) = s_2^2 \cdot s_1 \cdot YC(1) \\
&\vdots \\
YC(j) &= s_2^{j-2}\, s_1 \cdot YC(1)
\end{aligned}
\qquad (5.4\text{-}7)
$$

and

$$A = \sum_{j=2}^{12} s_1 \cdot s_2^{i-2} \cdot YC(1) = s_1 \cdot YC(1) \cdot \sum_{j=0}^{10} s_2^{j} \qquad (5.4\text{-}8)$$

Thus

$$s_1 = A \,/\, [YC(1) \cdot \sum_{j=0}^{10} s_2^{j}] \qquad (5.4\text{-}9)$$

If $s_2 = 0.33$, YC(1) = 83,724 and A = 18,158, then $s_1 = 0.1454$ or an instantaneous mortality rate of 1.928. Based on the above discussion of mortality rates, the initial age-class structure shown in Table 5.4-3 was assumed for the simulated population.

Tables 5.4-2 and 5.4-3 were used to estimate the mean fecundity of mature females as 350,296 eggs. Assuming 5,996 mature fish (Table 5.4-3), 70 percent females and a 10 percent successful hatching rate (Saila, 1961), then

$$(0.7)\ (5,996)\ (350,296)\ (0.1) = 1.469 \times 10^8$$

hatched eggs result in 83,724 yearling winter flounder or about 55 per 100,000 if the simulated population is at equilibrium. The agreement between the above and Pearcy's (1968) estimate of 44 yearlings per 100,000 hatched eggs is encouraging, since these results were obtained independently.

In order to apply the model described in Figure 5.4-9, a relationship between egg production and recruitment to year-class 1 is required. The ratio of 55 yearlings per 100,000 hatch eggs could be used to define such a realtionship as follows:

$$YC_i(1) = 0.000055\ P_{i-1} \qquad (5.4\text{-}10)$$

where i refers to the year and a 10 percent successful hatching rate is assumed. This relationship is density independent in that the survival rate to a year of age is independent of the numbers of eggs produced. Since the population cannot compensate for loss due to power plant mortality, even a very low value of M_{p1} will result in an exponential decay of the population eventually approaching zero. This situation is unrealistic since most populations are stabilized by density dependent stock-recruitment relationships (Ricker, 1954). The following density dependent relationship between egg production and recruitment was adapted from Ricker (1954):

$$YC_i(1) = P_{i-1}\ [e^{a-b\ \cdot\ P_{i-1}}] \qquad (5.4\text{-}11)$$

where a and b are parameters.

Using several values of $YC_i(1)$ and P_{i-1}, a and b can be estimated by simple linear regression after some manipulation of Equation 5.4-11. Unfortunately such data are rarely available, and when they are, the range of P_{i-1} is often so limited, that little confidence can be placed in the results. Therefore, a deterministic procedure for parameterizing Equation 5.4-11 based on a limited amount of data was developed.

If S_r is the fraction of females in the population, FEC is the average fecundity and R_1 is the expected number of recruits from N_1 mature fish, than using Equation 5.4-11,

$$a = \log_e \frac{R_1}{S_r \cdot FEC \cdot N_1} + b \cdot S_r \cdot FEC \cdot N_1 \qquad (5.4\text{-}12)$$

The Ricker Stock Recruitment function is based on the assumption, that in the absence of fishing, the population will adjust itself to a maximum level, N_{max}, at which it is at equilibrium (ignoring environmental fluctuations). This unfished equilibrium level occurs when the loss due to natural mortality equals the addition of recruits. Therefore, the second parameter of the stock recruitment function can be calculated if the size and average fecundity of the virgin (unfished) stock and level of natural mortality are known.

The annual natural mortality rate (M) times N_{max} was set equal to the recruitment to year-class 1 (for N_{max} mature fish) times the survival rate from age 1 to sexual maturity (s). Equation 5.4-12 was substituted and the result was solved for b yielding the following:

$$b = \frac{\log_e \left[\dfrac{M}{s \cdot S_r \cdot FEC}\right] - \log_e \left[\dfrac{R_1}{N_1 \cdot S_r \cdot FEC}\right]}{FEC \cdot S_r \cdot (N_1 - N_{max})} \qquad (5.4\text{-}13)$$

A reasonable estimate of N_{max} was sought in the historical literature. The longest series of relative abundance for a New England fishery was recorded by the United States Fish and Wildlife Service Hatchery at Boothbay, Maine, from 1910-1940 (reported by Perlmutter [1947]). The Fish and Wildlife Service used fyke nets to collect mature female winter flounder for hatchery use.

These data indicate that the Maine fishery has gone through three rather distinct levels of relative abundance (an indication of population size). The mean catch per net for the periods 1910-1919, 1920-1933, 1933-1940 was 267, 107 and 39 fish, respectively. The level of exploitation during the first period was probably very low, since the level of landings prior to 1919 was low, according to the limited amount of catch data available. A comparison of the mean relative abundance between the first and third period indicates that the level of exploitation reached during the late 1930's in Maine waters could reduce the population size of a virgin winter flounder stock by a factor of 7. Perlmutter's (1947) comparison of fisheries throughout New England and New York indicates that later trends in the Maine fishery were reflected in Connecticut waters. Poole (1969) showed that the level of exploitation reached during the late 1930's for the Great South Bay, New York, winter flounder population was similar to the present level of exploitation. Therefore, the assumption that $N_{max} = 8N_1$ seems reasonable, since the population size of Boothbay stock may have declined slightly from its virgin level prior to 1910.

Values of other constants in Equations 5.4-12 and 5.4-13 were assumed based on the earlier discussion of population parameters (N_1 = 5,996, R_1 = 83,724, FEC = 350,296, S_r = 0.7, M = 0.483 and s = $s_1 s_2$ = 0.0751). The estimate of a and b obtained were -9.66 and 7.54 x 10^{-11}, respectively. The results are based on the assumption that the average fecundity of the breeding stock was similar for populations of N_1 and N_{max} individuals. When the population was simulated using these estimates for zero fishing mortality, it converged to an equilibrium population level of 47,842 mature fish. This level is about 8 times the initial level assumed for the simulated population as desired.

The life expectancy of a nuclear power plant is about 35 years. Therefore, the system described above was simulated for 35 years at various levels of entrainment mortality (M_{p1}) and for an additional 65 years with $M_{p1} = 0$. The results are shown in Figure 5.4-10.

Since the Ricker stock-recruitment function was based on a rather limited amount of information, the model was also run under the unrealistic assumption that recruitment is density-independent (Equation 5.4-10) and thus there is no compensation for entrainment losses. The results do not differ drastically from Figure 5.4-10 during the first 35 years of the simulation. The population levels reached in 35 years are 4 to 40 percent lower than with the Ricker stock-recruitment function with the largest difference occurring for $M_{p1} = 0.20$. Using Equation 5.4-10, there is no recovery of the population after entrainment is terminated. The results based on Equation 5.4-10 are conservative since they do not permit compensation for entrainment mortality and thus certainly overestimate the potential effect of the plant.

For the level of M_{p1} indicated by the larval dispersion model (1 percent or less), Figure 5.4-10 indicates a potential impact of a 6 percent reduction in total population level after 35 years. If all compensatory mechanisms are ignored, a 9 percent reduction is indicated.

It must be emphasized that these results probably overestimate the effect of entrainment since they ignore (1) the survival of some organisms passing through the plant; (2) immigration of winter flounder; (3) input of larvae from outside the bight; (4) density dependent growth, fecundity, adult mortality and, in some cases, larval mortality; and (5) a reduction in fishing mortality as fishermen become discouraged and reduce their effort. Therefore, the results should not be taken as predictions, but as limits on the potential danger from various levels of M_{p1} based on the available information.

The initial estimate of power plant impact from larval winter flounder entrainment assumed an adult Niantic River population of 18, 158 based upon density information from other sources. In order to refine model predictions tag-recapture population estimates were made and the model rerun.

Estimates of the breeding population of winter flounder (>150 mm in length) in Niantic River were based on the Jolly-Seber technique and in 1975 gave an $\hat{N} = 160,073$ with an upper bound for the standard error of $\hat{N}$ estimated as $\hat{S.E.}(\hat{N}) = 18,300$ (Section 4.9.4). The previously described population model was run using the new estimate. The same values were used for age-specific fecundity, average fecundity, total mortality, fishing mortality, weight and range for plant mortality as were used initially.

Also the same sex ratio (7:3 females to males) and hatching survival rate were used. The population estimates were based on winter flounder at least two years old (>150 mm), so using the total mortality rate for these year-classes ($Z_i = 1.11$ for all $i \geq 2$),

$$\hat{N} = N_2 \sum_{i=1}^{10} e^{-iZ}$$

where N_2 is the size of the second year-class. So

$$N_2 = \hat{N} \Big/ \sum_{i=1}^{10} e^{-iZ}$$

$$= \hat{N} / 1.49156$$

Thus, using Jolly's estimate ($\hat{N} = 160{,}073$), $N_2 = 107{,}319$. By forward and back calculations based on the assumed mortality rates the remaining age structure was determined, and is given in Table 5.4-4. Table 5.4-5 gives the total population size of winter flounder for the next 100 years, under a range of plant mortality rates (0.0, 0.01, 0.03, 0.05, 0.08, 0.12, 0.20) for a 35-year period, and 0.0 plant mortality for the remaining 65 years. Figure 5.4-11 presents this data graphically.

There is a linear relationship in the model output based on the inputted population size. Under the varying plant induced mortality, after the plant ends its effect the winter flounder population responds to the lessening mortality rate and returns toward its original level. The greater than initial plant mortality the greater the response time.

Hydrodynamic Model Development

The hydrodynamic model that simulated the impact of entrainment on winter flounder larvae was developed using a finite-difference technique. The momentum equations for a fluid are solved along with the equation of mass conservation to give two horizontal velocity components and the surface water level at each of the square grids used to define the modeled region. Several types of input data are used to specify a particular geographic area:

gridnet configuration

local depths at grid nodes

local friction factors

terrestrial latitude

appropriate boundary inputs such as tides and river or plant flow rates.

Computed velocities represent the average over a section so that vertical current structure is hidden in the output. This limitation is not severe and can be compensated for in some ways. The computer works with a mathematical reproduction of the modeled region. Water flow is described by a set of equations, which are solved by numerical procedures. The equations central to the model are the Navier-Stokes momentum equations plus conservation of mass. They are examined in detail in Appendix B of URI's Interim Report (1975).

Gridnet Selection

Throughout the course of the winter flounder modeling project, the gridnet configuration was constantly being evaluated and refined, using data inputs and modeling experience. Consequently, at least four configurations were used for the study.

At the outset, a mesh of 78 squares, 2,000 feet on a side, was employed to model the Niantic Bay (Figure 5.4-12). This was later extended southward to include 20 more squares.

Concurrently a separate model of the Niantic River was developed (Figure 5.4-13) which had 123 squares, 500 feet on a side. This was to be used in connection with the Niantic Bay model.

Grid size is selected by applying several criteria. When modeling currents, local geomorphology guides the choice since topographic features, such as narrows, channels, islands and banks, and irregular shoreline, must be faithfully reproduced. However, mitigating against small grid size is the speed of the computing machine and the cost of computer time. The large-grid preliminary network was justified because it was a first attempt at modeling the region and was intended to highlight any problems which could arise. A more refined configuration with 1,000-foot squares was later introduced to bring out more details of the local circulation in crucial places, such as Twotree Island Channel, the Niantic River, and the area close the the intake structures. It is felt that this grid size is fully adequate for accurate current predictions.

Experience in the use of the two models (river and bay) quickly showed that several difficulties would make tandem operation cumbersome. The major drawback was that the specification of model boundary conditions at the interface (the mouth of the Niantic River), to be accurate, would force the two models to be run simultaneously. This could not be done conveniently, so a unified gridnet of the entire Millstone Bight was advanced. it contained 299 squares, 1,000 feet on a side (Figure 5.4-14). Preliminary larvae simulations were carried out using this mesh.

Finally, the above was extended eastward to Goshen Point by the addition of 63 squares (Figure 5.4-15). This was because some phenomena of concentration were not sufficiently well-known in the Twotree Island Channel.

Boundary Conditions

At all open water boundaries some parameter (velocity or water level) must be specified. The largest open bound is the southern interface with Long Island Sound. Here the water level is input as a simulation of a tide wave progressing roughly westward. A program of field observations was carried out to provide detailed information on the tide in the bight.

The power plant itself both extracts from, and discharges into, the waterway. An outflow was used to simulate the intakes, and an inflow to simulate the discharge from the quarry. Because of the large grid size the three intake structures are located in one grid square. An approximate flow rate of 4,000 cfs was used in the assessment of the effect of winter flounder entrainment for 3 unit operation. This approximation to the total flow for 3 unit operation (4342 cfs) is appropriate for the degree of resolution of the mathematical modeling study.

Small-Grid Modeling at the Intakes

The computer model of the bight has been used to assess the effects of entrainment on constituents in the waterway by employing an ouflow at one grid square representing the plant intakes. Since the circulation is rather crudely modeled in this region, another model was developed to predict the local currents on a smaller scale. A grid network consisting of 326 squares, 200 feet on a side, was developed for this purpose (Figure 5.4-16). Tidal currents in this network were computed using water levels from the larger model as boundary input. Current vectors at full flood (Figure 5.4-17) and at full ebb (Figure 5.4-18) have been plotted. The current speed appears to be considerably greater during ebb than during flood. The reasons for this are not as yet fully understood.

The three intake structures are modeled separately. The larger model could not attain this degree of resolution because of the large grid size (1,000 feet). The existing intakes (Units 1 and 2) and assumed to draw water about 1,000 cfs each and the proposed intake (Unit 3) about 2,000 cfs. A uniform concentration at the boundaries was used as input, and the mass flow was modeled over a full tidal cycle.

Unfortunately, the small-grid model did not include the effects of the outfall, which reduces the concentration somewhat at the southeastern boundary. However, after one cycle, the two estimates of total mass entrained as calculated by each model were within 30 percent of each other, with the large-grid model giving the lower value, as expected. Thus the large-grid model adequately incorporates the details of the local circulation around the intakes and error in the estimate of entrained mass will be only minimally dependent upon the single-square intake approximation.

Verification of the Hydrodynamic Model

The Niantic River-Niantic Bay system forms an inlet of Long Island Sound, and is subject to the tidal dynamics of that body of water. In addition, several small streams provide surface water runoff to the estuary at several locations. Finally seasonal winds are evident in the area. Each of these factors may be responsible for determining the water circulation in the inlet.

Tidal dynamics (Lelacheur, 1932) provide the basic repetitive patterns of circulation. A tide wave moving from Fishers Island westward at flood along the Sound causes westward currents nearly parallel to the shore. The ebb currents run in the opposite direction, eastward along the coast. The Coriolis force produces slightly stronger floods than ebbs, but the difference is slight and will be neglected. The tide can be thought of as a wave moving parallel to the coastline, with cophase lines extending southward (Bumpus et. al., 1973).

The drainage area of the inlet is only 30 square miles, according to Marshall (1960) and the streams that feed the river and bay introduce relatively little fresh water. The two largest, Latimer Brook and Jordan Brook, collectively add about 50 cfs on the average, although the maximum is about 150 cfs. Some reduction of salinity is evident in the upper reaches of the Niantic River, but negligible reduction occurs elsewhere in the inlet. Consequently, the additional circulation caused by both fresh water runoff and possible density-driven currents is ignored because it is much smaller than the tidal currents.

Seasonal winds in the area vary from the southwest during the summer to the northwest during winter. Because of the shallowness of the inlet, the wind-driven currents are parallel to the wind direction. Quicker response to changes in wind velocity are to be expected in shallower water (i.e., the river), with the surface waters reacting first. Steady winds could alter the basic tidal circulations; the data gathered during hydrographic surveys was used to assess these effects.

Tides and Tidal Currents

Local tidal conditions in Niantic Bay are dominated by the tides of Long Island Sound. In the Sound, the predominantly semidiurnal (two highs and two lows per day) tide can be thought of as a long wave which progresses westward and which is modified by local bathymetry to give various ranges and times of high water at different points along the coastline. Because the western entrance to Long Island Sound (the East River), offers relatively great resistance to tidal changes, the Sound behaves much like a simple bay in that the amplitude of the tide increases in the westward direction. Coriolis accelerations influence the circulations so that currents are stronger along the Connecticut shore during flood, although the difference may be as little as 0.1 knot, and coastal topography makes the difference less noticeable. As the wave progresses down the waterway the time of high water changes, so that any phase of the tide occurs earlier at the eastern entrance of the Sound.

As part of the ecological monitoring project for the Millstone Nuclear Power Station, two hydrographic surveys were performed (see Section 4.2). The knowledge of the tides gained from the surveys is used to drive the hydrodynamic model, and the velocity vector output used to check the accuracy of the predictions.

The field data were analyzed for mean tidal range and lag, and the results are given in Table 5.4-6. The numbers show the tendency for an increase in range and an increasing time lag in the more westerly stations, as would be expected from a knowledge of the tides in the Sound.

When the phase lag data are plotted as a function of distance along the coast (Figure 5.4-19) there appears to be a significant deviation from a linear relationship. This is believed to result from the presence of Twotree Island and Bartlett Reef which cause friction and retard the natural progression of the tide wave. Thus the phase lag is represented by a linear function plus a sinusoidal term to account for this local anomaly.

The data from the one offshore tide gauging station (T. G. 2, winter survey. Section 4.2) indicates that the phase offshore lags that at the coast by a few minutes. The likely reasons is that Coriolis pile-up at the shore produces a tide-like component. This effect can be put into the hydrodynamic model.

A two-day period (11-12 February, 1974) during the survey period was chosen as a data basis on which to verify the model because the tides were at their monthly mean. The tidal parameters and bottom friction coefficients were altered to achieve the best fit, in terms of flood and ebb current speed and direction. Winds were weak during the test period.

The tide range at Goshen Point, R_2, was taken to be 76.3 cm, and at Black Point the range, R_1, was 82.3 cm. If x is the dimensionless distance from Black Point to Goshen Point, then the tide at the southern boundary is

$$n = [R1 = X\ (R_2-R_1)]\ \sin \frac{2\Pi(t-e)}{12.42} \qquad (5.4\text{-}14)$$

where the phase lage is

$$e = 0.333\ x - 0.05\ \sin\ _{2\Pi x} \qquad (5.4\text{-}15)$$

The tide at the eastern (Goshen Point) boundary varies linearly, with the phase at shore occurring 5 minutes earlier. At the western (Black Point) boundary the tide is uniform and corresponds to the offshore value.

Bottom friction coefficients were varied but had relatively little effect on the flow. Differences in the ranges R_1 and R_2 caused a change in the time interval between low water and maximum flood. The total time lag across the bay, as well as its shape, had the most influence on the magnitude of the currents.

Plots of the data and the computed current magnitudes and directions for February 11, 1974 are shown in Figures 5.4-20 through 5.4-22 and a comparison by station at flood and ebb (Figures 5.4-23 and 5.4-24). In general, the agreement is good. At station cm4 in Jordan Cove, the computed current is considerably smaller than that found by the current meter. However, Richardson current meters often record wave motion, especially in shallow water at low velocities, so the data most likely contains this bias (Figure 5.4-24).

Influence of Winds

During the course of each survey the local wind conditions were recorded so that their influence can be ascertained. It was found that winds have only a minor effect on the circulation.

The seasonal pattern of winds in southern New England is characterized by strong (17 knots) winter winds blowing from the northwest, and weaker (11 knots) summer winds from the southwest. Each regime was captured during the survey periods (Figures 5.4-25 and 5.4-26).

Winter storms are occasional phenomena along the New England coast, with strong wind peaks occurring every several days (Figure 5.4-27). The effects of the peak of 5 February 1974 were examined. It was expected that shallow, nearshore currents would be the most vulnerable. A comparison of currents at the two stations cm4 and cm3 confirms the speculation (Figure 5.4-28). At the Jordan Cove station, there is evidence for increased wind-wave action with a peak in velocity corresponding to the peak winds. However, at cm3 in Twotree Island Channel, only a minor perturbation of the surface current is evident. Also, Shonting (1969) found that in Rhode Island Sound, an area similar to the Millstone Bight, winds contributed very little energy to the total flow, and that tidal energy was dominant. Thus it appears that winds have only a secondary influence on the circulation, especially when the event of interest, the hatch and larval stage of winter flounder, spans about 2 months in time. Over this interval the periodic tidal circulation can be expected to be more important than the random impact of atmospheric storms.

Concentration Model

The dispersal of larvae around the estuary may be simulated on the computer by considering the factors which contribute to their motion. The major cause of larvae transport is the ambient currents which carry the organisms along with the flow. A secondary cause is the self-propellant properties of the fish larvae, which usually contribute only a small fraction to the total motion. These effects are examined and an equation of larval dispersal is dericed for use as a predictive tool. The approach follows closely that of Leendertse (1970).

Fish larvae motions in a coordinate system can be described by two methods: (1) the Lagrangian and (2) the Eulerian. In the Lagrangian approach, each larvae is described separately and is followed around the waterway. The Lagrangian method has many advantages and is the preferred one for describing organisms with strong vertical migratory tendencies. (Such tendencies have not been found for winter flounder larvae) However, it was felt that the large number of individuals required to represent a hatch of flounder would necessitate long computer run times and would be too costly. The Eulerian approach describes a function (in this case a mass of larvae) at all points in space. This function is quite complicated, so the values at only certain points (the grid nodes) within the field are obtained. The approach assumes that the function is continuous in space.

In the Niantic River, the initial average concentration of larvae is average fecundity times the survival rate from egg to larvae times the number of females per total volume, or approximately

$$(350{,}000)\ (0.10)\ (10{,}000)/7{,}000{,}000 = 50.0\ \frac{\text{larvae}}{\text{m}^3}$$

Thus the estimated number is large enough so that the larvae can be reasonably well treated as a continuous concentration in the Eulerian sense. The detailed mathematical theory is given in Appendix C of URI's Interim Report (1975).

Concentration Model Verification

Comparison between observed and predicted entrainment of dye have been made in order to verify the concentration model of greater Millstone Bight. Ocean Systems, Inc., conducted five dye release experiments during June and July, 1975, and in March, 1976. The experiments consisted of the release of approximately 200-250 pounds of 20-percent Rhodamine WT solution at a fixed location (Figure 5.4-29). Background data for the experiments appear in Table 5.4-7. The duration of each dye release was nearly one tidal cycle.

The concentration of dye at the Unit intakes were recorded by Ocean Systems, Inc., over four-day periods, beginning with dye introduction. The results were integrated and reported as total percentage entrainment.

Given the location and time of the dye release (from which tidal stage was read from tide tables), the Concentration Model was run with this tidal phase input and with a simulated Unit intake. Predictions of percentage entrainment were obtained from the model print out. The observed and predicted results are compared in Table 5.4-8.

Details of each dye release can be found in the final report on modeling (URI, 1976b). Briefly, however, the results indicate that model entrainment predictions for Niantic Bay dye releases are in good agreement with field measurements (Table 5.4-8).

Assessment of Three Unit Impact

Entrainment

The effect of entrainment of winter flounder larvae was estimated from the hydrodynamic and population models described earlier in this section 5.4. The entrainment mortality (M_{p1}) has been estimated as 0.01 (Refer to Table 5.4-1). The effect of this mortality was simulated using the winter flounder population model and the population estimate in Table 5.4-4. After 35 years of power plant operation the simulated population would be reduced by about 6% (Figure 5.4-30).

An independent assessment of the number of winter flounder entrained by the power plant is available from the entrainment monitoring studies. Based on the 1975 entrainment results, the entrainment for 3 units was predicted to be between 1.99×10^8 and 2.61×10^8 larvae (Table 5.3-8).

Based on the population size presented in Table 5.4-4, the fecundities presented in Table 5.4-2, the sex ratio of 70 percent females, and the hatchability of eggs of 10 percent the number of larvae originating in the Niantic River can be calculated. This estimate is about 1.3×10^9 larvae. Comparing the number of winter flounder larvae entrained based on the entrainment monitoring studies with the number of larvae estimated to be produced in the

Niantic River gives between 15 percent and 20 percent of the larvae originating in the Niantic River passing through the intakes. The fate of these larvae is, if the power plant were not operating, unknown in terms of the probability of recruitment into the adult age classes.

This estimate does not consider the source of these larvae or the probability that these larvae would be recruited into the adult population. Therefore, the comparable estimate from the winter flounder modeling study is not the entrainment mortality (M_{p1} = 0.01) but the total number of larvae which pass through the intakes. Based on the results presented in Table 5.4-1 about 70 percent of the larvae originating in Niantic River pass through the open water boundaries. Of those transported out of the modeled area 28 percent pass through the intake (M. Sissenwine, pers. comm.). Therefore about 20 percent (.70 x .28 = .196) of the original cohort pass through the intake. This prediction is quite close to the estimate developed from the entrainment studies (15 to 20 percent.)

Impingement

The effect of the impingement of winter flounder on the traveling screens at Millstone was also simulated. Estimates of the average number of winter flounder which die from impingement at Unit 1 were developed from the number which are impinged at Unit 1 (Tables 4.10-1 through Table 4.10-4) and the mortality associated with impingement (Table 4.10-13).

The number of winter flounder impinged was converted to a mortality rate by considering the proportion of the winter flounder population impinged. The small and medium size classes of impinged flounder (Tables 4.10-1 through 4.10-4) correspond to the size of fish no older than age 1 (Table 5.4-2). The largest size class of fish impinged is most closely approximated by age class 2 winter flounder.

The number of winter flounder killed by impingement was then extrapolated from the information on Unit 1. As described in Section 3.2.2 Unit 3 will employ a fish handling system which should eliminate mortality due to impingement at Unit 3. Therefore the most probable number of winter flounder killed by impingement was derived by extrapolating from the Unit 1 information by the increased flow associated with Units 1 and 2. These estimates of annual impingement loss are 3381 age 1 and 2032 age 2 winter flounder.

The mortality rate associated with this loss was calculated by considering the proportion of the winter flounder population by age which would be affected. Based on the population structure in Table 5.4-4, the proportion of age 1 fish would be 0.004 and the proportion of age 2 fish would be 0.019. The total instantaneous mortality (Z_i).

$$Z_1^1 = 1.928 - \ln (1 - 0.004) = 1.933$$

The adjusted age 2 total instantaneous mortality rate is (Z_2^1).

$$Z_2^1 = 1.110 - \ln (1-0.019) = 1.129$$

The effect of impingement was then considered by a 35 year simulation with the adjusted mortality rates. The results of this simulation are presented in Figure 5.4-30. After 35 years of simulation the population size is reduced 12 percent compared to the equilibrium population size. The population was then simulated with a 65 year recovery after the terminaton of power plant related impingement mortality. The population recovered to within 2 percent of the equilibrium population.

Impingement and Entrainment

The combined effects of the mortality associated with entrainment and impingement for 3 unit operation was also simulated. The mortality rates associated with entrainment and impingement were the same as used in the preceeding sections of 3 unit assessment.

The results of this simulation are presented in Figure 5.4-30. The simulated population was reduced by 18 percent compared to the equilibrium population after a projected 35 years of power plant operation. The simulated population recovered to within 3% of the equilibrium after 65 years from the termination of the effect of power station operation.

These estimates of the change in the simulated winter flounder population from 3 unit operation can be compared with the annual variation in the winter flounder population. The variation between the Niantic River population estimate for 1975 and 1976 is 55 percent of the average for 1975 and 1976 (Tables 4.9-37 and 4.9-39).

Based on this comparison it would appear that the percent reduction predicted in the simulated winter flounder population experiencing the effects of entrainment and impingement for 3 unit operation is within the annual variability in the winter flounder population size estimates.

Caution should be applied however in the interpretation of these simulation results. They represent bounds within which the population may respond. Therefore they should not be interpreted as absolute predictions. Conservative assumptions have been made in portions of the model formulation which tend to overestimate the effect of the power station.

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5.5 Menhaden Population Dynamics - Power Plant Impact

5.5.1 Introduction and Summary

This section contains the results of a study on the population dynamics of the Atlantic menhaden and the effects of Millstone Nuclear Power Station - Units 1, 2, and 3 on that population. This study was developed by Dr. Thomas Horst of Stone & Webster. This section represents the report developed for Northeast Utilities on this study.

The study consisted of a review of the literature on the population ecology of Atlantic menhaden and a review of the published mathematical models for menhaden population dynamics. Concurrently with this study the University of Rhode Island (URI) has reviewed the literature on the methodology for the estimate of mortality in early life stages of fishes such as the menhaden. URI has developed a method for estimating the mortality to zero age class fish and has reported this method in Vaughan et al (1976). The information on menhaden population dynamics has been synthesized and used to develop a life cycle model (MENDYN) which has been computerized and used to make predictions of the effect of Millstone station on this species.

The results of this study suggest the effect of Millstone Station on the Atlantic menhaden population is so minor that it probably will be undetectable. The worst case estimate of power station mortality rate was 0.00087. This corresponded to a single incident which occurred once in the five years of Unit 1 operation. This degree of exploitation when projected each year for 50 years resulted in a reduction in population size by 1.1 percent compared to the unaffected population.

5.5.2 Menhaden Population Ecology

Atlantic menhaden are found from the central part of Florida to Nova Scotia (Nicholson, 1975). A tagging study, conducted by the National Marine Fisheries Service from 1966 through 1969, in which over one million adults were tagged with internal ferromagnetic tags, supports three general hypotheses (Dryfoos, et al., 1973). The adult fish appear to migrate southward in the fall and northward in the spring; the adult menhaden tend to migrate farther northward each spring as they become older and larger; the juvenile menhaden also migrate southward in the fall. This study also provides quantitative estimates of the percent of fish tagged in one area that would be expected to be found throughout the geographic range the following year.

The life history of the Atlantic menhaden has been described and summarized in a number of papers. The species spawns in the open ocean and larger sounds and bays. Spawning in the northern part of the geographic range generally occurs from May to October (Reintjes, 1969). After a period of time in the open ocean, the larvae move inshore and enter the estuaries where they metamorphose into young of the year menhaden (Kendall and Reintjes, 1975).

The adults exhibit a surface schooling behavior in the warmer months. As the waters cool, the adult menhaden no longer exhibit schooling behavior and move offshore as well as southward (Reintjes, 1969).

The life span of the Atlantic menhaden can be as long as 12 years, but the occurrence of individuals older than age seven is infrequent. Only one 12-year old specimen was noted in a sample of 116,000 fish (Reintjes, 1969). Menhaden begin to reach sexual maturity at age one, with all individuals sexually mature at age three (Higham and Nicholson, 1964).

The sex ratio of the population was analyzed by Reintjes from the 1955 to 1966 purse seine landings. Based on a sample of about 185,000 fish, the sex ratio remains essentially the same from year to year and between geographic areas. The number of males and females is approximately equal until about four years of age. Fish older than four years are represented by more females than males (refer to Table 5.5-1).

Fecundity can be determined from several relationships. Higham and Nicholson (1964) collected data on the number of ova as a function of length, from which the following relationship was developed by Vaughan, et al (1976).

$$F = (3.67\times10^{-7})\ L^{4.8} \qquad (5.5\text{-}1)$$

where:

F is the number of ova per female

L is the fork length in millimeters.

The relationships between length and age as well as weight and age have been determined separately for each sex by Reintjes (1969). These relationships for males are:

$$L_t = 334\ [1 - \exp - 0.484\ (t+0.025)] \qquad (5.5\text{-}2)$$

$$W_t = 724\ [1 - \exp - 0.475\ t]^3 \qquad (5.5\text{-}3)$$

where

L_t is the fork length, at time t, measured in millimeters

W_t is the body weight, at time t, measured in grams

t is the age in years equal to one more than the number of annuli

The relationships for females are:

$$L_t = 345\ [1 - \exp - 0.464\ (t+0.032)] \qquad (5.5\text{-}4)$$

$$W_t = 817\ [1 - \exp - 0.478\ t]^3 \qquad (5.5\text{-}5)$$

From the basic population parameters, a life table of age, sex ratio, length, weight, and fecundity can be constructed (Table 5.5-1).

The information available on mortality has mostly been derived for the adult portion of the life cycle. Observations have been reported by Reintjes (1969) and Westman and Nigrelli (1955) of mass localized mortalities of menhaden. The causes of these incidents have not been conclusively determined, but they appear to be related to (a) capture by a fishing net which failed to hold the catch, (b) near freezing temperatures in estuaries and the lower reaches of tributaries, (c) low dissolved oxygen, and (d) pollution by industrial wastes or agricultural chemicals. Similar localized mortalities have occurred at power stations (Young, 1974).

Estimates of the mortality rate have been made for both natural and fishing mortality. Dryfoos, et al, 1973, determined an instantaneous natural mortality of 0.52 and an instantaneous fishing mortality of 0.95 from tag return data. Schaaf and Huntsman (1972) determined a relationship between total instantaneous mortality rate and effort. The instantaneous natural mortality rate in this function was 0.368 and the optimum instantaneous rate of fishing mortality was 0.8.

Less information is available on the mortality rate during the first year of life. Schaaf and Huntsman (1972) fit a Ricker (1958) stock and recruitment function from number of adults age three and older to the number of age one fish with a time lag of one year, as follows:

$$R = S \exp\left[(1{,}626-S)/654\right] \qquad (5.5\text{-}6)$$

where:

R is the number of recruits, in millions

S is the number of spawners, in millions

This relationship was modified by Jensen (1975) using an age specific probabilistic approach. A density independent estimate of the zero age class mortality has been made by Vaughan et. al., (1976). This estimate was developed from an updated data base presented by Nicholson (1975). The total instantaneous rate of natural mortality for age zero was estimated to be 9.475.

The information reviewed for this report on the population ecology of the Atlantic menhaden has been used by several people in the development of mathematical models to describe the population dynamics of the species.

5.5.3 Menhaden Population Dynamics Models

The mathematical models developed to describe the dynamics of the Atlantic menhaden have been variations on the self-regenerating dynamic pool concept. This idea is illustrated in the Leslie model (Leslie, 1945).

$$\underline{N}_{t+1} = \underline{A}\, N_t \qquad (5.5\text{-}7)$$

where:

$\underline{N}$ is a 1 by x column vector corresponding to the number of individuals from age zero to x

$\underline{A}$ is the transition matrix from time t to t+1

$$\underline{A} = \begin{bmatrix} F_o & F_1 & \cdots & F_{x-1} & F_x \\ S_o & 0 & \cdots & 0 & 0 \\ 0 & S_1 & \cdots & 0 & 0 \\ \cdot & \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot & \cdot \\ 0 & 0 & & S_{x-1} & 0 \end{bmatrix} \qquad (5.5\text{-}8)$$

where:

F_i is the number of offspring of individuals age i represented in the zero age group in time t+1

S_i is the probability of survivorship of an individual of age i from time t to t+1

The parameters F_i and S_i can be constants or functions of an independent variable, such as population density. The reproduction portion of this model (F_i) can be made independent of the age of the spawners by applying a stock and recruitment function.

Previous Models for Menhaden Population Dynamics

Schaaf and Huntsman

This model for the Atlantic menhaden population is a self-regenerating dynamic pool model. The data base for this model was taken from a number of published studies with data collected up to 1969, which are referenced by Schaaf and Huntsman (1972).

The model assumes nine age groupings beginning with year class one through age eight. The last age grouping is ages eight to ten years. The recruitment which occurs at 1.5 yr. is modeled with a Ricker stock and recruitment function. This is the only density dependent or compensatory mechanism in the population.

The instantaneous rate of natural mortality was estimated to be 0.368. The maximum sustained yield produced by this model was about 300,000 to 400,000 metric tons. This yield was obtained at an instantaneous rate of fishing mortality of 0.8.

Jensen

The data base and population statistics used by Schaaf and Huntsman (1972) were modified in another self-regenerating dynamic pool model developed by Jensen (1975).

The major difference between the models is the method of modeling the reproduction process. Jensen's model calculates the survivorship of the prerecruitment portion (Sr) of the life cycle:

$$Sr = \exp\left(-k \sum_{x=r}^{v} N(x,t-1) + e\right) \qquad (5.5\text{-}9)$$

where:

k — is the empirical survival constant for the prerecruitment phase

N(x,t-1) — is the number of age x individuals at time t-1

r — is the age of recruitment

v — is the maximum age attainable

e — is the unexplained variability assumed to be normally independently distributed with mean zero standard deviation

The number of recruits can then be calculated by:

$$N(r,t) = h \sum_{x=r}^{v} N(x,t-r)\ Sr \qquad (5.5\text{-}10)$$

where:

h — is the empirical reproduction constant

N(x,t-r) — is the number of individuals of age x at time t-r

The new information incorporated into Jensen's model is the random variability or e. A sensitivity analysis is performed for increases in natural mortality from hatching to recruitment and decreases in the reproduction constant. Perturbations of 0, 10, 20, 30, 40, and 50 percent of each parameter values were made while the others were held constant.

The analysis suggests that yield to the fishery is most sensitive to changes in the growth constant and least sensitive to changes in natural mortality and survival from fry to recruits.

<u>URI Estimate of Age Zero Mortality</u>

A method has been developed by Vaughan, et al (1976), for estimating the zero age class mortality from the vital statistics contained in the Leslie (1945) transition matrix (A):

$$\underline{A} = \begin{bmatrix} F_o & F_1 & \cdots & F_{x-1} & F_x \\ S_o & 0 & \cdots & 0 & 0 \\ 0 & S_1 & \cdots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & & S_{x-1} & 0 \end{bmatrix} \qquad (5.5\text{-}8)$$

For definition of terms see Section 5.4.3.

The data are available for estimating all elements of this matrix except S_o. The assumption is made that the population is in equilibrium such that each individual in this generation will be replaced by one individual in the next generation. A stable age distribution is also assumed. A deterministic equation using the same terms as equation (5.5-8) can be deduced for the calculation of S_o:

$$S_o = \frac{1}{F_1 = \sum_{i=3}^{x} F_{i-1} \prod_{j=1}^{i-2} S_j} \qquad (5.5\text{-}11)$$

Once an estimate of S_o is obtained, a projection of the population structure through time can be made by the following model:

$$\underline{N}_{t+1} = \underline{A}\,\underline{N}_t \qquad (5.5\text{-}7)$$

The Present Model (MENDYN)

The model developed for this study is an extension of the models outlined above. The model assumes that the population age structure is partitioned into ages one year to ten years. The model is basically a self-regenerating dynamic pool model using the Leslie model (1945).

The dimensionality of the model is increased by partitioning the population into three subpopulations: north of the Chesapeake Bay, Chesapeake Bay area, and south to Florida. The subpopulations basically correspond to the partitioning used by the National Marine Fisheries Service for the statistics which are generated on the distribution of the species. The movement between locations in successive years was analyzed in the tagging study reported in Dryfoos et al (1973). These data are presented for both years of study and the combination of years (Table 5.5-2). These percentages were assumed to be probabilities of migration to another area the following year. These probabilities were assumed to be estimates from populations which were normally distributed with a standard deviation equal to the standard deviation between years.

Little information is available on the geographic distribution of the egg and larval stages of the Atlantic menhaden. Recent data from Kendall and Reintjes (1975) provide patterns of the distribution and abundance of menhaden larvae. These data were integrated in both time and space, using the same partitioning of the data as Dryfoos et al (1973) to determine the percent of the 1966 larval cohort which would be found in each of the three areas. The proportions by area are 0.4013, 0.4626, and 0.1361 for north of Chesapeake Bay, Chesapeake Bay and south to Florida, respectively. The year to year variability in this larval pattern is unknown. It seems reasonable to assume that the larvae are as variable as the adults. Therefore the year to year variability in larval distribution was assumed to be the same as for the adults.

The remaining aspects of the model are similar to those discussed for the previous models. The menhaden population at any year t is represented by:

$$\underline{n}_t = \begin{bmatrix} n_{01} & n_{02} & n_{03} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ n_{81} & n_{82} & n_{83} \end{bmatrix} \tag{5.5-12}$$

where:

n_{ij} is the number of individuals of age i, where i = 0-8, in location j, where j = 1-3.

The temporal transition in the number of individuals in the population as a result of the processes of birth and death can be explained by the Leslie model (equation 5.5-7) for any one of the three spatial locations j:

$$\begin{bmatrix} N_{oj} \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ n_{8j} \end{bmatrix}_{t+1} = \begin{bmatrix} F_o & F_1 & \cdot\cdot\cdot\cdot & F_7 & F_8 \\ S_o & 0 & \cdot\cdot\cdot\cdot & 0 & 0 \\ 0 & S_1 & \cdot\cdot\cdot\cdot & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ 0 & 0 & & S_7 & 0 \end{bmatrix} \begin{bmatrix} N_{oj} \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ n_{8j} \end{bmatrix}_t \tag{5.5-13}$$

It is assumed that matrix A is invariant in time (t) and over the three subareas.

The dispersion of the population among the three subareas can be characterized for rows two through nine of the N_t matrix by multiplication by the migration matrix (M):

$$[n_{i1}\ n_{i2}\ n_{i3}]_{t+1} = \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix} [n_{i1}\ n_{i2}\ n_{i3}]_t \tag{5.5-14}$$

and for the first row of the N_t matrix:

$$[n_{01}\ n_{02}\ n_{03}]_{t+1} = \begin{bmatrix} e_1 \\ e_2 \\ e_3 \end{bmatrix} \ n_{o1}\ n_{02}\ n_{03}]_t \qquad (5.5\text{-}15)$$

The elements m_{ij} of the M migration matrix in equation (5.5-14) are the transpose of the matrices in Table 5.5-2. The combined data for both years was used in the model. The elements e_j of the E column vector in equation (5.5-15) are the proportion of larvae in each subarea.

The estimates of F_i and S_i in the A matrix in equation (5.5-8) depended upon which of two simulation strategies was used. The two strategies involved an A matrix using the Jensen parameters, which includes a density dependent function for F_i, and the URI parameters, which are density independent.

5.5.4 Estimation of Power Station Effects

The effects of Millstone Nuclear Power Station on the Atlantic menhaden could consist of entrainment into the circulating water system, entrapment at the intake with impingement on the traveling screens, and mortality due to the thermal plume. The magnitude of these effects has been assessed from the routine entrainment and impingement monitoring studies. There have also been two incidents during the operation of Unit 1 which are assumed to represent worst case mortalities. Methods to alleviate future incidents have been employed since these two incidents in 1971 and 1972. No further incidents of these magnitudes have occurred to date.

Entrainment

The effect of entrainment of menhaden larvae on the population can be determined from the estimates of the density of menhaden larvae entrained at Millstone Unit 1. Figure 5.5-1 is a graph, developed from the entrainment studies of menhaden larval density entrained for the period June 1973 to April 1975.

An estimate of the total number of larvae entrained (E) in any year can be estimated as:

$$E = \int f(t, Q)\ dt \qquad (5.5\text{-}16)$$

where f(t, Q) is a time and flow dependent function of the larvae entrained, Q is the flow through the circulating water system and t is the time measured in days.

If the entrainment prediction is made for the three units and it is assumed that the units operate continuously at full load, the combined circulating and service water flow would be about 4,350 cubic feet per second. This is equivalent to 10.7 million cubic meters per day. The above expression can then be rewritten as:

$$E = 10.7 \times 10^6 \int g(t)\ dt \qquad (5.5\text{-}17)$$

where g(t) is the time dependent function of menhaden larval density in the area of influence of the intakes. This function has been evaluated at the times of field observation. From Figure 5.5-1, the highest density of larvae observed on each day is used to make the estimate of the number of larvae entrained per year. This strategy inflates the estimate for a more conservative analysis. The number of menhaden larvae predicted to be entrained at all three units, based on the field data, is 4×10^7 for 1973, 3.5×10^7 for 1974, and 2×10^6 for January through April of 1975. Thus, the variability between 1973 and 1974 was 13 percent of the 1973 estimate.

This estimate is converted to a mortality by considering the proportion of larvae in the NY-NJ subpopulation from the simulation model which could have been entrained. Using the highest yearly entrainment estimate of 1973, the mortality due to entrainment would be:

$$Me = 4 \times 10^7 / 2.6 \times 10^{12} = 0.000015$$

Impingement

Impingement of menhaden on the traveling screens is monitored at Unit 1 and at Unit 2, which began commercial operation late in 1975. The information obtained from the impingement monitoring studies for menhaden in 1975 is presented in Table 5.5-3.

The extrapolation of the number of fish which will be impinged when all three units are operating was made from the number impinged at Unit 1. If fish are impinged in proportion to flow, the estimates for Unit 1 can be extrapolated by the ratio of the total flow for three units to the flow at Unit 1. The number of menhaden predicted to be impinged (I) each year for all three units is:

$$I = 4350/1002\ (234) = 1018$$

Most of the menhaden impinged are 6 inches or less in length and are, therefore, probably age 1 or younger. The assumption was made that all fish impinged are of age 1 which probably overestimates the effect of impingement. The mortality due to impingement is calculated as the proportion of the age 1 fish in the NY-NJ subpopulation from the simulation model which are estimated to be impinged:

$$M_I = 1018/1.96 \times 10^9 = 0.0000005$$

Because this mortality is of such small magnitude, it is not considered in the simulations.

Thermal Effects

Surveillance in the Millstone area since Unit 1 began operation in December, 1970, has revealed no apparent routine mortality from the thermal plume to schools of menhaden in the area of migrating through the area. Therefore, no mortality from the thermal plume to menhaden is considered in this simulation analysis.

Worst Case Estimate

Two incidents of larger than average menhaden mortalities have occurred since the beginning of operation of Unit 1. The larger of the two occurrences was in late summer-early fall of 1971, when about 50 million juvenile menhaden and blueback herring were killed at the intake of Unit 1. The menhaden were determined to be about three months old. If this mortality is extrapolated in proportion to flow, the estimate for all three units would be a mortality of 2.1×10^8. If all these fish are assumed to be juvenile menhaden at age three months, the proportion of the three month old menhaden in the NY-NJ subpopulation from the simulation model representing this loss would be:

$$M = 2.1 \times 10^8 / 2.41 \times 10^{11} = 0.00087$$

This event has occurred only once in five years. Therefore, estimates from the entrainment and impingement studies probably are more representative of the average annual mortality to the menhaden population expected from the three units operating at Millstone.

In April and May of 1972, between 20,000 and 30,000 adult menhaden died in the discharge quarry. Although no conclusive source of mortality was identified, evidence suggested that the effects of the heated discharge water was responsible for the mortality. A fixed screen barrier across the opening of the quarry has since been installed. No further incidents of menhaden mortality associated with the heated discharge water have occurred. It appears reasonable to assume that the situation which occurred in 1972 has been mitigated by the fixed screens and no future mortality of this magnitude should occur.

Mortality Estimates for Population Simulation

The preceeding sections have addressed all known and potential sources of impact to the Atlantic menhaden population as a result of operation of three units at the Millstone site. The effects of the thermal plume and impingement do not appear to be of sufficient magnitude to justify further consideration. The effect of entrainment may be expected to result in a routine mortality of 0.0015 percent of the larval menhaden north of the Chesapeake Bay. Since this mortality is also small, for the purposes of simulation the largest mortality (0.087 percent) which has occurred since the operation of Unit 1 is assumed to occur each year. This analysis is highly conservative because in the five years following the 1971 mortality, no further incident of similar size has been reported. This mortality rate is further inflated as it represents the proportion of individuals north of Chesapeake Bay which were killed in the 1971 event. Since menhaden are believed to be an interbreeding population throughout their geographic range, the effect of increased mortality will eventually be distributed throughout the population.

5.5.5 Results of the Population Simulation

The population size and characteristics of the Atlantic menhaden were projected for a period of 50 years using the population dynamics model MENDYN. The 50-year projection was chosen to conform with the projected period of operation of Millstone Nuclear Power Station.

Two formulations were chosen for the reproductive process for menhaden. The first was the density independent survival in the first year of life as estimated by Vaughan et al (1976). This formulation assumes no mechanism by which the population can compensate for decreases in population density. Thus, increased mortality will be reflected in a reduced population size.

The second formulation is a density dependent survival in the first year of life, as developed by Jensen (1975) and recomputed for this analysis. This recomputation includes more recent data on the menhaden population. This approach enables the population to respond to decreases in population size by a higher rate of survival.

The first approach is more conservative in that it probably overestimates the effect of an increase in mortality rate. It is generally agreed, however, that populations have some ability to compensate for increases in mortality. Therefore, the second simulation strategy with compensation is believed to be a more realistic assessment.

Results of Density Independent Simulation

The projected menhaden population size for a simulation in which migration is deterministic is presented in Figure 5.5-2. In this situation the migration coefficients presented in Table 5.5-2 were assumed to be constant for the 50 years. The population size is essentially stable at approximately 6.23 x 10^9 individuals. The proportion of the population located north of Chesapeake Bay subarea is about 40 percent.

The population was also simulated with an increased mortality equivalent to that estimated for the 1971 incident at Millstone. This additional mortality rate of 0.00087 was added to the natural and fishing mortality each of the 50 years, thus assuming that the level of exploitation was as great as occurred in 1971 every year the power station operates.

The effect of this additional exploitation is shown in Figure 5.5-2. The population size is decreased to 6.16 x 10^9 individuals in the whole population and approximately the same decrease in the size of the northern subpopulation. These decreases are about a 1.1 percent reduction after 50 years of power plant related mortality.

To determine the effect of migration changing through time, the same simulation strategy as discussed above was repeated except that the migration coefficients were generated as samples from a normally distributed population. The mean value (see Table 5.5-2) for each coefficient and the between-years standard deviation of 0.048 was used.

The stochastic migration coefficient population projection is similar with respect to population size to the projection in Figure 5.5-2. The proportion of the population which is represented in the northern most subarea, however, varies from year to year. Figure 5.5-3 is a plot of this proportion for a selected simulation. The effect of additional mortality related to the power plant was again simulated by assuming that the effect each year was similar to the 1971 mortality. The average reduction in population size is about the same as the deterministic simulation.

A third simulation strategy for the density independent model was developed to analyze the recovery of the population from varying levels of power plant mortalities. A mortality equivalent to the 1971 event at Millstone simulated for one year produced no noticeable change in population size or age structure. The level of mortality was increased to 100 times the 1971 level and the effect for a one-year power plant mortality was almost immeasurable in terms of population size and age distribution.

The level of exploitation of the power plant was fixed at 100 times the 1971 incident and a 5-year period of exploitation at this level was simulated. Table 5.5-4 presents the results of this severe overestimate of impact. After 5 years of this exploitation the population is depressed about 10 percent of its size under natural conditions. The population recovers in terms of the age structure within 3 years in the affected NY-NJ area, within 4 years in the Chesapeake subarea and within 3 years in the southern most subarea.

Results of the Density Dependent Simulation

The formulations developed by Jensen (1975) were used to develop a density dependent reproductive process. The parameters of equation (5.5-10) were estimated based on the population statistics from 1955 through 1971. The more recent data not used by Jensen (1975) was taken from Nicholson (1975). The survivorship for the prerecruitment portion of the life cycle (Sr) was estimated as 3.4×10^{-13}, the reproductive constant (h) was estimated as 18,679, and the unexplained variability or standard deviation was estimated as 0.953.

The simulation of the population with the density dependent model produced a similar projection to the density independent model. The effect of the Millstone Nuclear Power Station was conservatively estimated by assuming that the level of exploitation was as great each year as was estimated for the 1971 worst case event. The average reduction in population size for many simulations after 50 years of exploitation was about 0.08 percent. The result of one such projection is shown on Figure 5.5-4. This change is about 10 times that predicted by the density independent model. The difference between the two predictions is an indication of the ability of the population to compensate for changes in the mortality rate.

Conclusion

The effect of the operation of the Millstone Nuclear Power Station, Units 1, 2, and 3 on the Atlantic menhaden population has been analyzed. The mortality associated with the power station has been intentionally overestimated, based on 5 years of field study, to provide a conservative analysis.

Simulations for both density independent and density dependent models have been analyzed. Under all simulation strategies the effect of the power station appears to be of a minor nature with respect to population size and age distribution. It appears highly unlikely that the effect of the Millstone Nuclear Power Station on the population could be detected by field observation.

It would appear that, based on this analysis, no detectable change in the population dynamics of the Atlantic menhaden population will result from the operation of the Millstone Nuclear Power Station.

5.6 Lobster

The assessment of the effect of three-unit operation on the lobster utilizes a comparison of the number of individuals impinged to estimates of the lobster population in the area and the commercial catch in New London county. No population dynamic approach has been utilized due to the heavily exploited nature of this species. The degree of exploitation is so high as to be one of the dominant if not the dominant aspect of their population dynamics.

Entrainment

The entrainment of lobster larvae by Millstone Units 1, 2 and 3 is expected to have virtually no impact on the population. This conclusion is based upon the results of entrainment monitoring conducted at Unit 1. Samples taken in the discharge during 1975 and during the first six months of 1976 have yielded a total of 26 lobster larvae.

It is felt that if lobster larvae were entrained abundantly, their occurrence would best be detected at the discharge. Here turbulent flow and larvae disorientation would facilitate capture. Because of this relatively low entrainment rate no further assessment of impact to lobster from entrainment by three units is attempted.

Impingement

Impact to the lobster population in the Millstone area then will result primarily from impingement. Calculation of the number of lobsters to be lost annually by three-unit operation is shown in Table 5.6-1. The estimate of the number of lobsters to be impinged annually by three units is 4,664. Based upon actual Unit 1 data for 1975, the survival of lobsters was quite high, with only 21 percent being lost to the population. Using the 21 percent figure, the estimate of lobsters lost to the population is 979.

Using the monthly population estimates shown in Table 4.10-16, a mean annual estimate of 7,059 lobsters can be calculated. In this calculation the initial population estimates of May and June 1974 were not included since enough tag returns were not obtained to provide reasonable estimates.

Compared to the mean annual population estimate the number of lobsters lost from impingement during three-unit operation would be slightly less than 14 percent of the local population. This potential change is well within the variability observed for example between 1974 and 1975 population estimates compared on a monthly basis (Table 4.10-16).

Impact to the lobster population from impingement can also be assessed by converting the numbers estimated to be impinged by three units into pounds and comparing this to commercial lobster landings. Table 5.6-2 shows the calculation of the pounds of lobsters that could be impinged annually by three-unit operation. The estimate of three-quarters of a pound per lobster was made by weighing 50 lobsters from a sample of lobsters approximately the same size as those most frequently impinged.

Using that figure, an estimate of about 3,400 pounds of lobsters could be impinged as a result of the simultaneous operation of three generating units. Using the figures for commercial lobster landings supplied by the Connecticut Department of Environmental Protection (see Table 4.10-18 in Section 4.10, Impingement Monitoring), the mean annual lobster poundage landed in eastern Long Island Sound (New London county) from 1972 through 1975 was approximately 216,000. The 3,400 pounds estimated to be impinged annually as a result of a three-unit operation therefore represents about 1.6 percent of the annual commercial catch.

If the observed survival (79 percent) of impinged lobsters is taken into account and if the Unit 3 fish handling facility is successful, then the pounds lost to the commercial catch by impingement at Millstone Units 1, 2 and 3 would be less than 1 percent.

SECTION 6

IMPACTS OF UNIT 3 CONSTRUCTION

Introduction

The Unit 3 circulating and service water pump house will be located on the west side of Millstone Point, approximately 300 feet northwest of the Unit 2 intake structure. Although the dune area, located just behind the pump house will be disturbed, it is expected that efforts to restore this area will be accomplished shortly after completion of construction. These efforts should be limited to reconstruction and revegetation of the effected areas.

Installation and Removal of Cofferdam

The most noticeable physical change to the natural conditions of Niantic Bay will be the construction of a temporary cofferdam to permit dry construction of the intake structure. The Unit 3 intake cofferdam is constructed of sheet piles driven down into the bottom of Niantic Bay and braced with about 20,000 cu. yd. of bedrock excavated on land. When rock excavated on site was placed in Niantic Bay to form the cofferdam, soil was excluded to the extent practicable so as to minimize the additional turbidity created by such dumping. This method of construction is expected to minimize the amount of bottom area covered by the cofferdam and the consequent loss of the benthic community. When construction of the cooling water intake structure has been completed, the cofferdam and materials will be removed and disposed of in an approved offshore dumping site. Suitable signs or signals on or near the cofferdam will be provided to warn boats of its presence.

Construction of the cofferdam will disrupt the benthic habitat in an area slightly over one acre. Benthic samples were taken in the general area of the cofferdam prior to its construction. Table 6-1 contains the densities of the benthic invertebrates observed in the area of the cofferdam and the projected number that would be displaced after construction of the cofferdam. Benthic samples taken inside the cofferdam, after construction was completed, revealed that the benthic community was almost eliminated with the exception of one amphipod and one annelid. Based on the precofferdam samples, the predicted number of organisms lost from the benthic community during the presence of the cofferdam is presented in Table 6-1. This loss would be between 3 and 12 million benthic invertebrates. Following removal of the cofferdam, this area should return to a condition similar to that prior to construction activities. The time for this recovery will depend upon local conditions. In similar situations, recovery has taken place within a year or two.

The temporary cofferdam for Unit 3 may create an artificial embayment in the area of the Unit 2 intake, thus it could potentially attract fish. If fish are impinged in proportion to their local abundance, impingement on the Unit 2 traveling screens may increase during construction of the

Unit 3 intake. The cofferdam will be in place for a period of approximately four years. The rate of impingement at the Unit 1 and Unit 2 intakes has been quite low and, therefore, a slight increase would probably not present a problem to the effected populations.

Dredging of Intake Channel

Disruption of an additional two acres and increased turbidity may be expected during dredging of the intake channel, but the effects will be short-term. This habitat is not unique to the area, and the displaced organisms will be of similar types and densities as presented in Table 6-1. The dredged material will total approximately 40,000 cu. yd. and will be disposed of in an approved offshore dumping site. Construction of the cofferdam and its removal, and the dredging of the approach channel, will not preclude any present uses of the waters of Long Island Sound.

Shore Protection

A seawall has been constructed north of the Unit 2 intake structure and will eventually extend to the east wall of the Unit 3 intake structure. It has been designed to withstand the expected wave conditions of the site and will provide shore protection between the pump houses of Units 2 and 3. On the western side of the Unit 3 intake structure, other means of shore protection are being investigated. These methods include groins, breakwaters, and/or protection with armor stone. Presently, field surveys are being conducted to determine the nature of the near-shore sediment movement. The results from these studies will be used to determine and design the method required to provide adequate shore protection and to prevent sediment buildup in the Unit 3 intake channel. If armor stone protection is required, additional beach area will be lost.

Loss of Land

Construction of the pump house will alter Bay Point Beach. Approximately one acre of land or approximately 20 percent of Bay Point Beach will be lost for other uses with the construction of the Unit 3 intake. Attempts will be made to restore the disturbed areas not occupied by the pump house.

C95

MILLSTONE NUCLEAR POWER STATION

UNITS 1, 2 AND 3

ENVIRONMENTAL ASSESSMENT

OF THE

CONDENSER COOLING WATER INTAKE STRUCTURES

(316 (b) DEMONSTRATION)

VOLUME II

Submitted to

The

State of Connecticut

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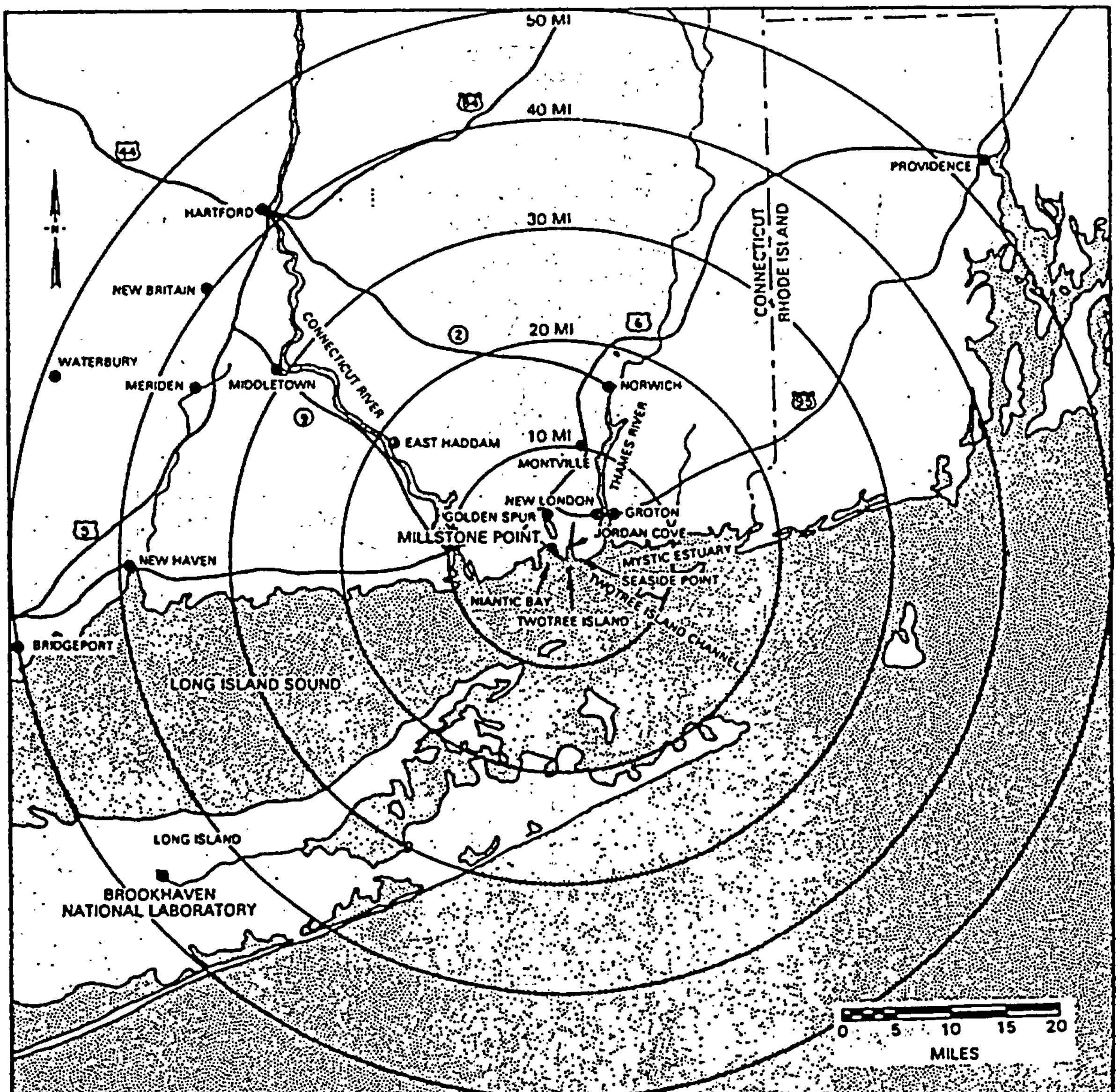


FIGURE 2.1-1 MILLSTONE STATION GENERAL SITE LOCATION

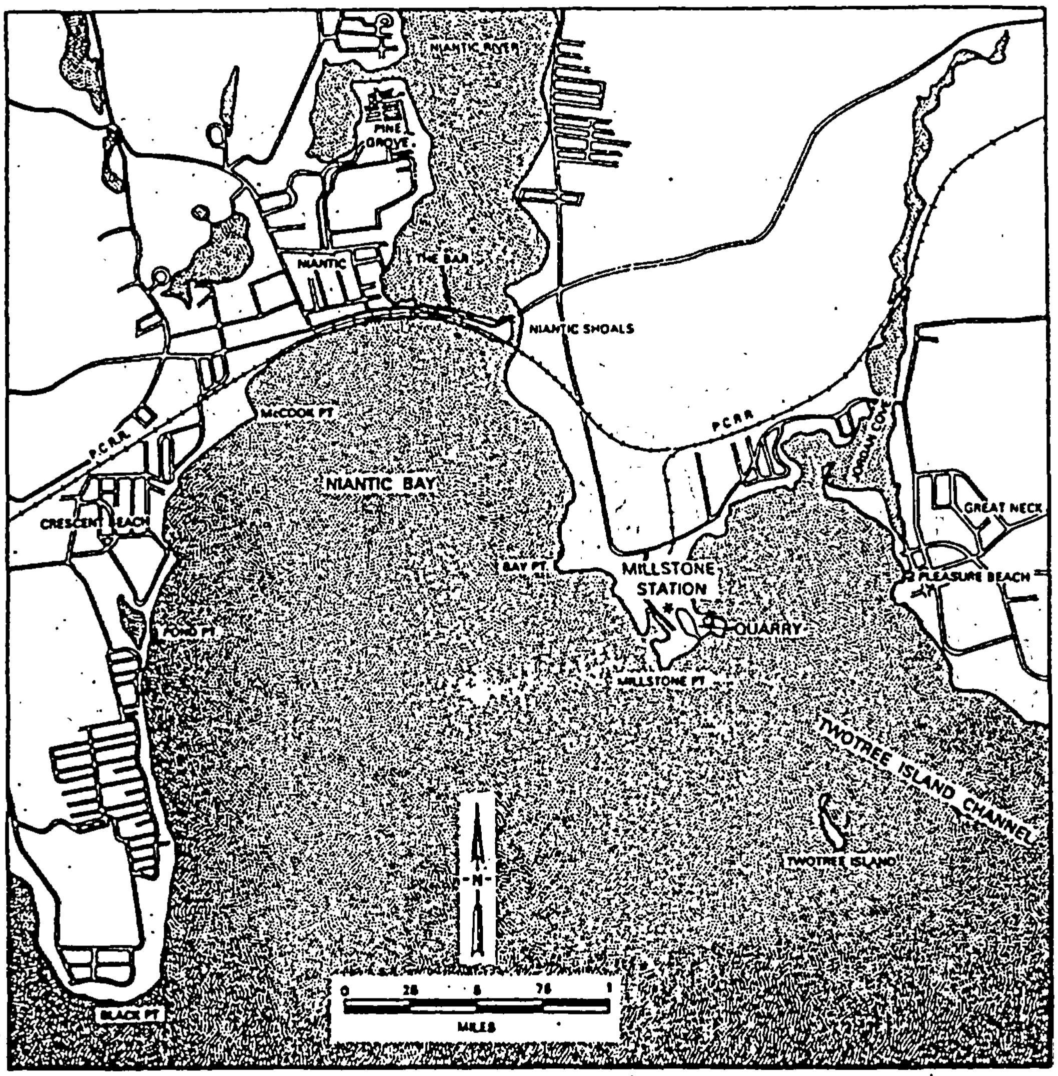


FIGURE 2.1-2 MILLSTONE STATION AREA PLOT

TABLE 2.2-1 WIND SPEED JOINT FREQUENCY DISTRIBUTION, MILLSTONE METEOROLOGICAL TOWER 33 FEET LEVEL, JANUARY-DECEMBER 1975

	Speed (M/sec)						
	Calm	0.5-1.5	1.6-3.3	3.4-5.5	5.6-8.2	8.3-10.8	10.9
Jan	0.4%	3.9	23.0	36.0	24.1	8.1	4.3
Feb	1.2	9.3	30.9	29.6	15.2	10.7	3.2
Mar	0.4	10.0	22.4	26.0	29.1	9.9	2.2
Apr	0.1	6.0	17.0	37.0	27.7	7.7	4.5
May	1.5	20.7	42.0	26.4	8.4	1.0	0
Jun	0.7	17.6	36.2	31.5	11.8	1.8	0.3
Jul	0.8	23.5	40.0	28.3	6.8	0.3	0
Aug	0.9	17.0	38.1	33.2	10.3	0.4	0
Sep	0	13.6	39.6	32.3	11.9	1.6	1.0
Oct	2.5	9.7	30.0	35.6	20.0	2.2	0
Nov	0.4	8.8	27.7	33.7	20.9	5.8	2.6
Dec	0	3.0	23.6	37.2	26.2	8.5	1.4

TABLE 2.2-2 MEAN MONTHLY CONCENTRATIONS (mg/l) OF CERTAIN SEAWATER CONSTITUENTS MEASURED AT NINE STATIONS AROUND MILLSTONE POINT, 1974.

Constituents		Year 1974											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BOD	max	-	-	1.48	2.56	1.60	2.88	1.45	2.40	1.25	1.50	3.09	1.49
	avg	-	-	0.64	1.76	1.05	1.98	0.73	1.50	0.72	1.20	2.49	0.59
	min	-	-	0.16	1.08	0.44	1.43	0.33	0.80	0.03	0.57	1.48	0.14
Ammonia Nitrogen	max	0.06	0.020	0.08	0.040	0.160	0.120	0.280	0.30	0.40	0.38	0.14	0.08
	avg	0.03	0.018	0.04	0.025	0.087	0.090	0.075	0.17	0.10	0.09	0.07	0.05
	min	0.02	0.008	0.02	0.020	0.020	0.040	0.010	0.02	0.02	0.02	0.02	0.04
Nitrite Nitrogen	max	-	0.001	0.004	0.002	0.002	0.001	0.001	0.002	0.100	0.08	0.012	0.003
	avg	-	0.001	0.003	0.002	0.001	0.001	0.001	0.001	0.007	0.07	0.007	0.002
	min	-	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.005	0.04	0.004	0.001
Nitrate Nitrogen	max	0.95	0.40	0.67	0.64	1.460	0.100	0.140	0.08	0.14	0.07	0.038	0.170
	avg	0.64	0.31	0.17	0.18	0.738	0.045	0.067	0.03	0.04	0.04	0.021	0.129
	min	0.42	0.19	0.03	0.03	0.420	0.020	0.020	0.01	0.02	0.01	0.014	0.081
Organic Nitrogen	max	0.36	0.48	0.32	0.56	0.600	0.50	0.50	0.660	1.20	0.840	0.706	0.320
	avg	0.29	0.29	0.25	0.31	0.425	0.37	0.40	0.453	0.45	0.324	0.378	0.248
	min	0.18	0.04	0.22	0.20	0.300	0.14	0.34	0.360	0.40	0.220	0.280	0.200
Total Phosphate	max	0.80	0.70	0.40	0.40	0.10	0.90	0.20	0.20	0.4	0.2	0.3	0.3
	avg	0.31	0.60	0.20	0.18	<0.10	0.18	0.15	0.17	0.3	0.2	0.2	0.2
	min	0.12	0.50	<0.1	0.10	<0.10	0.10	0.10	0.10	0.2	0.1	<0.1	0.2
Ortho Phosphate	max	ND	0.30	ND	<0.10	<0.10	<0.10	<0.10	<0.01	<0.2	<0.1	<0.1	<0.1
	avg	ND	0.20	ND	-	-	-	-	-	-	-	-	-
	min	ND	0.20	ND	-	-	-	-	-	-	-	-	-
Condensed Phosphate	max	0.18	0.50	0.1	0.3	<0.1	0.1	<0.1	0.2	0.2	0.2	0.2	<0.1
	avg	0.10	0.27	-	-	-	-	-	0.2	-	-	-	-
	min	0.04	0.20	<0.1	<0.1	-	0.1	-	0.1	<0.1	<0.1	<0.1	-
Soluble Organic Carbon	max	61.0	10.0	30.0	20.0	25.0	21.0	13.5	19.0	41.5	30.2	9.3	32.0
	avg	21.8	5.1	12.2	7.8	10.9	9.11	5.5	8.14	17.5	19.9	3.7	21.9
	min	4.0	1.0	1.0	1.0	2.0	4.0	1.0	2.5	5.4	7.3	1.0	12.0

Table 2.2-2 (Cont'd)

Constituents		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		Year 1974											
Oil and Grease	max	81.54	29.44	18.68	22.28	15.16	29.4	6.98	14.16	12.02	7.88	6.10	8.76
	avg	22.50	17.12	10.51	15.33	10.16	11.1	4.09	6.31	2.11	2.49	2.55	1.88
	min	12.48	10.78	3.18	12.92	3.62	1.42	0.82	0.24	0.06	0.10	0.54	0.32
Sulfates	max	2600	2750	2800	2500	2450	2900	3240	2850	3300	2425	2400	2575
	avg	2400	2375	2560	2260	2100	2600	2870	2520	2271	2185	2385	2373
	min	2000	1800	2000	1900	1990	2330	2610	2330	2020	1800	2150	2225
MBAS	max	0.12	0.396	0.15	0.45	0.20	0.224	0.045	0.077	0.115	0.240	0.133	0.224
	avg	0.08	0.188	0.09	0.11	0.08	0.098	0.026	0.045	0.062	0.110	0.067	0.098
	min	0.03	0.042	0.03	0.03	0.04	0.032	0.010	0.023	0.010	0.028	0.020	0.032
Free Cl2 (Residual)	max	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	avg	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Combined Cl2 (Residual)	max	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	avg	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Suspended Solids	max	37.2	47.6	40.7	38.4	31.15	45.55	41.1	45.7	50.7	36.9	41.3	38.2
	avg	27.6	19.0	31.2	30.1	23.66	32.20	32.0	36.3	31.1	28.1	30.5	28.3
	min	19.0	10.7	20.6	20.2	15.75	19.05	23.6	24.0	17.6	14.2	21.1	18.1
Boron	max	1.28	1.80	1.95	3.44	3.10	3.32	3.20	3.68	3.68	3.30	3.40	4.04
	avg	1.01	1.58	1.49	3.14	2.52	2.54	2.94	3.40	3.19	2.68	3.02	3.18
	min	0.80	1.10	0.85	1.70	2.00	1.56	2.26	3.10	2.20	2.28	2.45	2.20
Copper	max	-	-	-	-	-	-	0.08	0.04	0.17	0.05	0.07	0.003
	avg	-	-	-	-	-	-	0.05	0.03	0.08	0.03	0.03	0.001
	min	-	-	-	-	-	-	0.04	0.02	0.06	0.03	0.03	0.001
Nickel	max	0.20	0.140	0.30	0.24	0.27	0.190	0.10	0.065	0.073	0.28	0.05	ND
	avg	0.13	0.079	0.24	0.12	0.20	0.116	0.09	0.032	0.034	0.13	0.04	ND
	min	0.05	0.050	0.20	0.08	0.10	0.095	0.08	0.025	0.028	0.10	0.03	ND

Table 2.2-2 (Cont'd)

Constituents		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
				Year 1974									
Iron	max	0.25	0.40	0.19	0.25	0.22	0.14	1.70	0.11	0.48	0.14	0.02	0.09
	avg	0.19	0.09	0.13	0.12	0.15	0.09	0.09	0.06	0.18	0.06	0.02	0.06
	min	0.16	0.05	0.10	0.10	0.09	0.05	0.07	0.01	0.01	0.04	0.02	0.05
Manganese	max	0.06	0.045	0.062	0.050	0.040	0.110	0.050	0.040	0.040	0.040	0.01	ND
	avg	0.03	0.019	0.040	0.038	0.025	0.030	0.030	0.020	0.027	0.014	0.01	ND
	min	0.01	0.005	0.020	0.020	0.010	0.020	0.020	0.010	0.015	0.010	0.01	ND
Zinc	max	0.014	0.010	0.007	0.025	0.085	0.013	0.043	0.013	0.015	0.057	0.055	0.050
	avg	0.010	0.004	0.011	0.009	0.034	0.006	0.026	0.005	0.006	0.015	0.021	0.019
	min	0.008	0.001	0.030	0.003	0.010	0.003	0.015	0.003	0.003	0.010	0.015	0.015
Aluminum	max	3.20	1.3	2.1	2.70	2.36	1.00	10.0	2.80	7.2	ND	1.00	0.60
	avg	1.14	0.8	1.3	1.40	0.83	0.34	4.97	1.10	2.9	ND	0.67	0.31
	min	0.50	0.2	0.6	0.70	0.24	0.23	1.0	0.40	1.2	ND	0.20	0.20
Total Chromium (Soluble)	max	-	-	-	-	-	-	0.17	0.23	0.30	ND	ND	ND
	avg	-	-	-	-	-	-	0.11	0.15	0.17	ND	ND	ND
	min	-	-	-	-	-	-	0.08	0.06	0.10	ND	ND	ND
Lead	max	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	avg	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Alkalinity	max	-	-	276.8	-	-	244	-	-	248	-	-	272
	avg	-	-	230.1	-	-	237	-	-	236	-	-	257
	min	-	-	213.2	-	-	226	-	-	208	-	-	252
Chloride	max	-	-	18100	-	-	19375	-	-	24375	-	-	18750
	avg	-	-	16970	-	-	17045	-	-	17955	-	-	17560
	min	-	-	16200	-	-	13750	-	-	17500	-	-	16250
Potassium	max	-	-	600	-	-	680	-	-	575	-	-	675
	avg	-	-	580	-	-	588	-	-	475	-	-	636
	min	-	-	500	-	-	400	-	-	460	-	-	600

Table 2.2-2 (Cont'd)

Year 1974

Constituents		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Calcium	max	-	-	270	-	-	269	-	-	244	-	-	250
	avg	-	-	265	-	-	259	-	-	234	-	-	232
	min	-	-	260	-	-	245	-	-	218	-	-	220
Magnesium	max	-	-	825	-	-	1805	-	-	1170	-	-	900
	avg	-	-	780	-	-	1465	-	-	1120	-	-	852
	min	-	-	600	-	-	1190	-	-	1100	-	-	825
Arsenic	max	-	-	ND	-	-	ND	-	-	ND	-	-	ND
	avg	-	-	ND	-	-	ND	-	-	ND	-	-	ND
	min	-	-	ND	-	-	ND	-	-	ND	-	-	ND
Molybdenum	max	-	-	0.60	-	-	1.00	-	-	0.056	-	-	ND
	avg	-	-	0.35	-	-	0.50	-	-	0.045	-	-	ND
	min	-	-	0.20	-	-	0.25	-	-	0.040	-	-	ND
Titanium	max	-	-	ND	-	-	ND	-	-	ND	-	-	ND
	avg	-	-	ND	-	-	ND	-	-	ND	-	-	ND
	min	-	-	ND	-	-	ND	-	-	ND	-	-	ND
Vanadium	max	-	-	0.27	-	-	0.20	-	-	0.027	-	-	ND
	avg	-	-	0.16	-	-	0.16	-	-	0.016	-	-	ND
	min	-	-	0.02	-	-	0.10	-	-	0.008	-	-	ND
Cadmium (Soluble)	max	-	-	-	-	-	-	-	-	ND	-	-	ND
	avg	-	-	-	-	-	-	-	-	ND	-	-	ND
	min	-	-	-	-	-	-	-	-	ND	-	-	ND
Mercury	max	-	-	ND	-	-	ND	-	-	ND	-	-	ND
	avg	-	-	ND	-	-	ND	-	-	ND	-	-	ND
	min	-	-	ND	-	-	ND	-	-	ND	-	-	ND
Total Solids	max	-	-	35600	-	-	43500	-	-	41017	-	-	40600
	avg	-	-	34490	-	-	35400	-	-	32515	-	-	33500
	min	-	-	28350	-	-	30600	-	-	30511	-	-	27500

Table 2.2-2 (Cont'd)

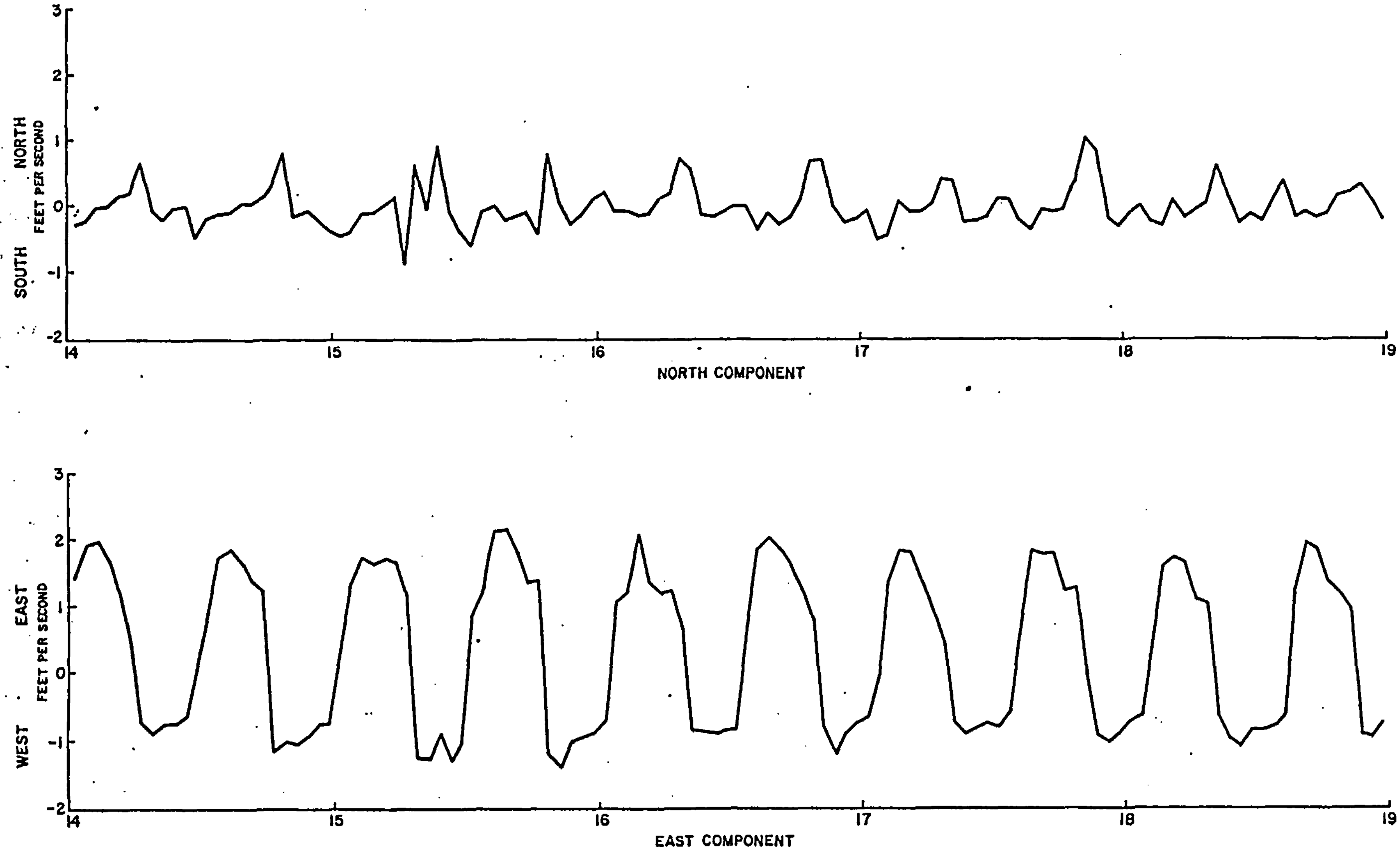
Constituents		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
				Year 1974									
Volatile Solids	max	-	-	7400	-	-	14950	-	-	24012	-	-	9700
	avg	-	-	5810	-	-	7730	-	-	7218	-	-	4530
	min	-	-	4900	-	-	4000	-	-	5164	-	-	2700
Tin	max	-	-	-	-	-	ND	-	-	ND	-	-	ND
	avg	-	-	-	-	-	ND	-	-	ND	-	-	ND
	min	-	-	-	-	-	ND	-	-	ND	-	-	ND
Phenol	max	-	-	0.009	-	-	ND	-	-	0.003	-	-	ND
	avg	-	-	0.009	-	-	ND	-	-	0.003	-	-	ND
	min	-	-	0.009	-	-	ND	-	-	0.003	-	-	ND
Beryllium	max	-	-	ND	-	-	ND	-	-	ND	-	-	ND
	avg	-	-	ND	-	-	ND	-	-	ND	-	-	ND
	min	-	-	ND	-	-	ND	-	-	ND	-	-	ND

ND: Nondetectable within limits specified by analytical techniques.

TABLE 2.2-3 MEAN MONTHLY CONCENTRATIONS (mg/1) OF CERTAIN SEDIMENT CONSTITUENTS MEASURED IN LONG ISLAND SOUND AROUND MILLSTONE POINT, 1974

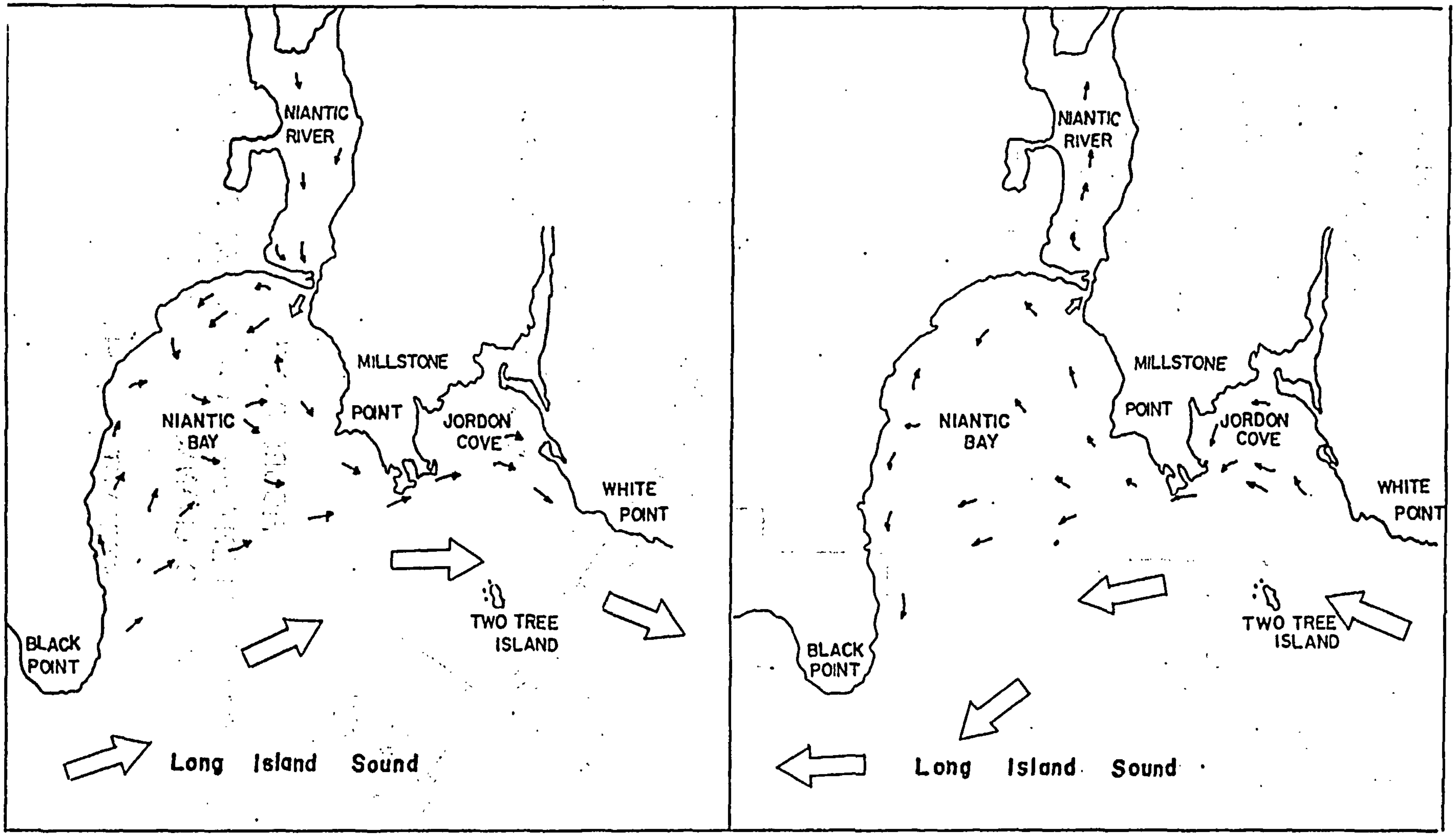
Constituents	Quarry Cut			Twotree Island			Quarry Cut and Twotree Island		
	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
Total Nitrogen as N	0.06033	0.01741	0.00041	0.13333	0.0477	0.0013	0.13333	0.03111	0.00041
Total Phosphate	0.0033	0.0016	0.0002	0.00323	0.0019	0.0003	0.0033	0.0017	0.0002
Soluble Organic Carbon	0.015	0.009	0.0015	0.02236	0.0122	0.0046	0.02236	0.0100	0.0015
Volatile Solids	9.8	3.1	0.78	3.6100	2.231	0.544	9.8	2.7	0.544
Boron	0.012	0.011	0.0109	0.0026	0.0025	0.0024	0.012	0.007	0.0024
Aluminum	0.086	0.044	0.010	0.051	0.035	0.010	0.086	0.040	0.010
Iron	0.39333	0.186	0.034	1.11333	0.351	0.034	1.11333	0.269	0.034
Copper	0.0005	0.0004	0.0003	0.0034	0.0012	0.0002	0.0084	0.0008	0.0002
Nickel	0.0006	0.0004	0.00006	0.0009	0.0008	0.0006	0.0009	0.0006	0.00006
Lead	0.0004	0.0002	0.00002	0.0004	0.0003	0.00013	0.0004	0.0003	0.00002
Mercury	<0.00001	-	-	<0.00001	-	-	<0.00001	-	-
Zinc	0.0011	0.0005	0.0002	0.0032	0.0013	0.0004	0.0011	0.0009	0.0002
Beryllium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	0.00003	-	<0.00001	0.00006	-	<0.00001	0.00006	-	<0.00001
Vanadium	0.008	0.006	0.003	0.010	0.007	0.003	0.010	0.006	0.003
Titanium	0.036	0.025	0.003	0.05133	0.034	0.003	0.05133	0.029	0.003
Molybdenum	0.07966	0.0272	0.0003	0.01100	0.0038	0.00007	0.07966	0.01547	0.00007
Managanese	0.0077	0.0051	0.0023	0.01666	0.0093	0.0047	0.01666	0.0072	0.0023
Arsenic	0.00656	0.0041	0.0017	0.02950	0.0156	0.0017	0.02950	0.0099	0.0017
Total Chromium	0.0014	-	<0.0001	0.00333	-	<0.0001	0.00333	-	<0.0001
HCr^6	ND	ND	ND	ND	ND	ND	ND	ND	ND
Oil and Grease	0.158	0.057	0.00002	0.0082	0.0590	0.0082	0.158	0.058	0.00002
Phenols	0.0006	0.0003	0.00003	0.00002	0.0003	0.00002	0.0006	0.0003	0.00002

ND: Nondetectable within limits specified by analytical techniques.



NOTE:
NIANTIC BAY SURVEY STATION I2 TOP
14 AUG. TO 19 AUG. 1973.

FIGURE 2.2-1
TIDAL CURRENT COMPONENTS
MILLSTONE NUCLEAR POW[illegible]TATION



a. EBB

b. FLOOD

FIGURE No. 2.2-2 GENERAL CIRCULATION PATTERNS IN THE VICINITY OF MILLSTONE POINT DURING EBB (a) AND FLOOD (b) TIDE.

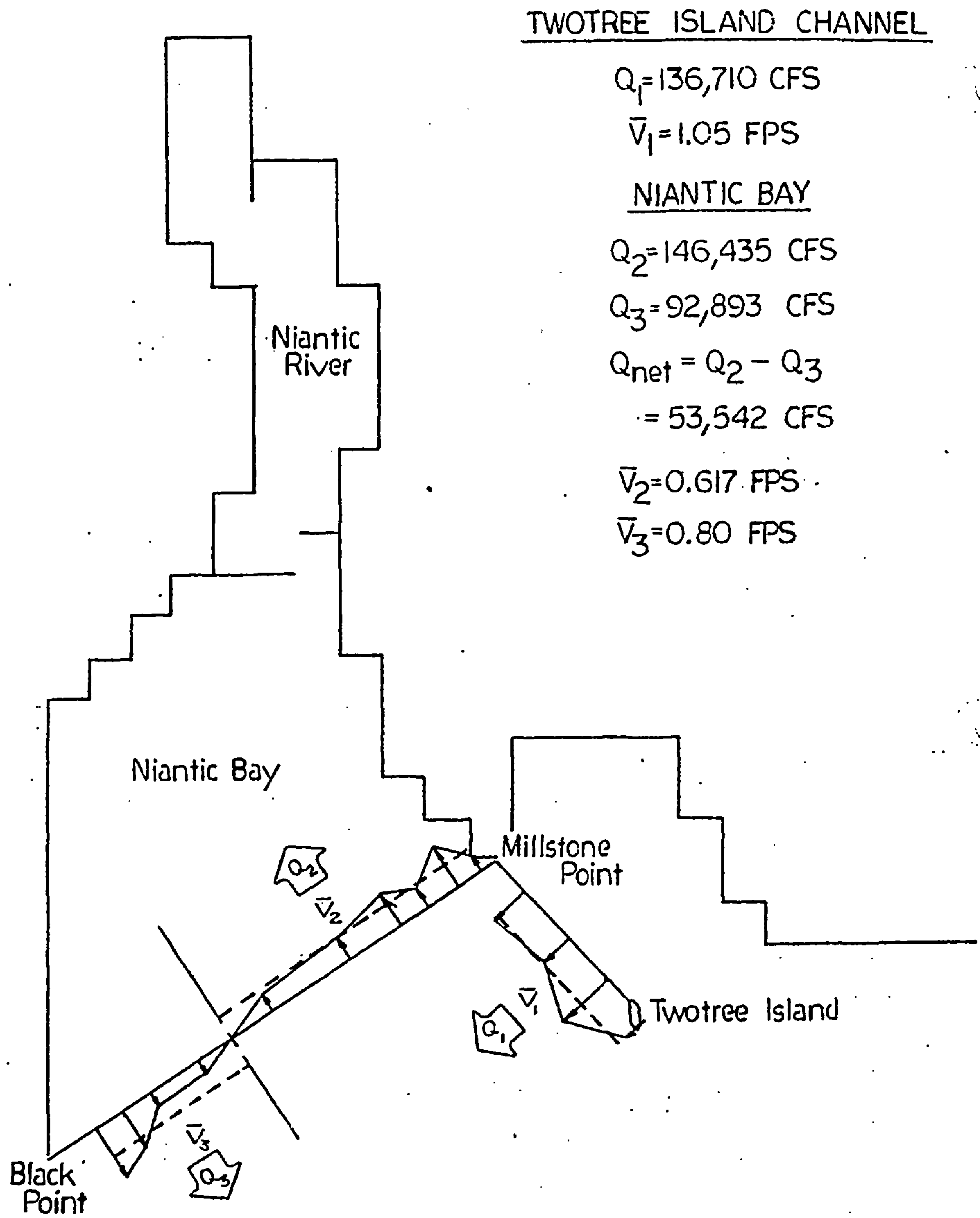


FIGURE 2.2-3

TIDAL CURRENT and FLOW ACROSS TWOTREE ISLAND CHANNEL and NIANTIC BAY

STRENGTH OF FLOOD

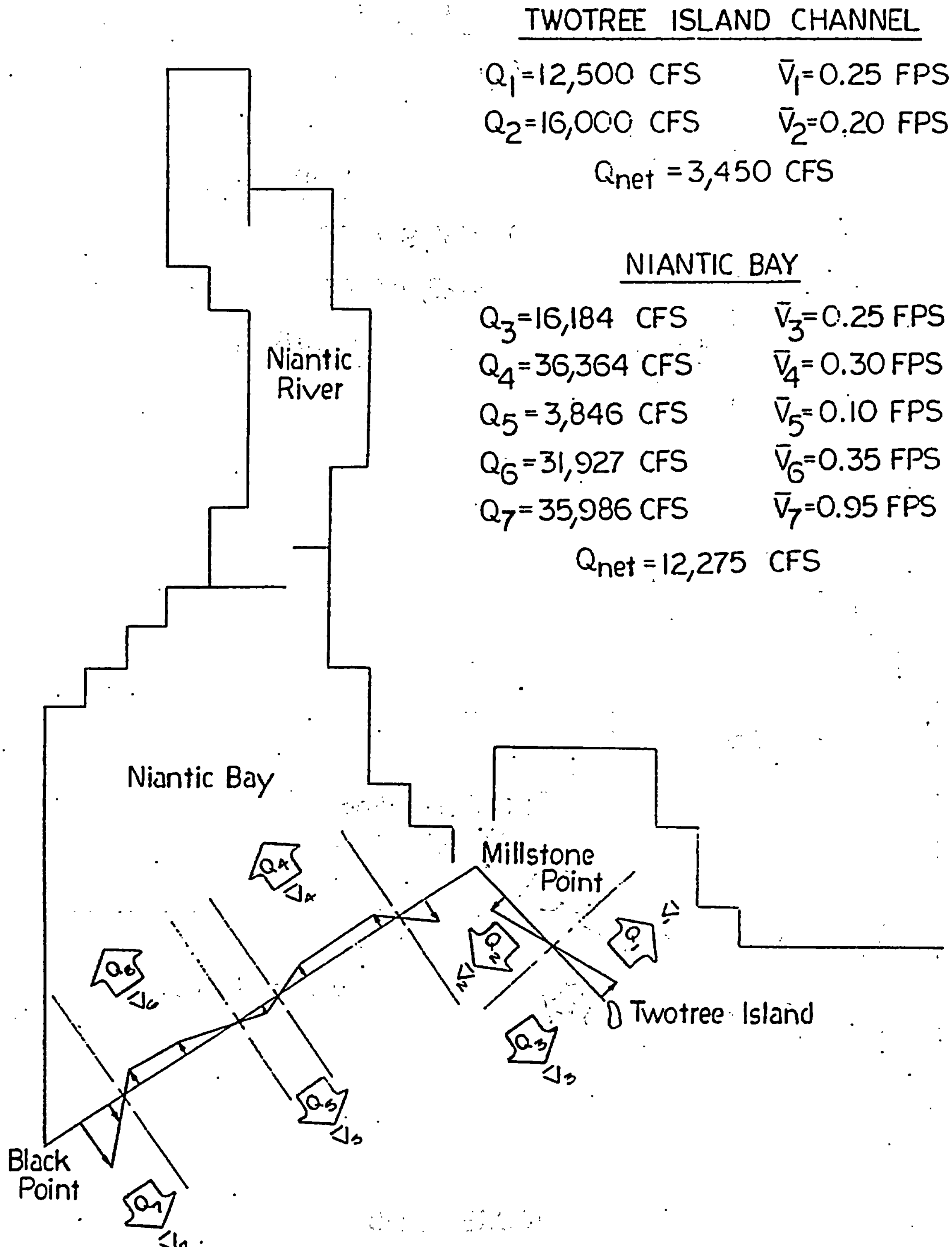


FIGURE 2.2-4

TIDAL CURRENT and FLOW ACROSS TWOTREE ISLAND CHANNEL and NIANTIC BAY

HIGH SLACK

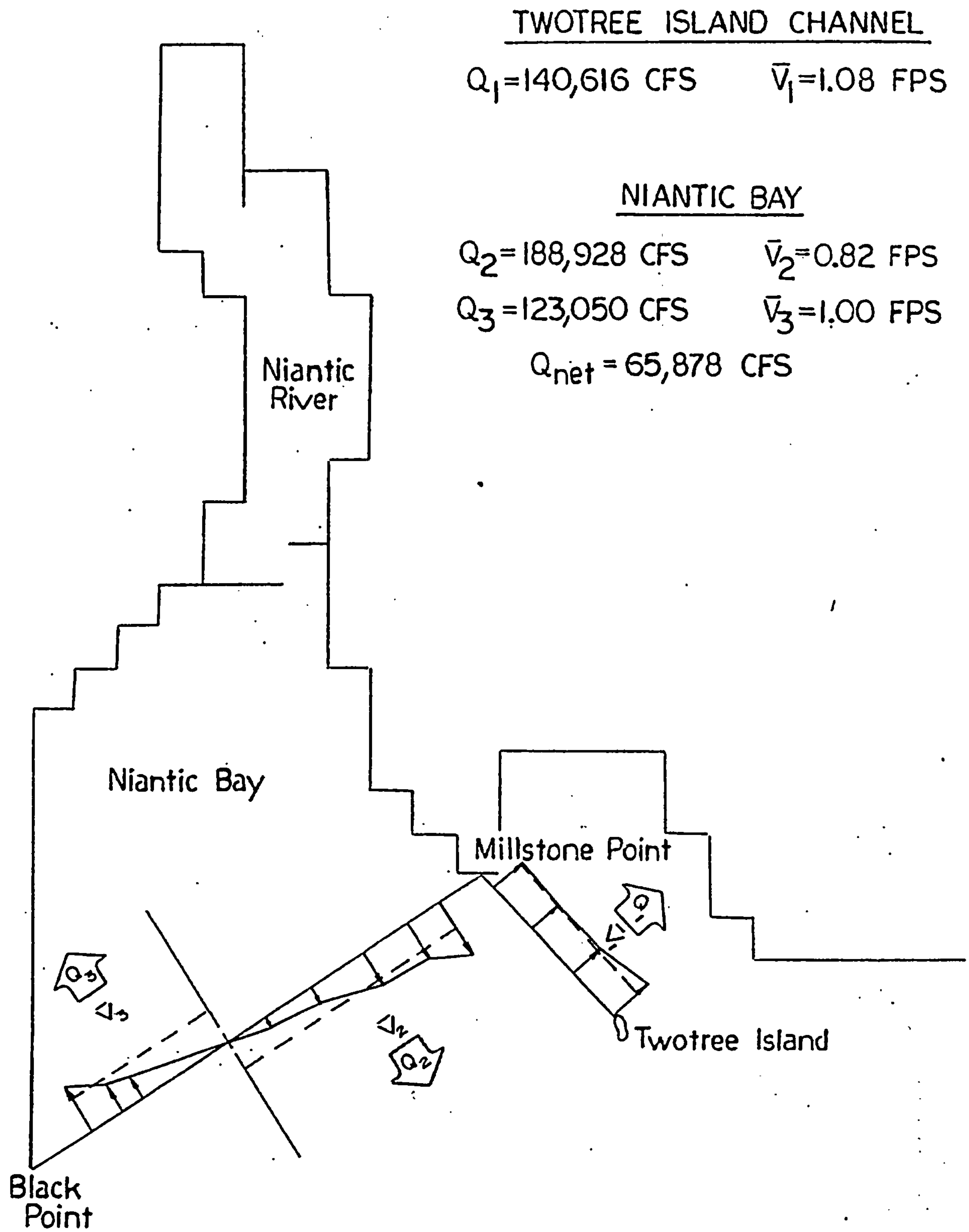
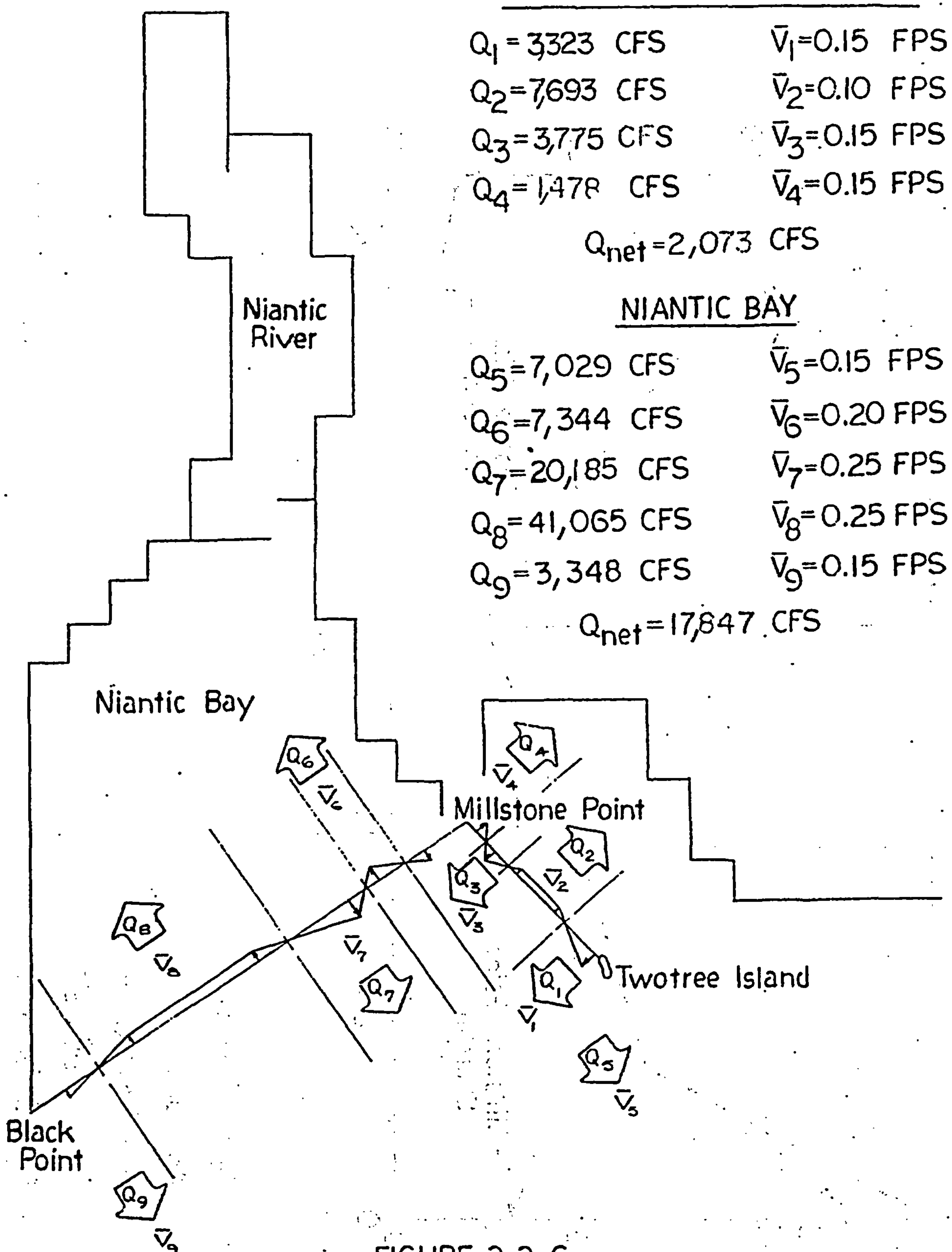


FIGURE 2.2-5

TIDAL CURRENT and FLOW ACROSS TWOTREE ISLAND CHANNEL and NIANTIC BAY

STRENGTH OF EBB



TWOTREE ISLAND CHANNEL

Q_1 = 3323 CFS	$\bar{V}_1$=0.15 FPS
Q_2=7,693 CFS	$\bar{V}_2$=0.10 FPS
Q_3=3,775 CFS	$\bar{V}_3$=0.15 FPS
Q_4=1,478 CFS	$\bar{V}_4$=0.15 FPS

Q_{net}=2,073 CFS

NIANTIC BAY

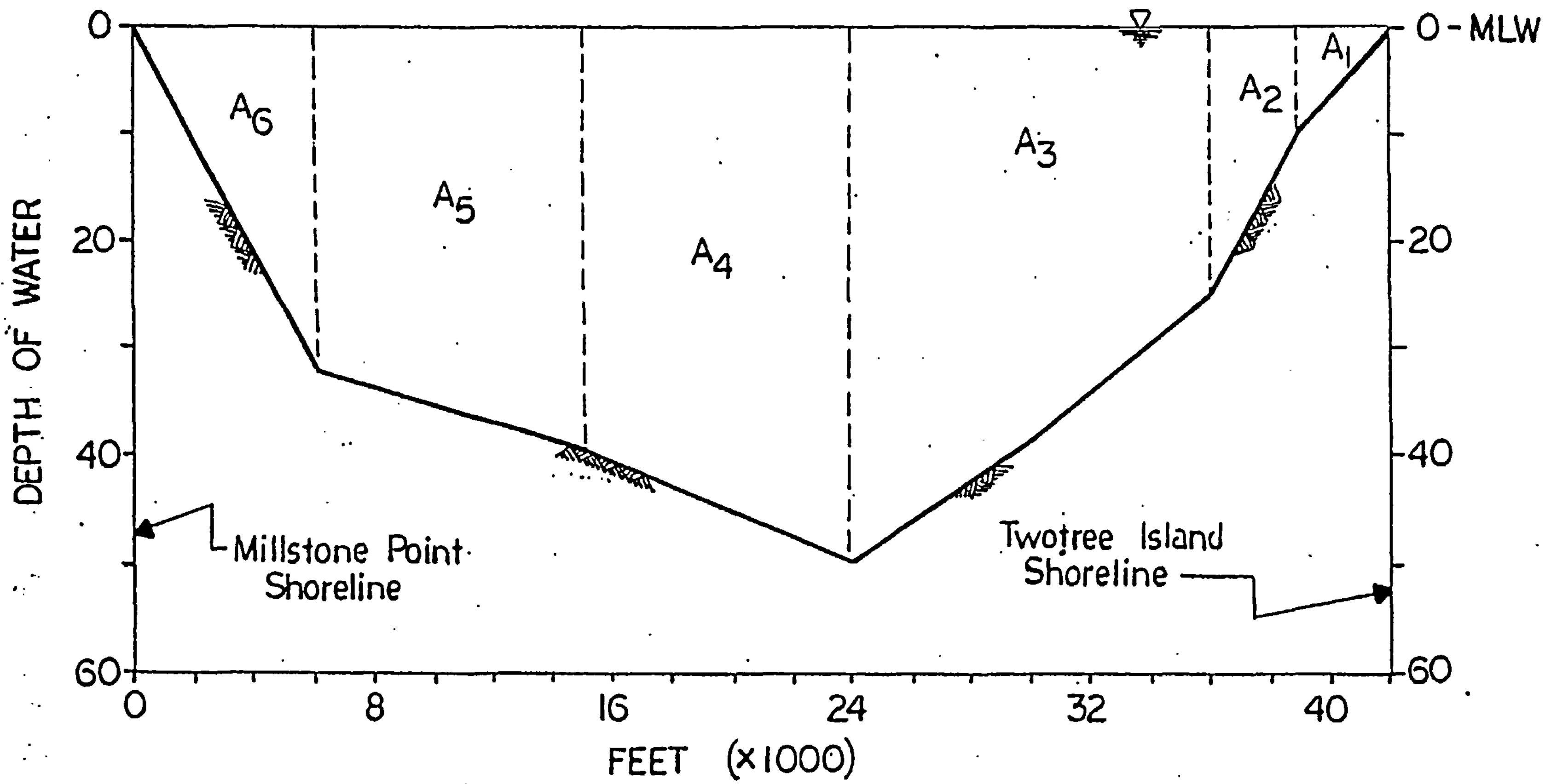
Q_5=7,029 CFS	$\bar{V}_5$=0.15 FPS
Q_6=7,344 CFS	$\bar{V}_6$=0.20 FPS
Q_7=20,185 CFS	$\bar{V}_7$=0.25 FPS
Q_8=41,065 CFS	$\bar{V}_8$=0.25 FPS
Q_9=3,348 CFS	$\bar{V}_9$=0.15 FPS

Q_{net}=17,847 CFS

FIGURE 2.2-6

TIDAL CURRENT and FLOW ACROSS TWOTREE ISLAND CHANNEL and NIANTIC BAY

LOW SLACK

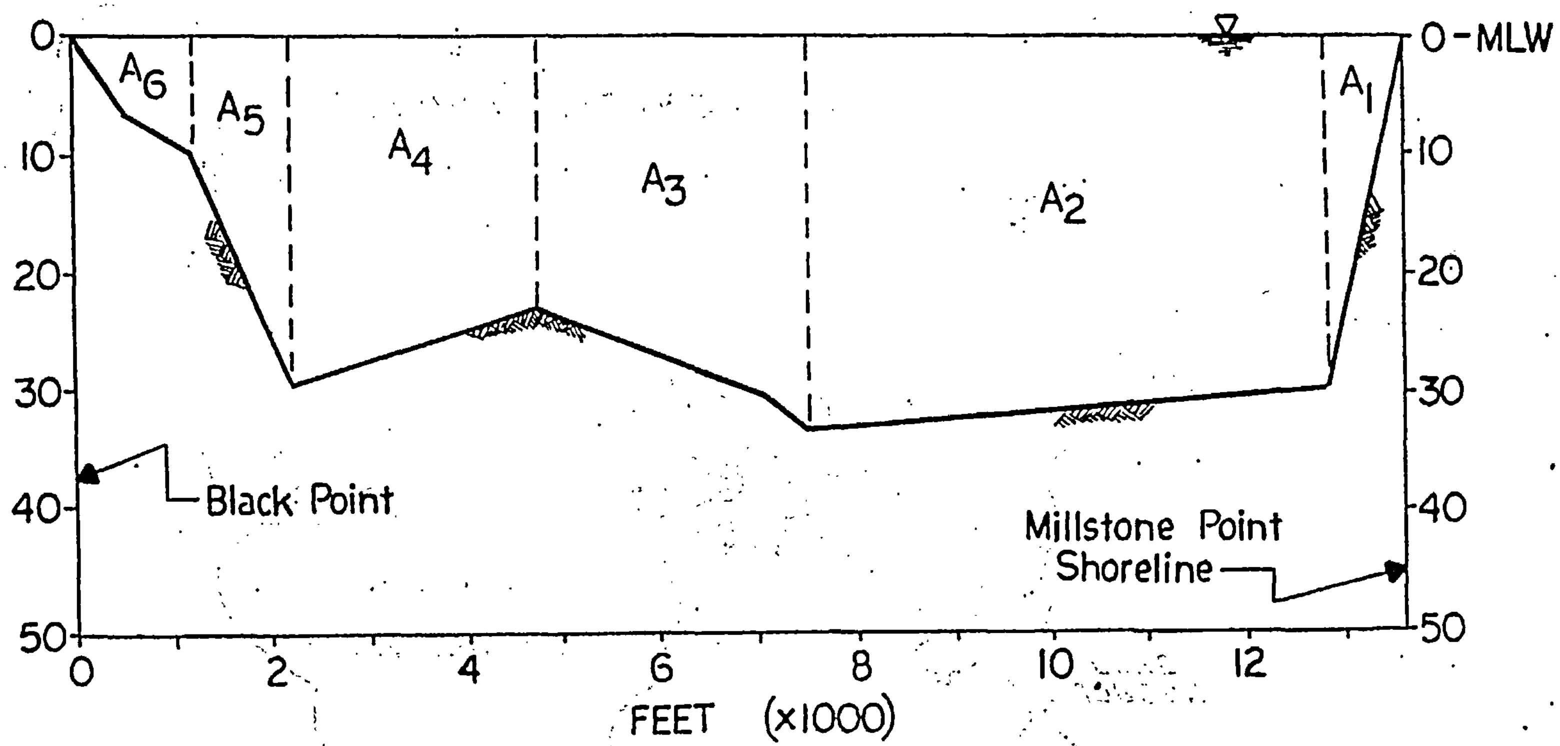


A_1 = 1,500 SF
A_2 = 5,250 SF
A_3 = 45,000 SF
A_4 = 38,250 SF
A_5 = 30,600 SF
A_6 = 9,600 SF

170,200 SF

FIGURE 2.2-7

CROSS SECTION OF TWOTREE ISLAND CHANNEL



A_1 = 12,000 SF
A_2 = 166,950 SF
A_3 = 78,400 SF
A_4 = 68,900 SF
A_5 = 20,000 SF
A_6 = 7,200 SF

A_{total} = 353,450 SF

FIGURE 2.2-8
CROSS SECTION OF NIANTIC BAY

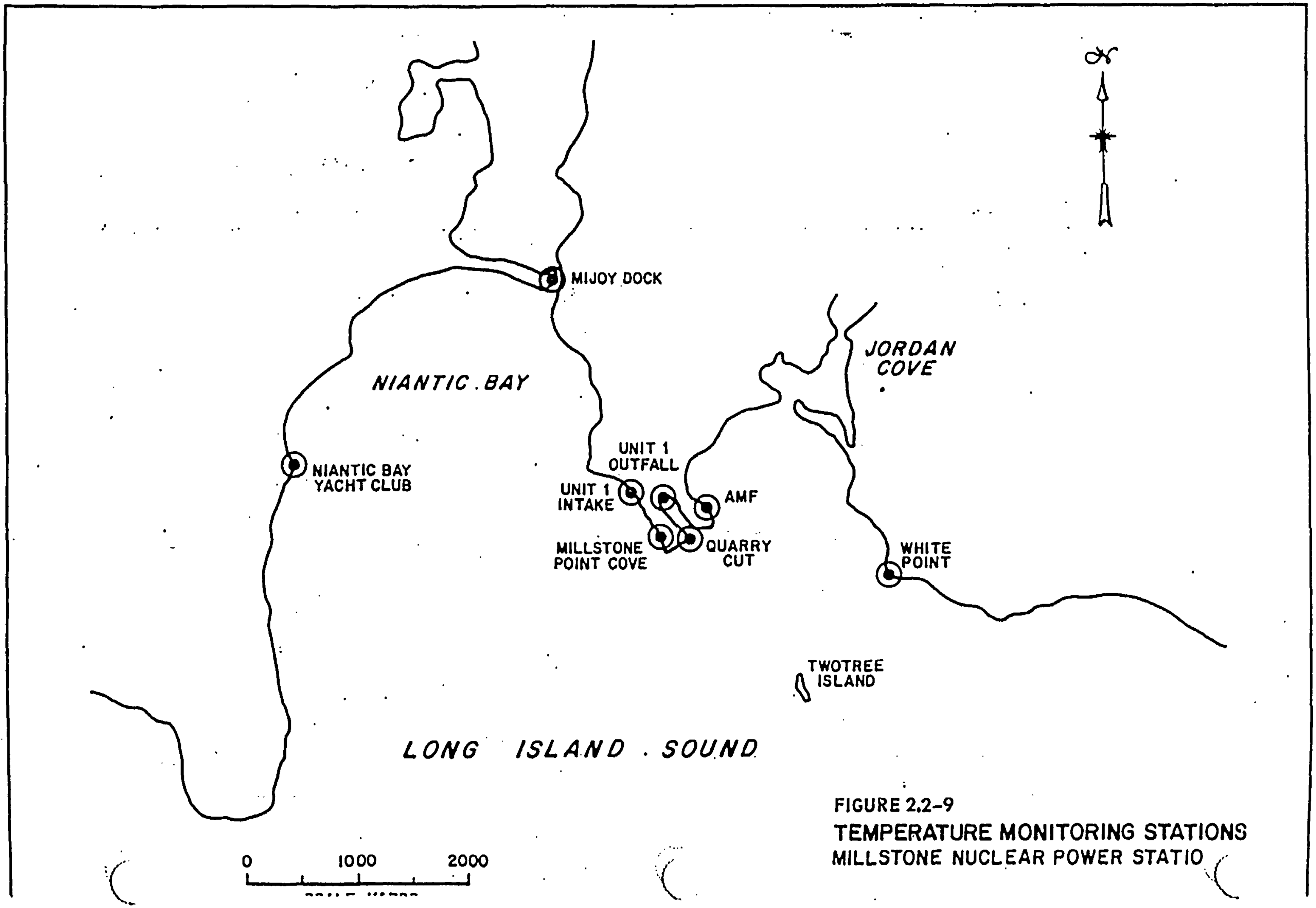


FIGURE 2.2-9
TEMPERATURE MONITORING STATIONS
MILLSTONE NUCLEAR POWER STATIO

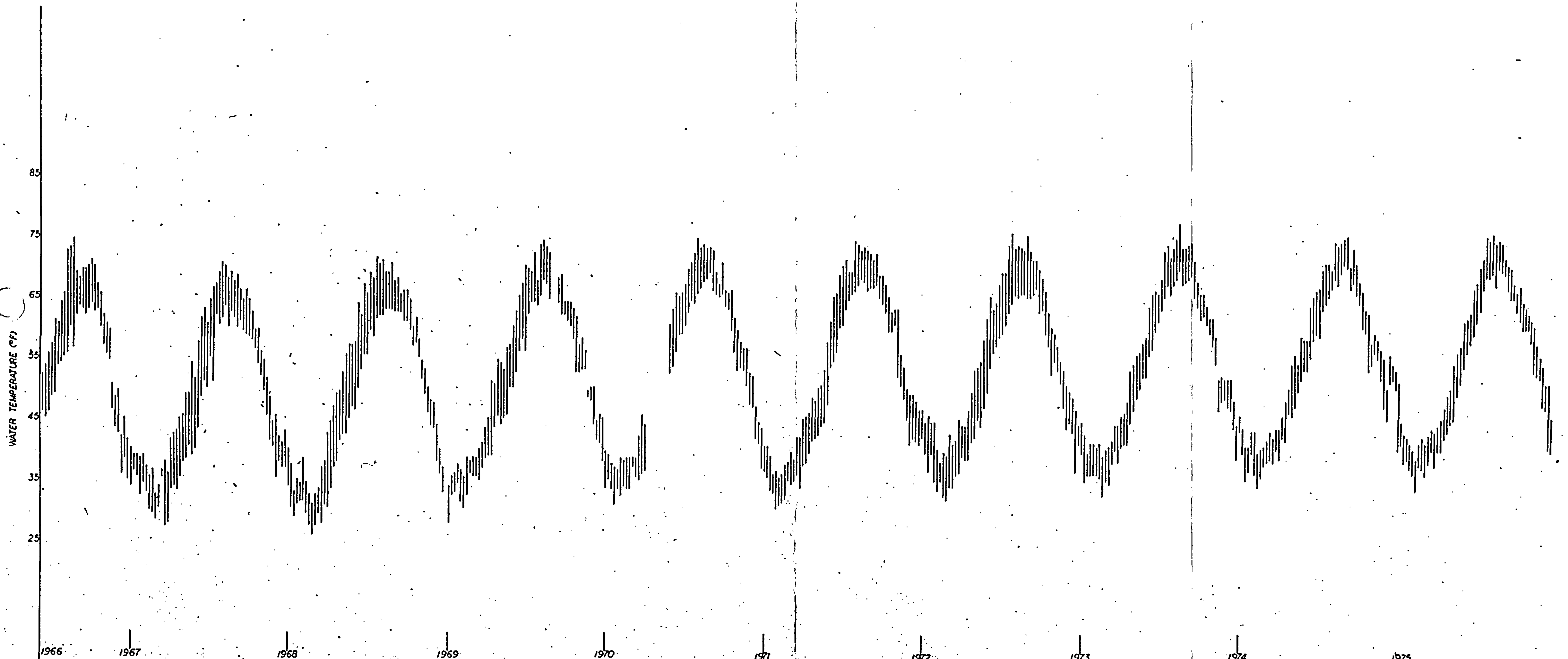
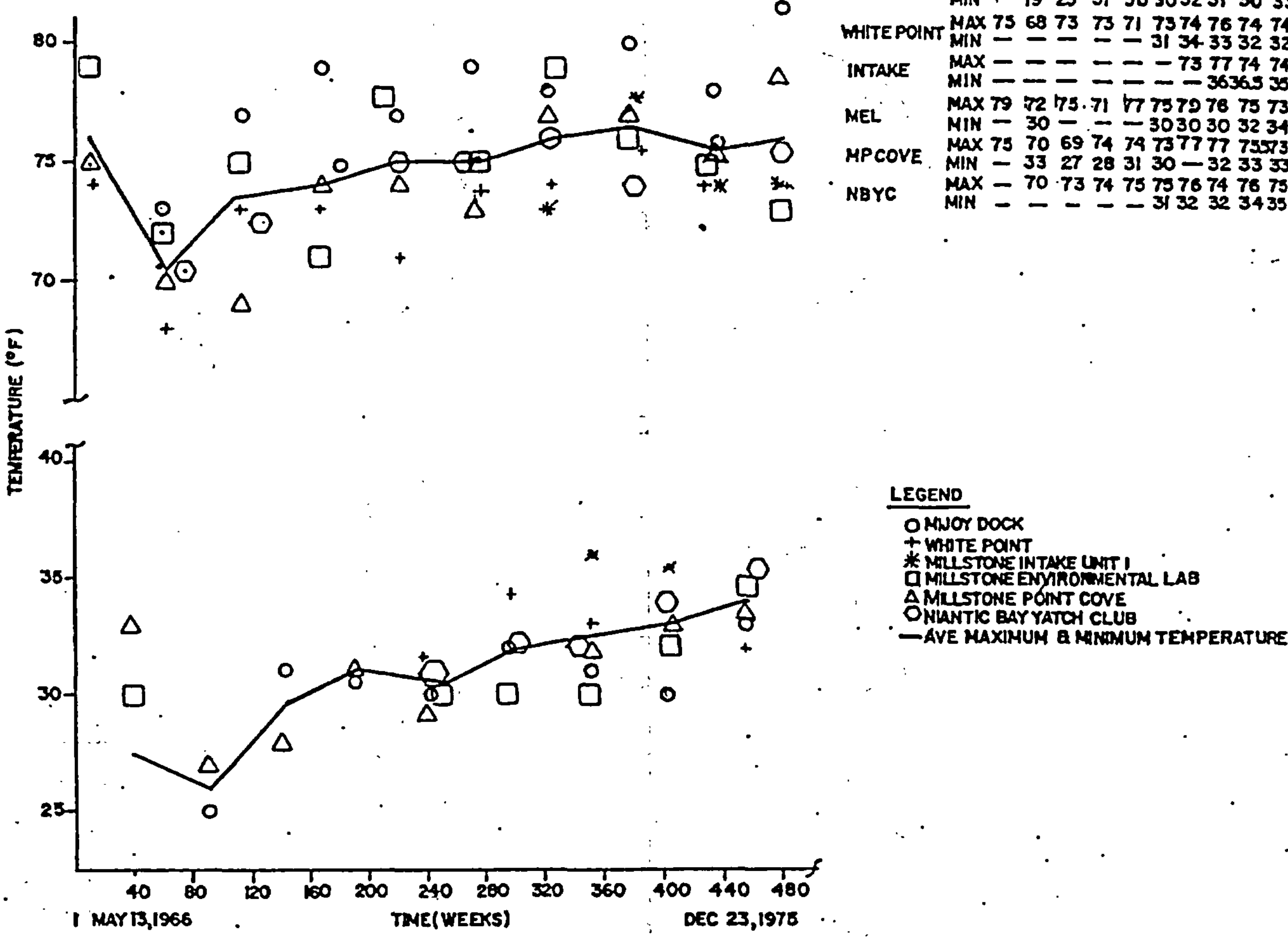


FIGURE 2.2-10 AVERAGE WEEKLY TEMPERATURE RANGES FROM SHORE BASED CONTINUOUS TEMPERATURE RECORDERS AROUND MILLSTONE POINT, MAY 1966 TO DECEMBER, 1975 (EXCLUDES QUARRY CUT AND PLANT DISCHARGES)



YEAR 19—		66	67	68	69	70	71	72	73	74	75
MIJOY DOCK	MAX	76	73	77	79	77	79	78	80	78	81.5
	MIN	—	19	25	31	30	30	32	31	30	33
WHITE POINT	MAX	75	68	73	73	71	73	74	76	74	74
	MIN	—	—	—	—	—	31	34	33	32	32
INTAKE	MAX	—	—	—	—	—	—	73	77	74	74
	MIN	—	—	—	—	—	—	—	36	36.5	35
MEL	MAX	79	72	75	71	77	75	79	78	75	73
	MIN	—	30	—	—	—	30	30	30	32	34.5
MP COVE	MAX	75	70	69	74	74	73	77	77	75.5	73.5
	MIN	—	33	27	28	31	30	—	32	33	33.5
NBYC	MAX	—	70	73	74	75	75	76	74	76	75.5
	MIN	—	—	—	—	—	31	32	32	34	35

FIGURE 2.2-11 AVERAGE MAXIMUM AND MINIMUM WATER TEMPERATURE FOR NIANTIC BAY (1966—1975)

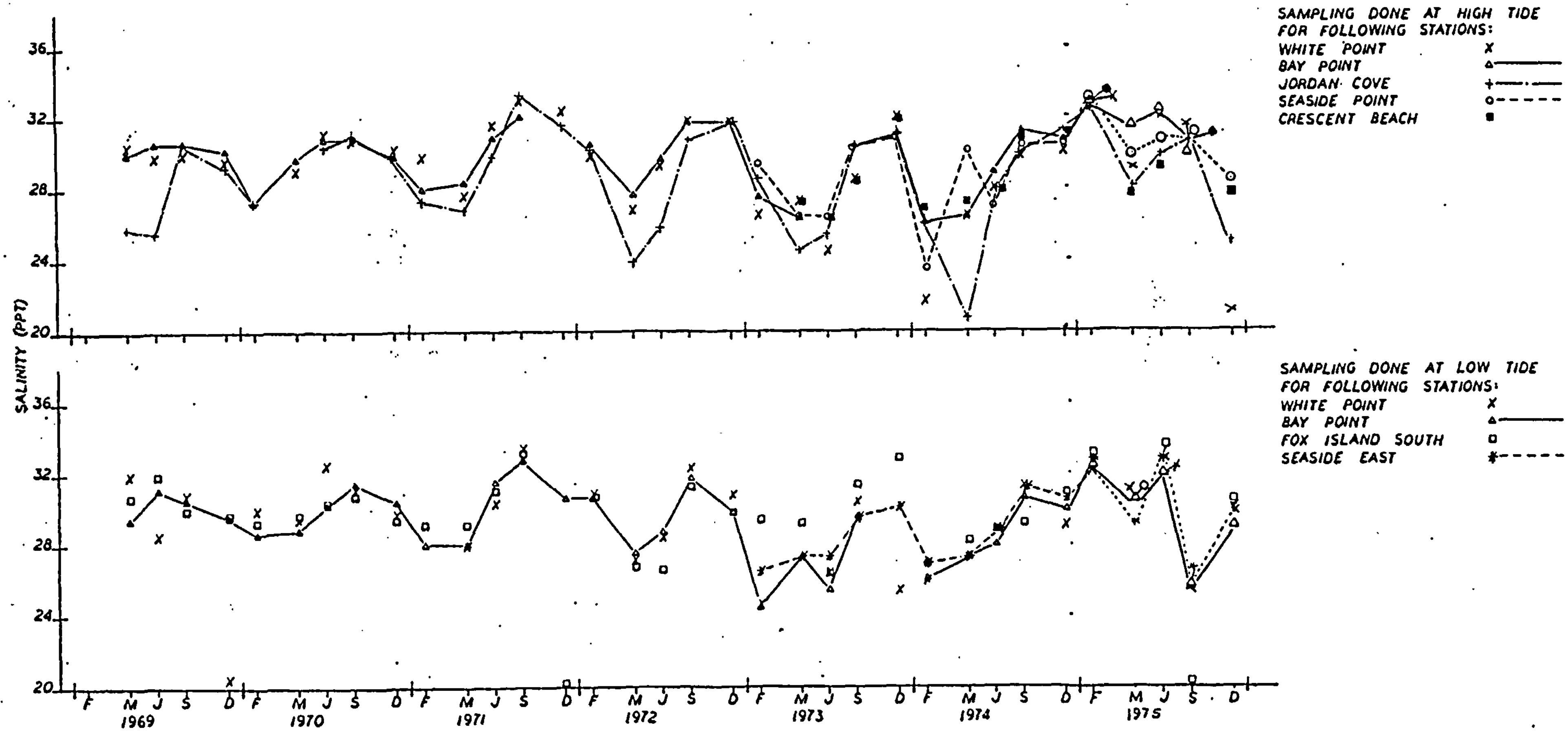
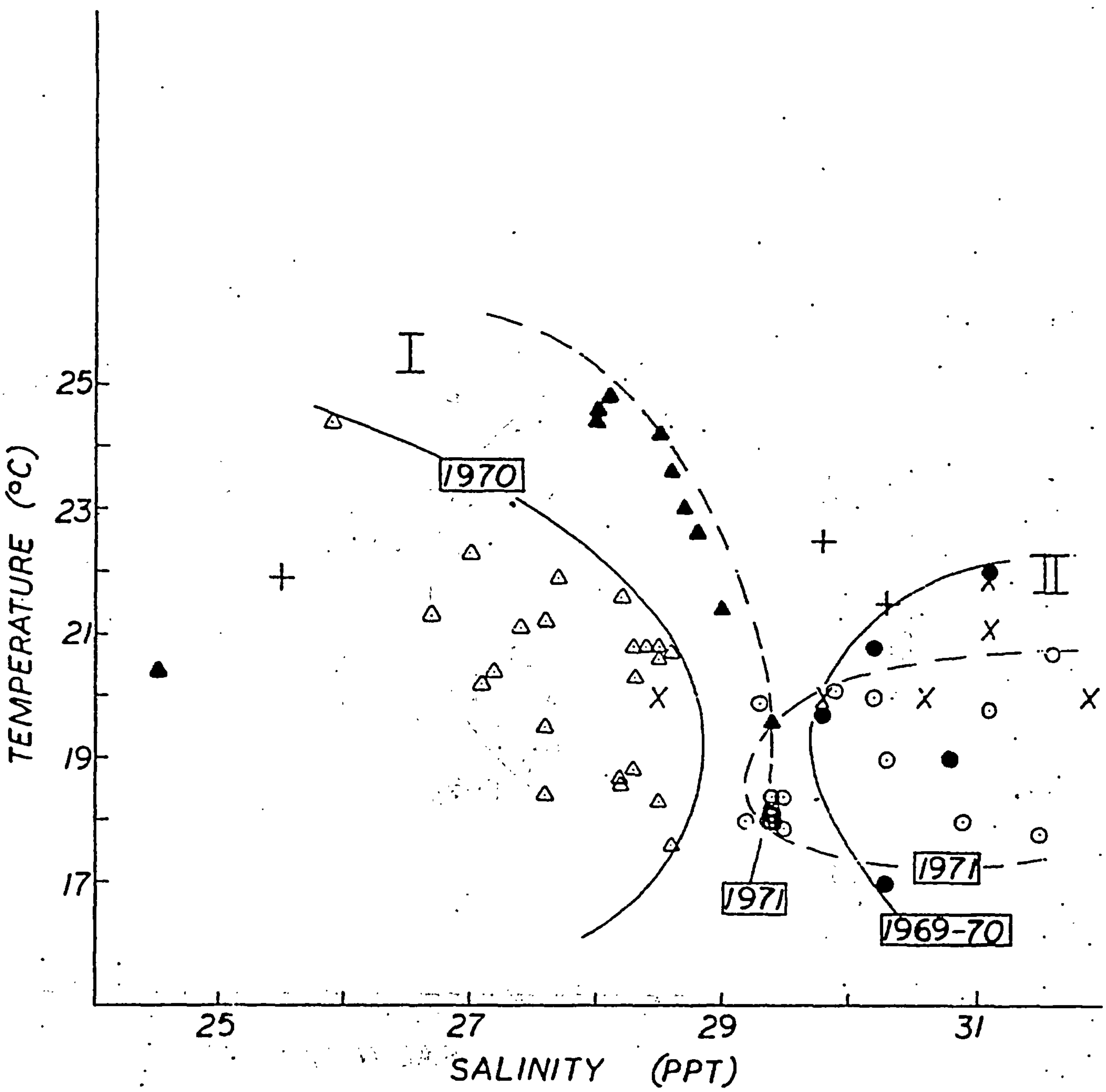


FIGURE 2.2-12 TIME HISTORY OF SALINITY MEASUREMENTS AT VARIOUS ECOLOGICAL SAMPLING STATIONS AROUND MILLSTONE POINT, 1969--1975



LEGEND:

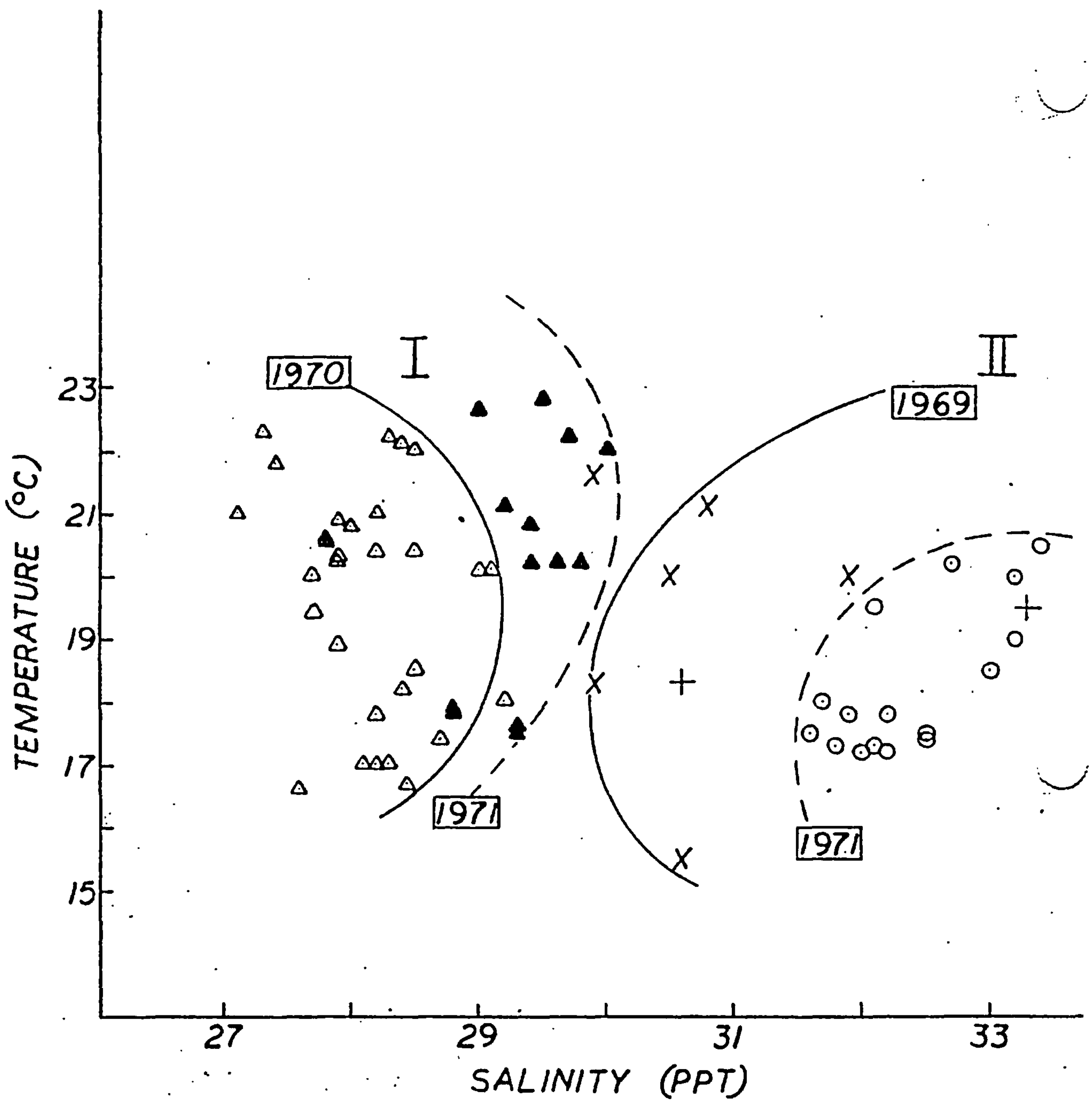
I { NIANTIC RIVER (USCG) 1970 △
1971 ▲

II { NIANTIC BAY (CLAPP) 1969 X
1970 ●
1971 ⊙

JORDAN COVE (CLAPP) +

FIGURE 2.2-13

TEMPERATURE-SALINITY DIAGRAM
JULY, 1969-1971
MILLSTONE NUCLEAR POWER STATION



LEGEND:

I { NIANTIC RIVER (USCG) 1970 △
1971 ▲

II { NIANTIC BAY (CLAPP) 1969 X
1970 ●
1971 ○

JORDAN COVE (CLAPP) +

FIGURE 2.2-14

TEMPERATURE - SALINITY DIAGRAM SEP-OCT., 1969 MILLSTONE NUCL. POWER STATION

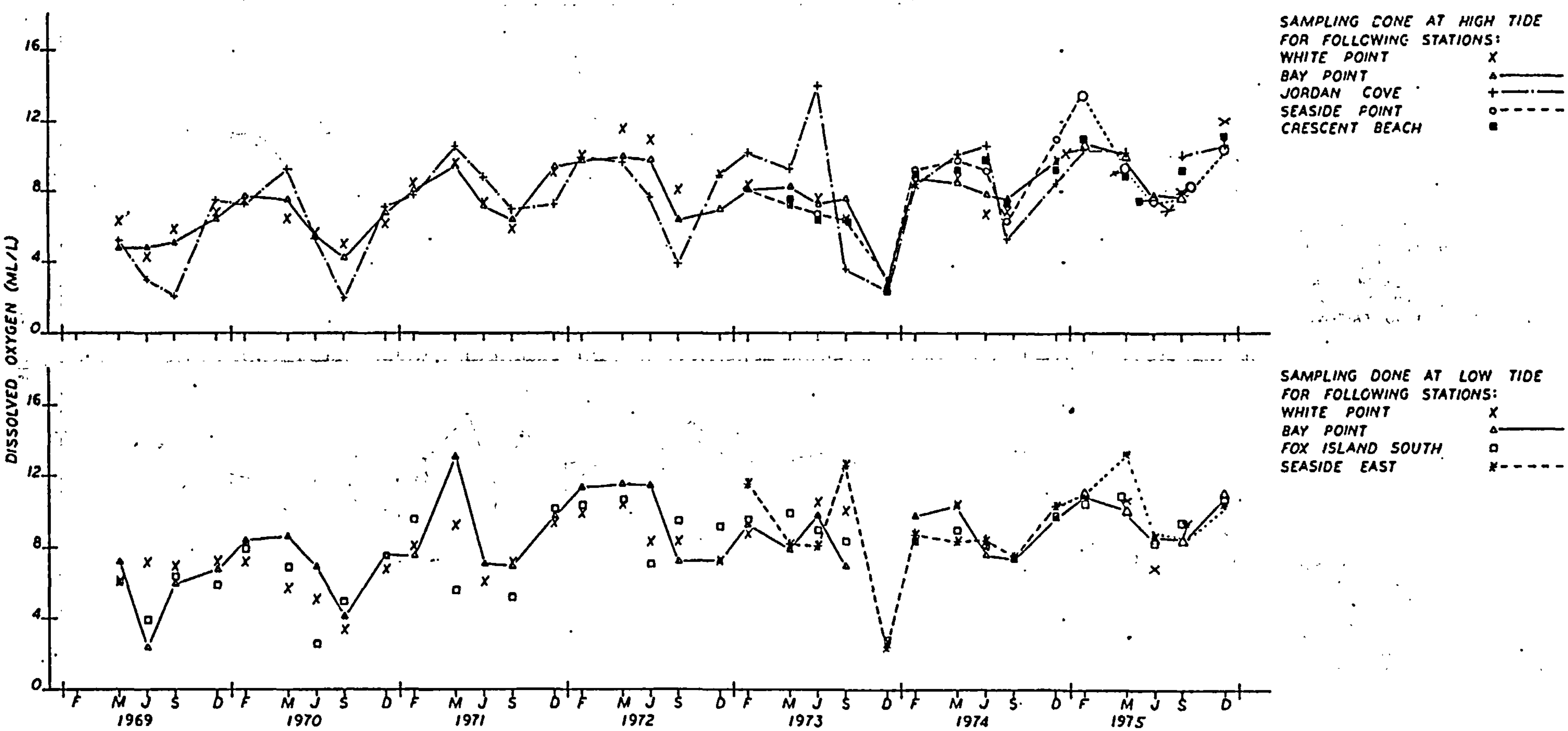


FIGURE 2.2-15 TIME HISTORY OF DISSOLVED OXYGEN MEASUREMENTS AT VARIOUS ECOLOGICAL SAMPLING STATIONS AROUND MILLSTONE POINT, 1969--1975

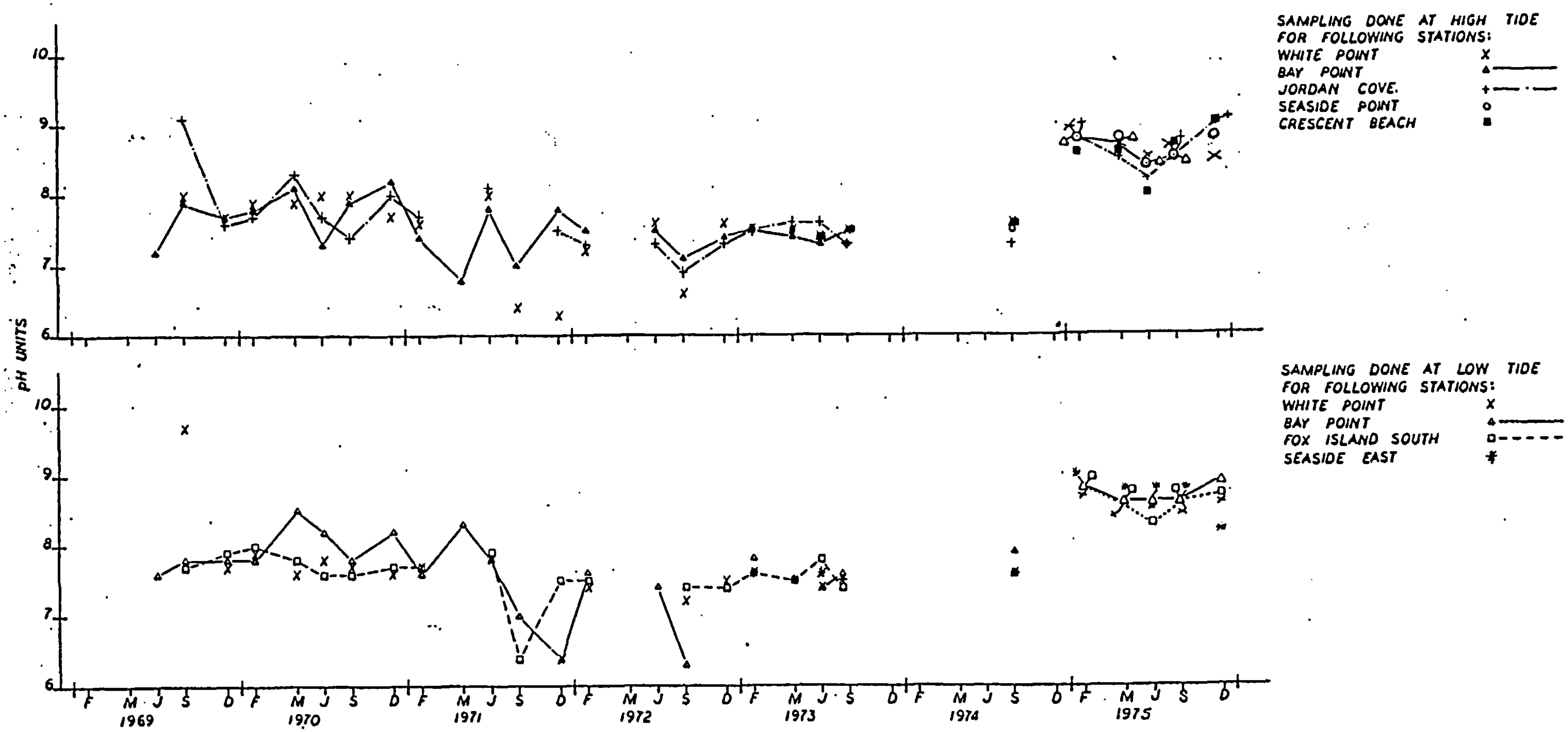


FIGURE 2.2-16 TIME HISTORY OF pH MEASUREMENTS AT VARIOUS ECOLOGICAL SAMPLING STATIONS AROUND MILLSTONE POINT, 1969--1975

TABLE 2.3-1. SPECIES COMPRISING 75 PERCENT OF ALL FISH IMPINGED ON THE INTAKE SCREENS DURING 1975

Species	Number	Percent	Cumulative Percent
Pseudopleuronectes americanus	2,917	20	20
Merluccius bilinearis	1,693	12	32
Gasterosteus aculeatus	1,450	10	42
Myoxocephalus aenaeus	1,074	7	49
Menidia spp.	974	7	56
Urophycis spp.	780	5	61
Tautoga onitis	738	5	66
Morone americana	680	5	71
Tautogolabrus adspersus	580	4	75

TABLE 3.1-1. MILLSTONE UNIT 1 GROSS MWe DAILY MEAN
NOVEMBER 1970 - DECEMBER 1975

	1970	1971	1972	1973	1974	1975
January	-	214	665	0	492	441
February	-	194	155	0	491	278
March	-	333	564	261	505	434
April	-	481	671	380	542	444
May	-	464	654	0	536	447
June	-	501	641	0	496	436
July	-	652	607	23	536	366
August	-	532	540	515	464	252
September	-	330	0	381	0	169
October	-	170	0	388	0	80
November	2	644	0	433	501	279
December	89	621	0	309	599	452

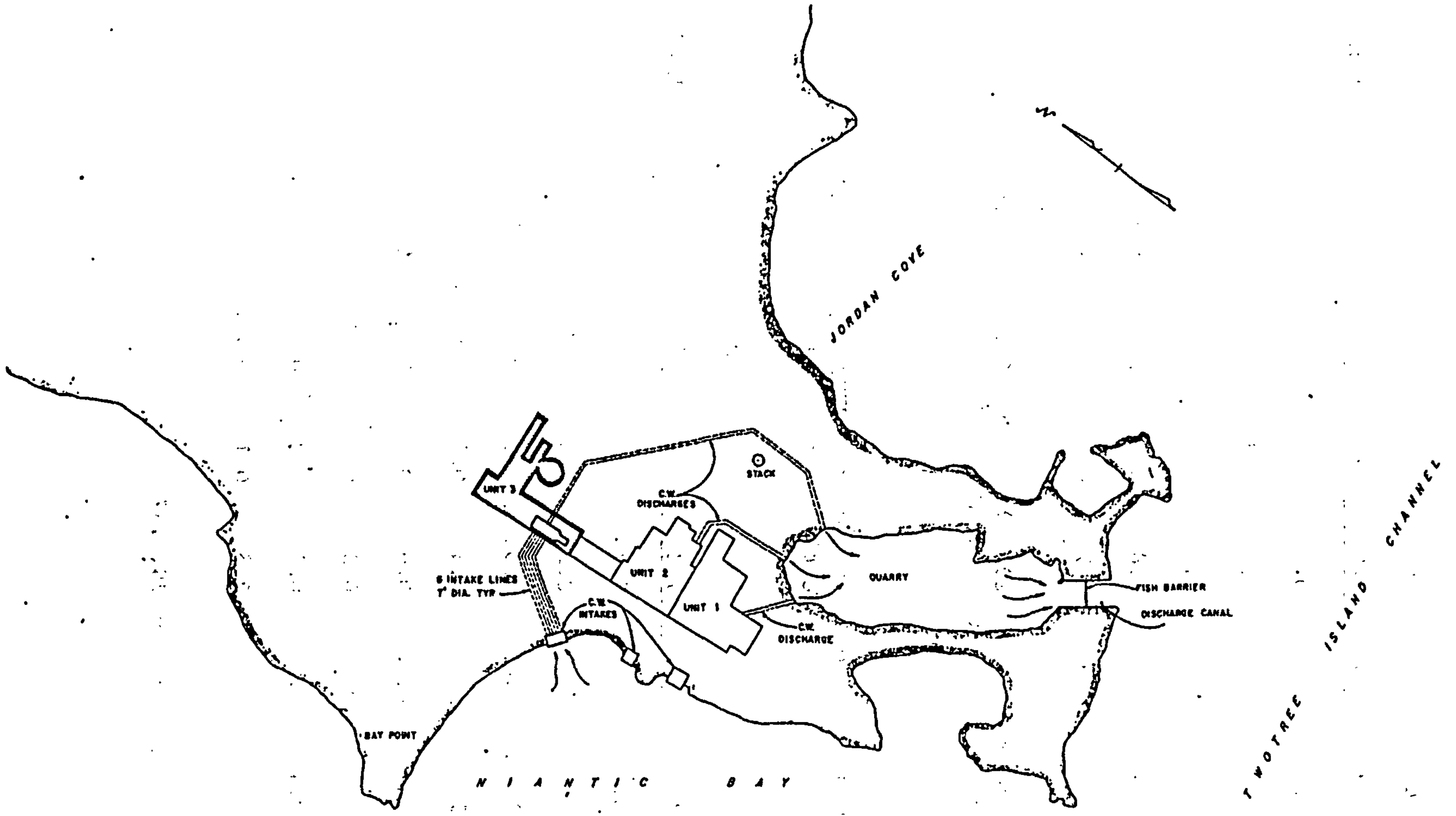


FIGURE 3.1-1

ONCE-THROUGH QUARRY DISCHARGE CIRCULATING WATER SYSTEM
MILLSTONE NUCLEAR POWER STATION

TABLE 3.2-1. UNIT I INTAKE WATER VELOCITY PROFILES: TRASH RACKS
(Velocities in ft/sec.)

Feet From Bottom	A		B		C	D	Bay
	1/2	1/4	1/2	3/4	1/2	1/2	Bay Width
3	1.8	1.4	0.7	1.0	0.5	0.7	
6	1.8	1.7	1.2	1.3	0.8	1.0	
9	2.4	1.5	1.9	1.1	0.8	0.9	
12	2.4	1.7	1.8	1.9	1.1	1.4	
15	0.8	0.8	0.7	0.6	1.2	1.1	

Measurements made on December 29, 1975 with a Cushing Engineering, Inc. electromagnetic water current meter Model 632P.

UNIT II INTAKE WATER VELOCITY PROFILES: TRASH RACKS
(Velocities in ft/sec.)

Feet From Bottom	A		B		C	D	Bay
	1/2	1/4	1/2	3/4	1/2	1/2	Bay Width
3	0.7	0.5	0.3	0.1	0.7	1.0	
6	1.1	0.1	0.1	0.2	0.7	1.2	
9	1.0	0.4	0.3	0.3	0.8	1.1	
12	1.5	0.3	0.4	0.4	1.0	1.1	
15	1.3	0.6	0.6	0.6	0.9	1.1	
18	0.4	0.4	0.3	0.2	0.5	0.4	
21	0.4	0.4	0.2	0.3	0.4	0.3	
24	0.3	0.4	0.3	0.1	0.2	0.5	

Measurements made on December 29, 1975.

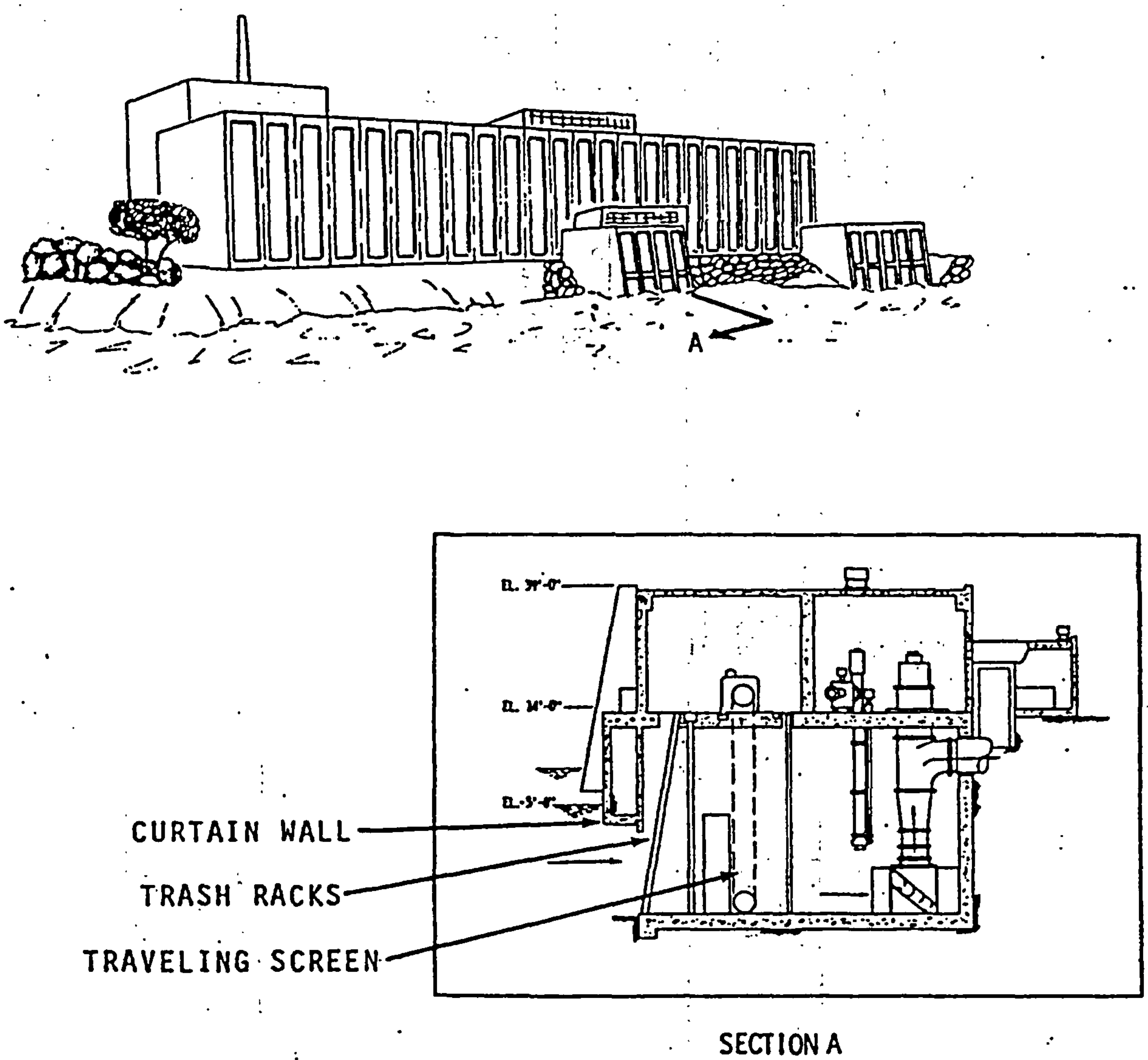


FIGURE 3.2-1 UNITS 1 AND 2 CIRCULATING WATER INTAKE STRUCTURES

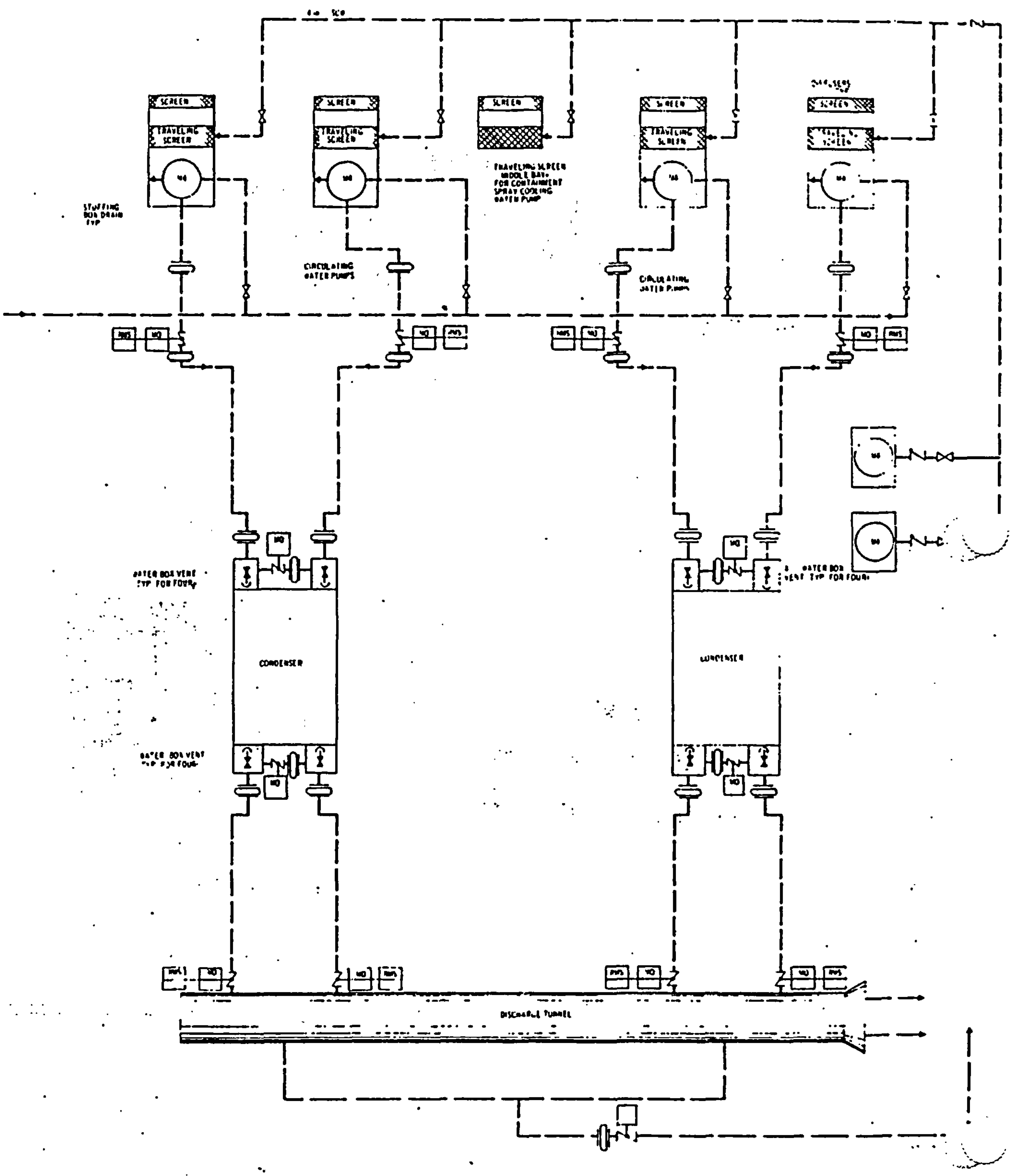


FIGURE 3.2-2

CIRCULATING WATER PIPING DIAGRAM

MILLSTONE UNIT 1

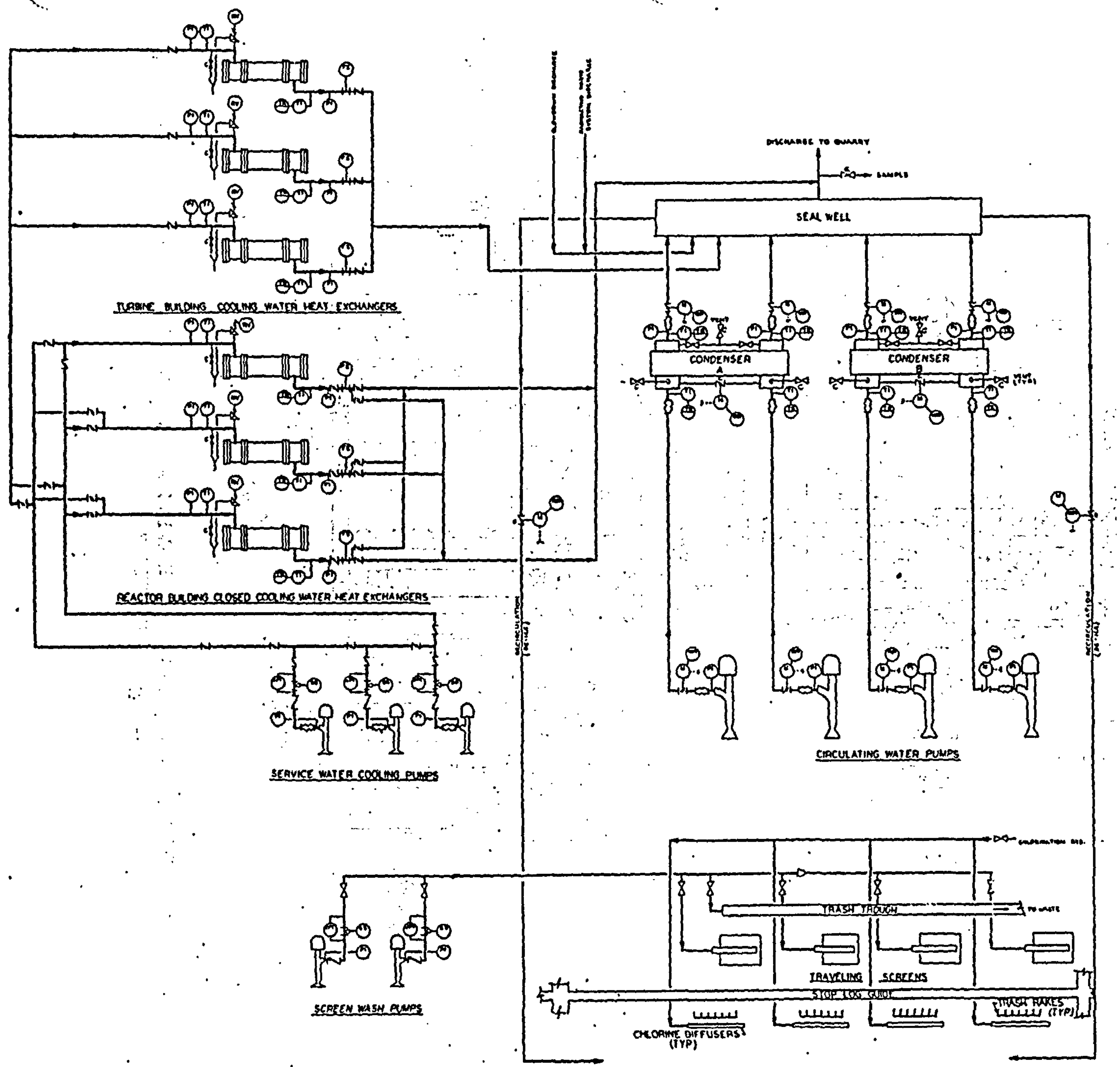


FIGURE 3.2-3

CIRCULATING WATER PIPING DIAGRAM

MILLSTONE UNIT II

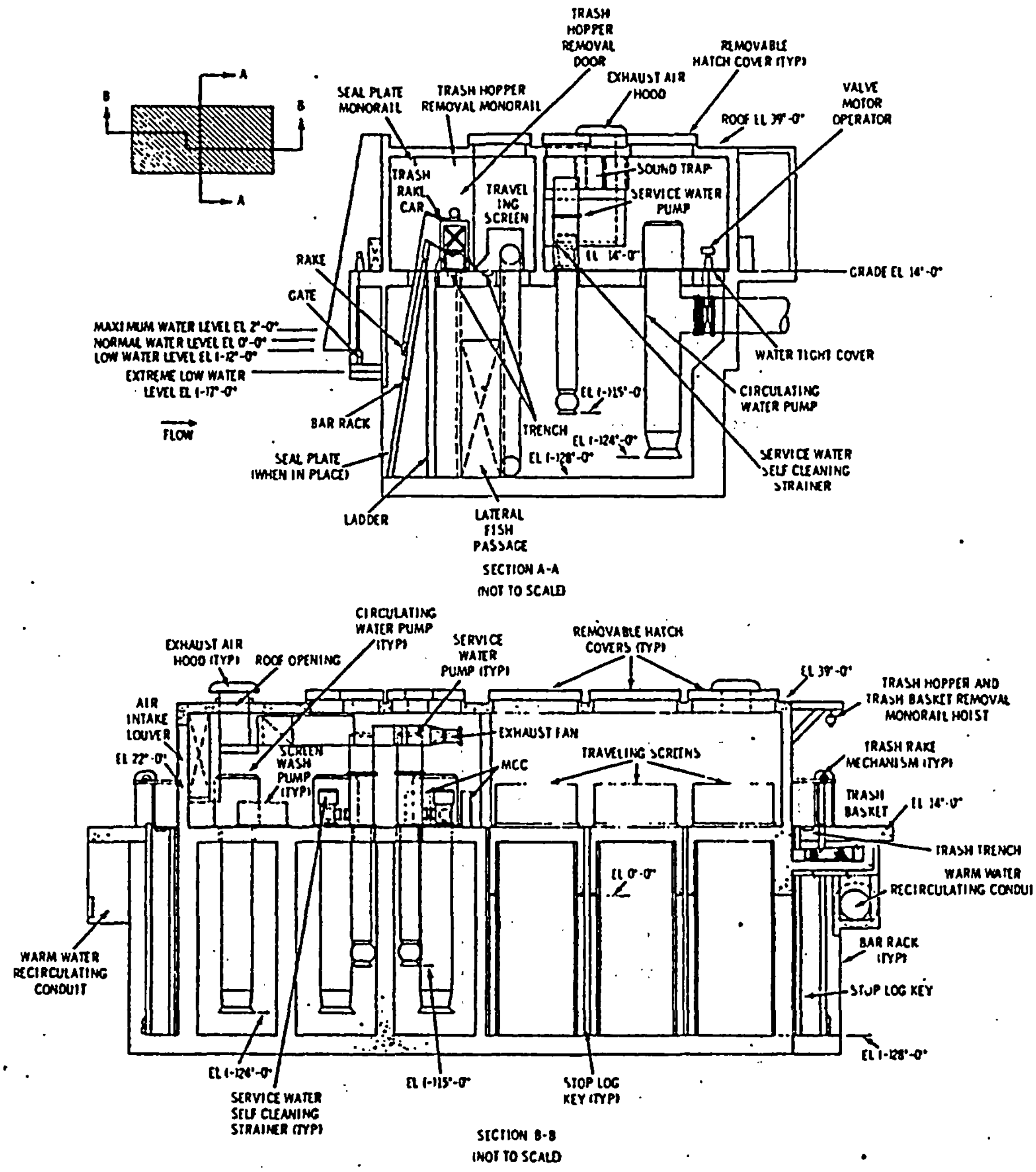


FIGURE 3.2-4 CIRCULATING AND SERVICE WATER PUMPHOUSE, MILLSTONE NUCLEAR POWER STATION UNIT 3

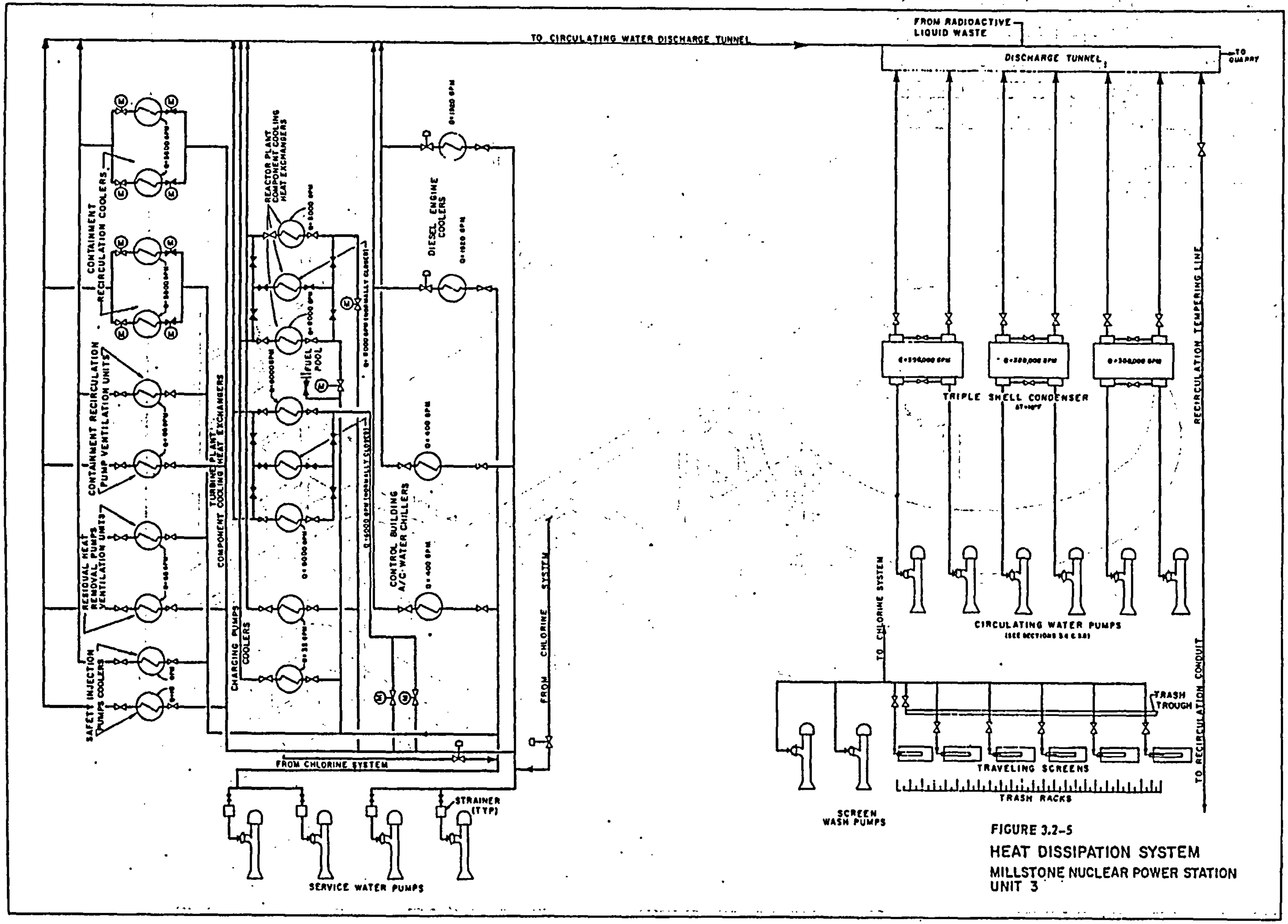


FIGURE 3.2-5

HEAT DISSIPATION SYSTEM

MILLSTONE NUCLEAR POWER STATION UNIT 3

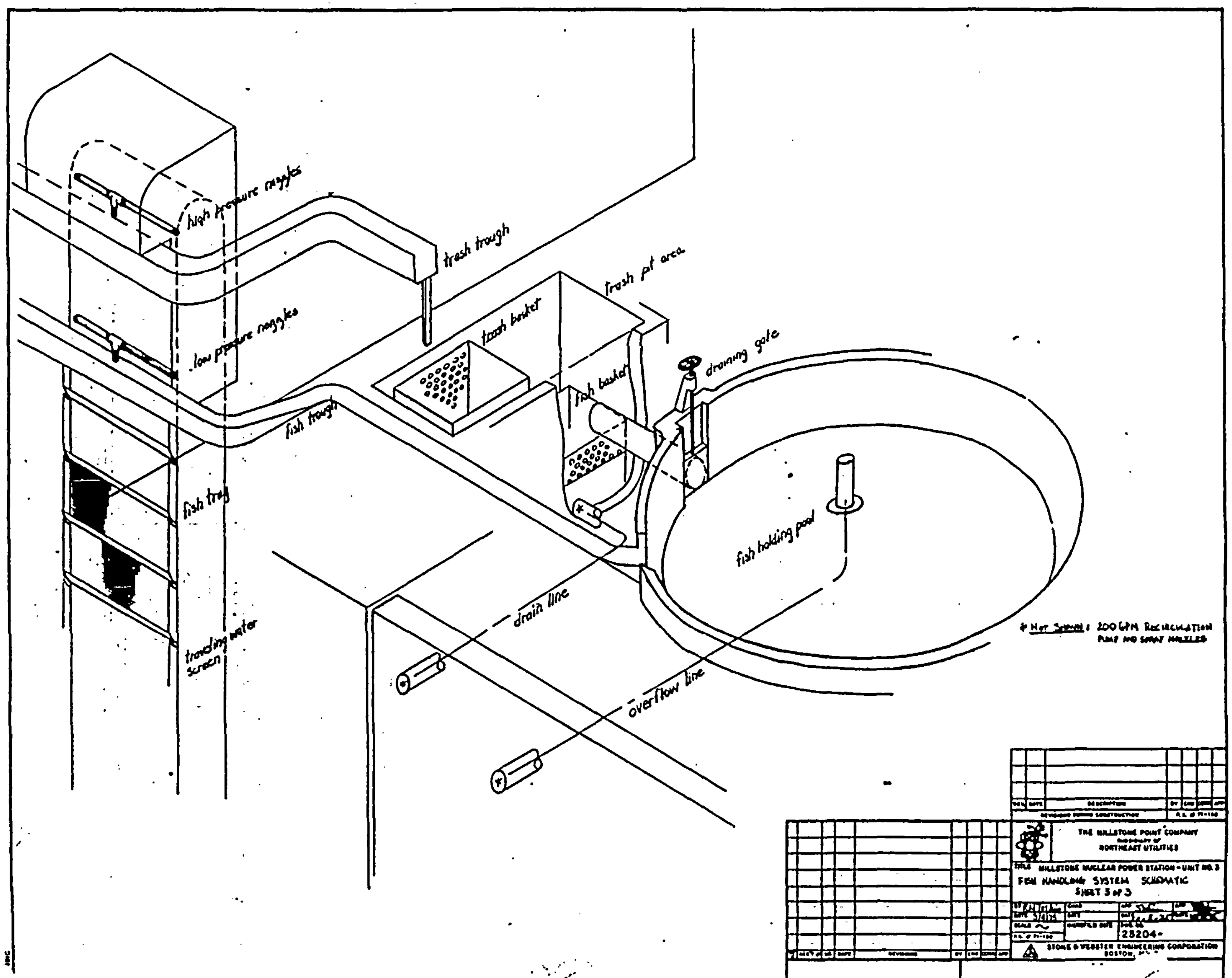


FIG. 3.2-6 F HANDLING SYSTEM

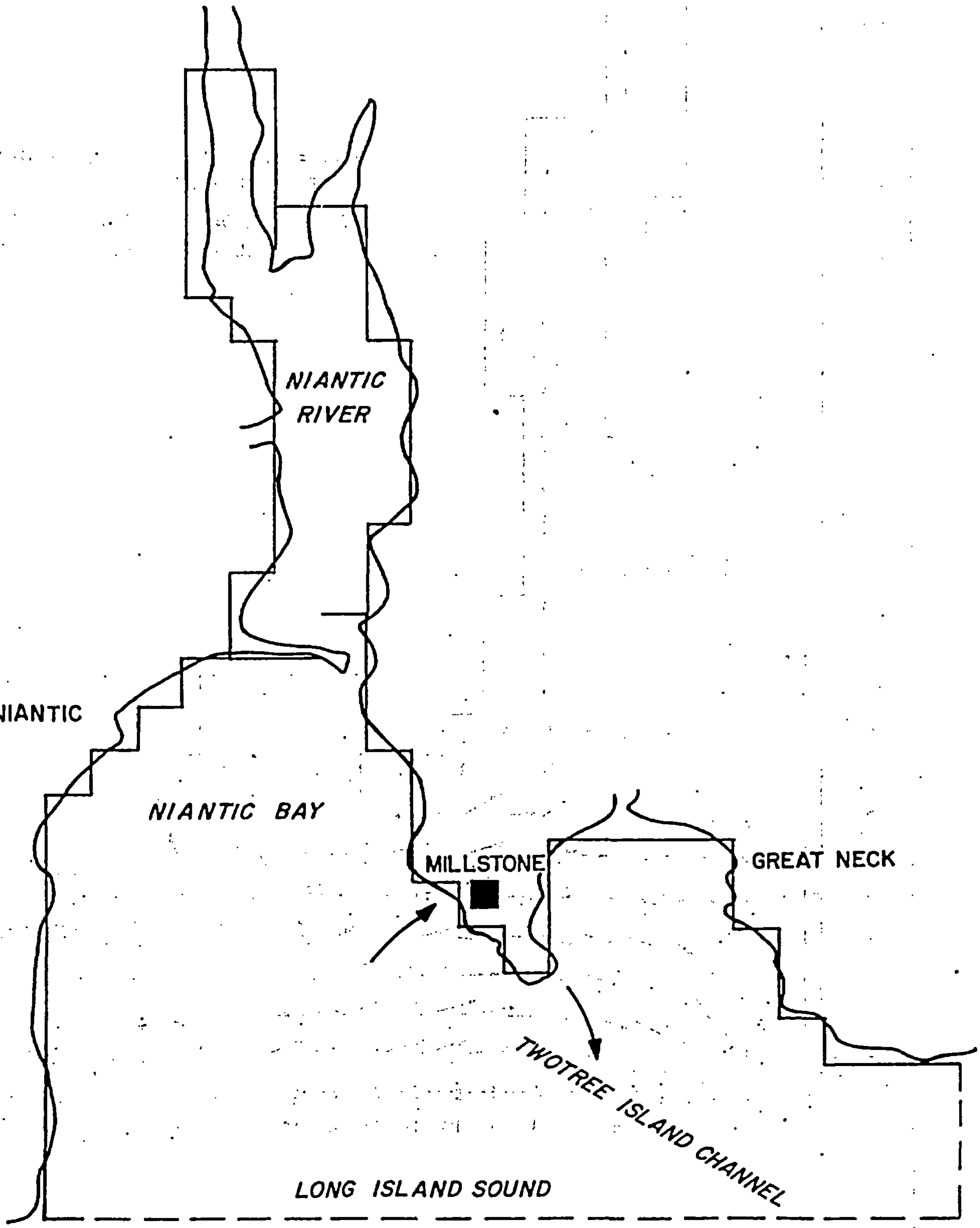


FIGURE 4.2-1
TIDAL CIRCULATION MODEL
MILLSTONE NUCLEAR POWER STATION

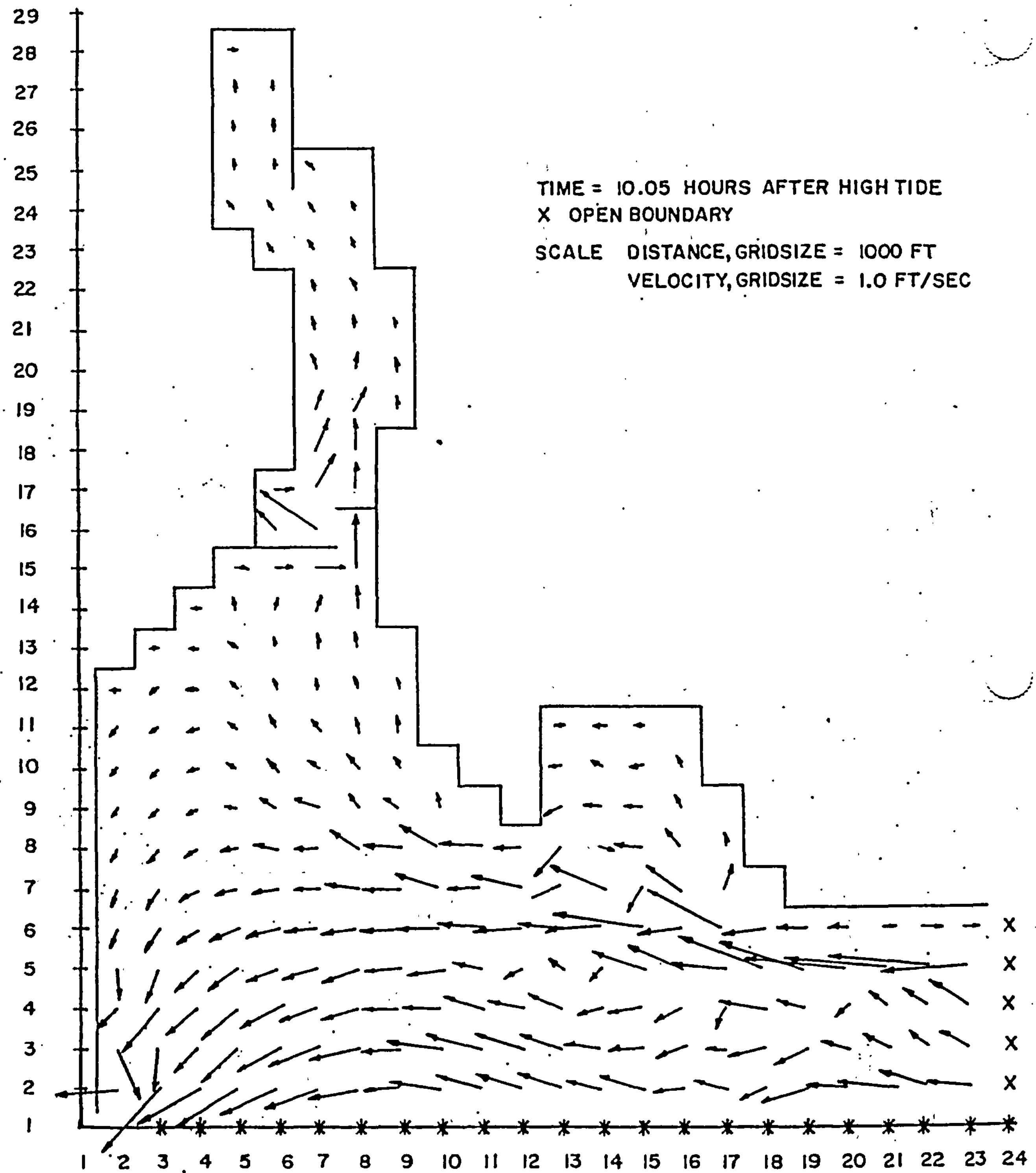


FIGURE 4.2-2
STRENGTH OF FLOOD
MILLSTONE NUCLEAR POWER STATION

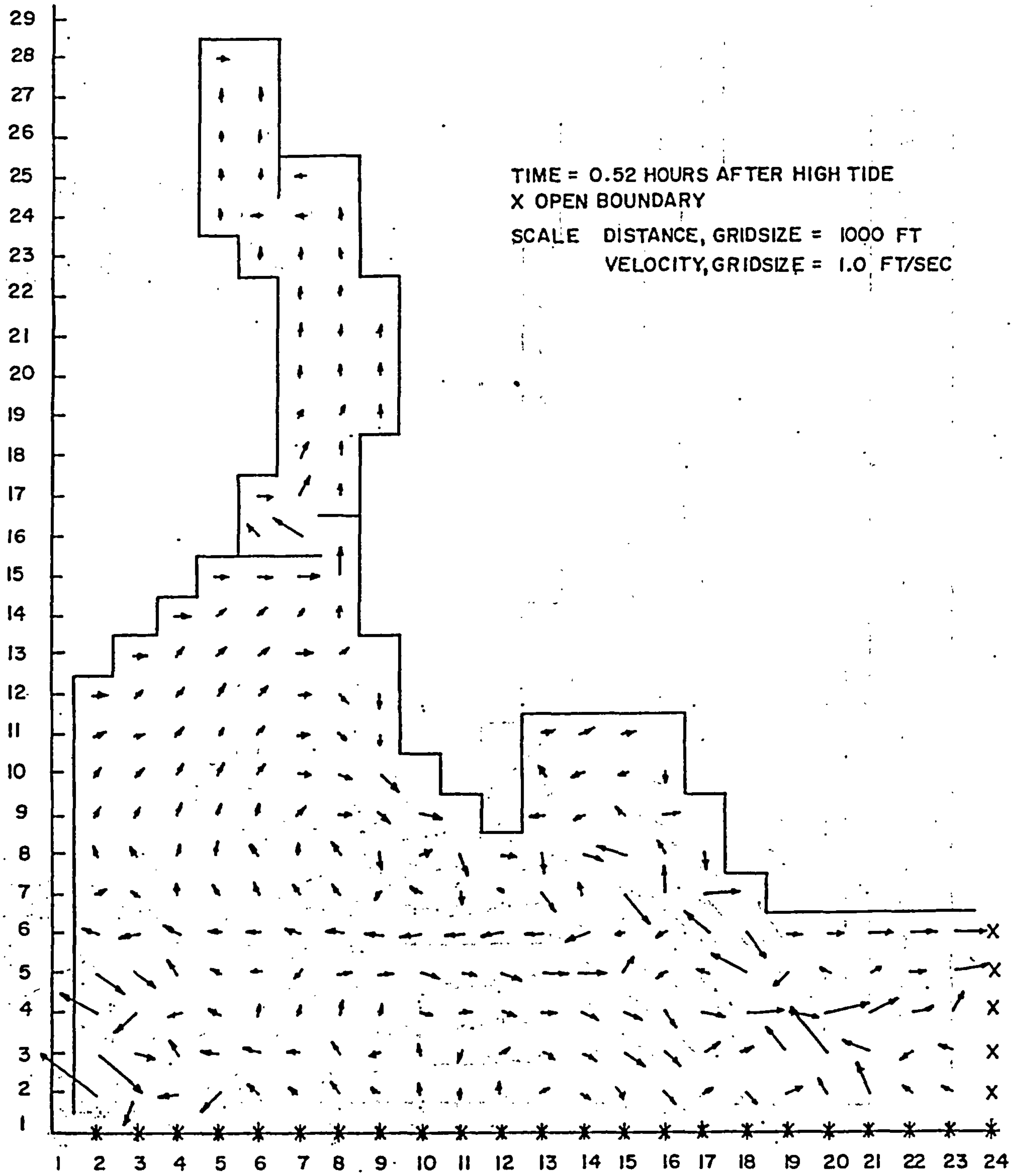


FIGURE 4.2-3
HIGH SLACK
MILLSTONE NUCLEAR POWER STATION

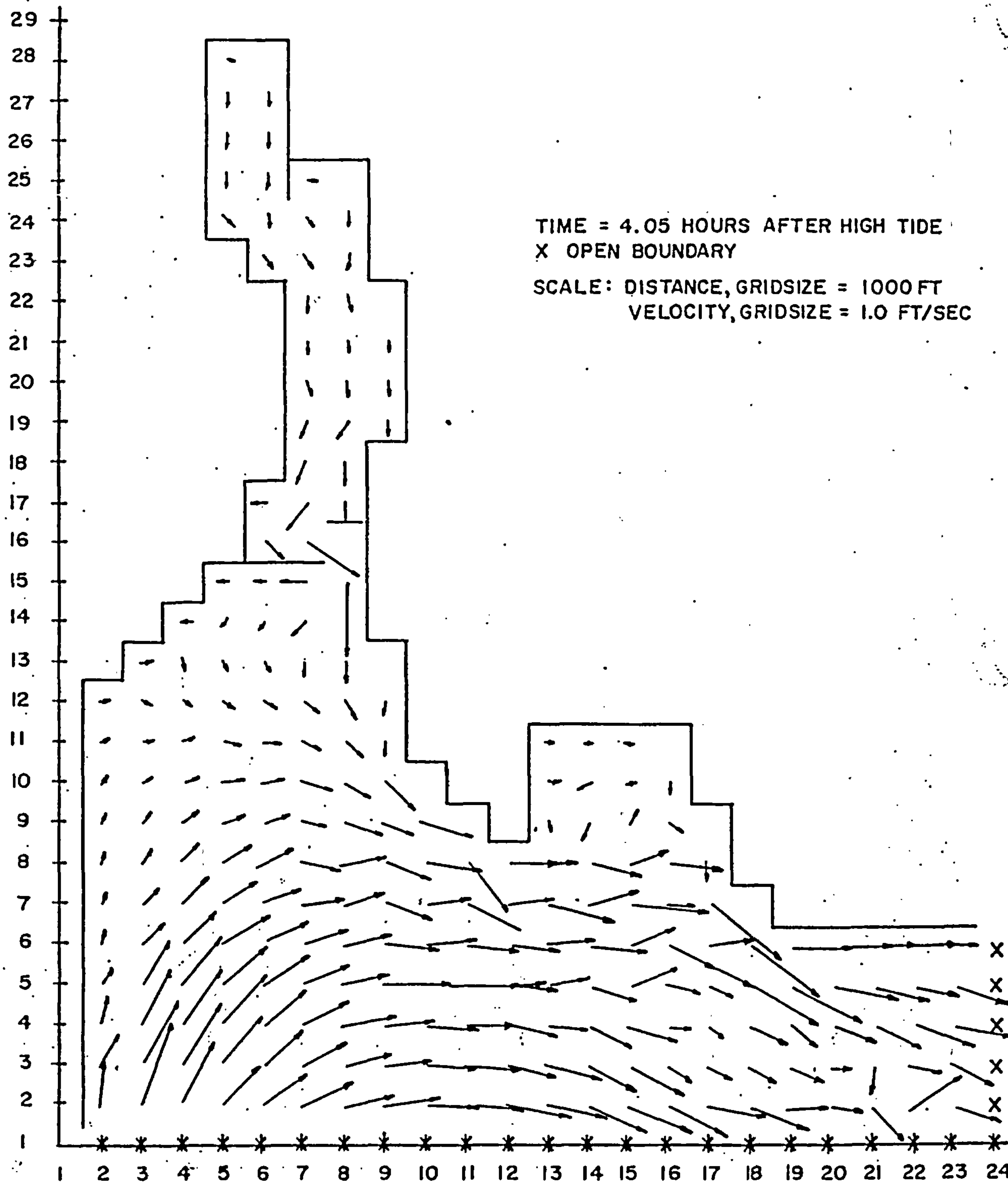


FIGURE 4.2-4
STRENGTH OF EBB
MILLSTONE NUCLEAR POWER STATION

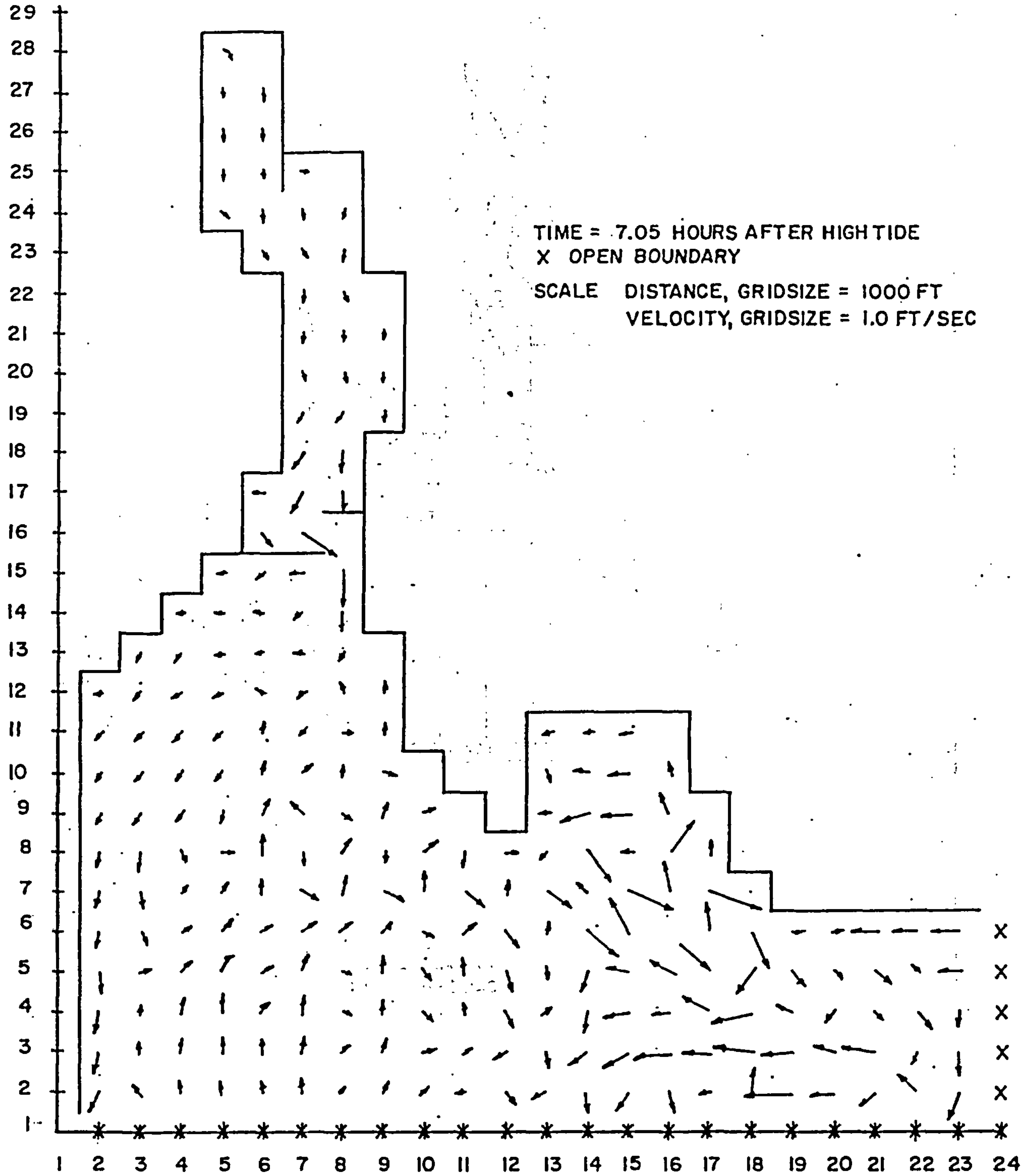


FIGURE 4.2-5
LOW SLACK
MILLSTONE NUCLEAR POWER STATION

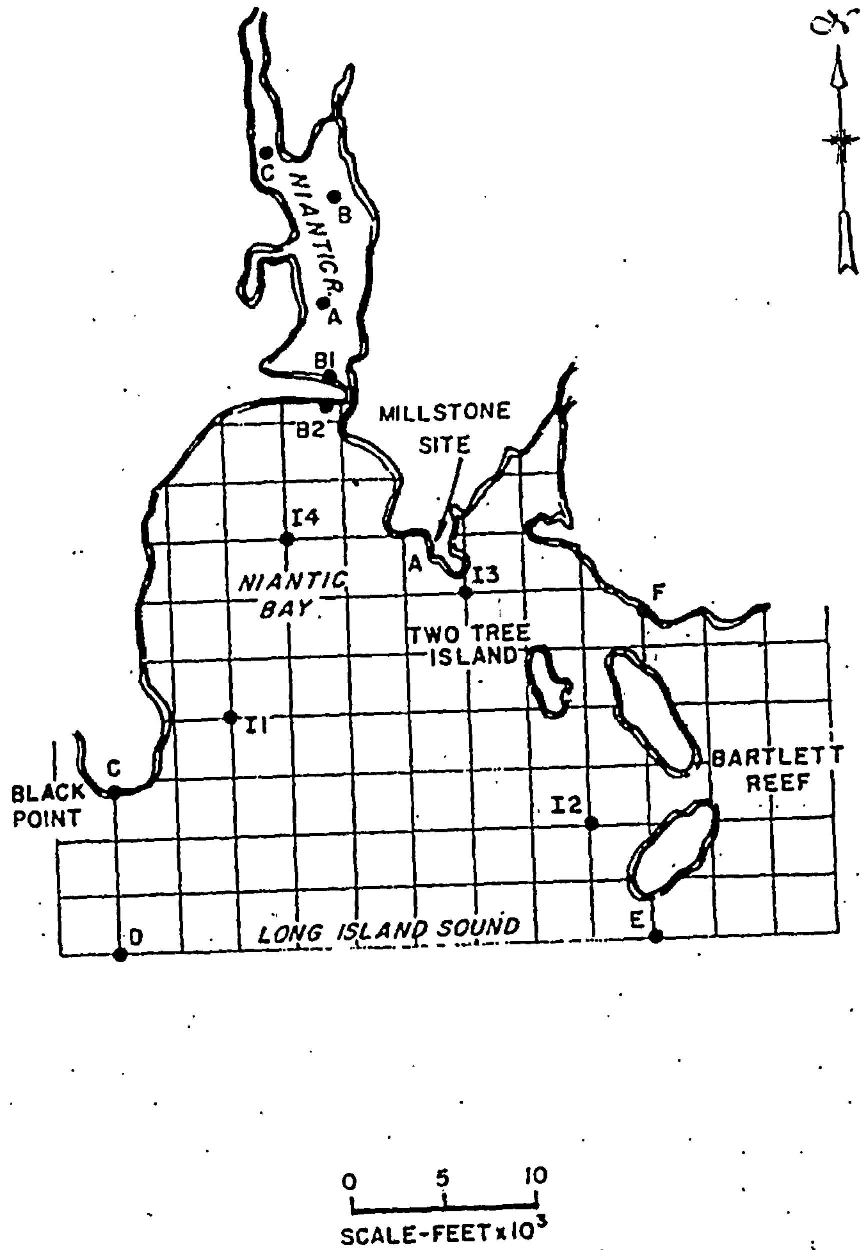


FIGURE 4.2-5A

LOCATION OF
FIELD SURVEY STATIONS
AUGUST-SEPTEMBER 1973

MILLSTONE NUCLEAR POWER STATION

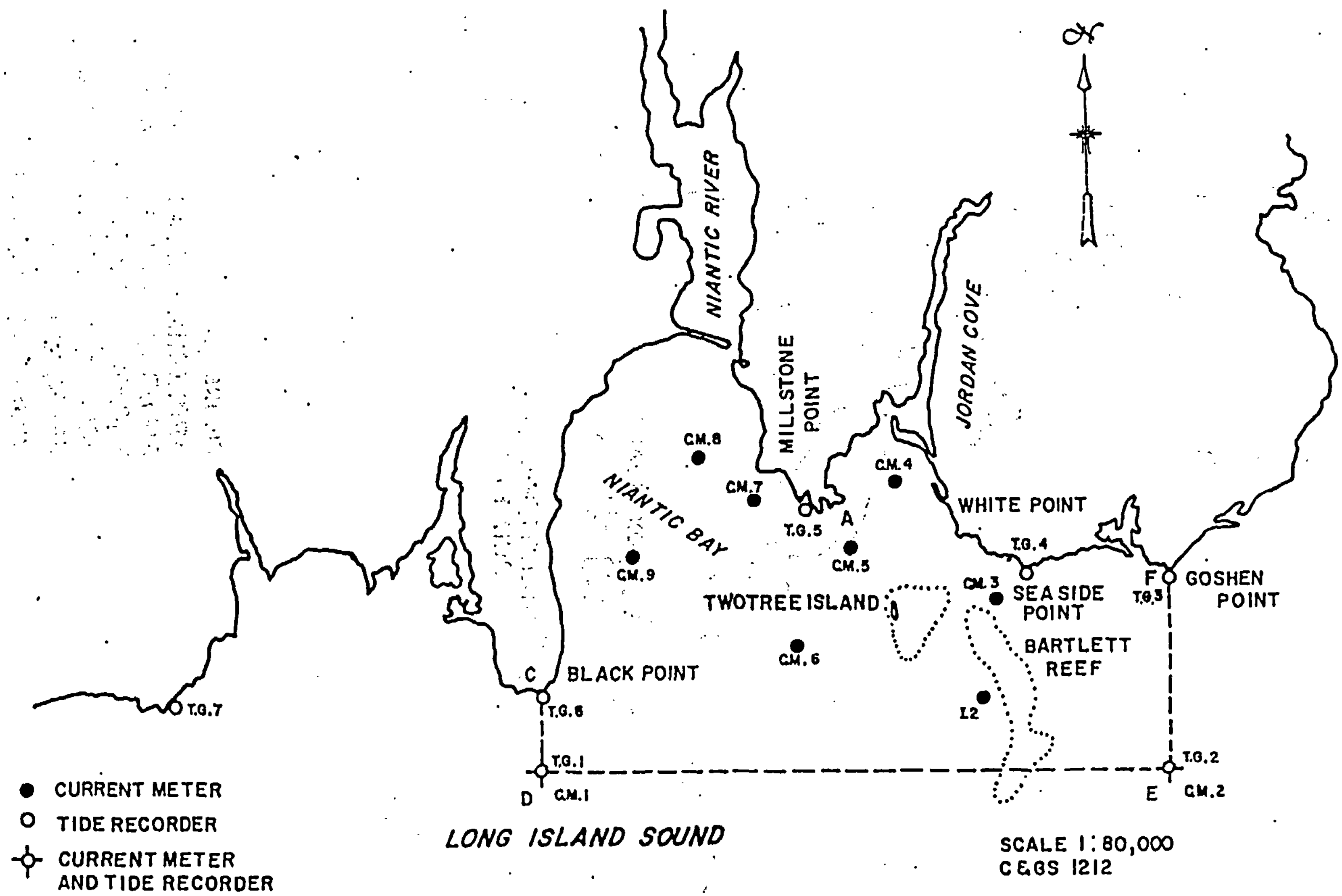


FIGURE 4.2-6

APPROXIMATE LOCATION OF FIELD SURVEY STATIONS FEBRUARY 1974

MILLSTONE NUCLEAR POWER STATION

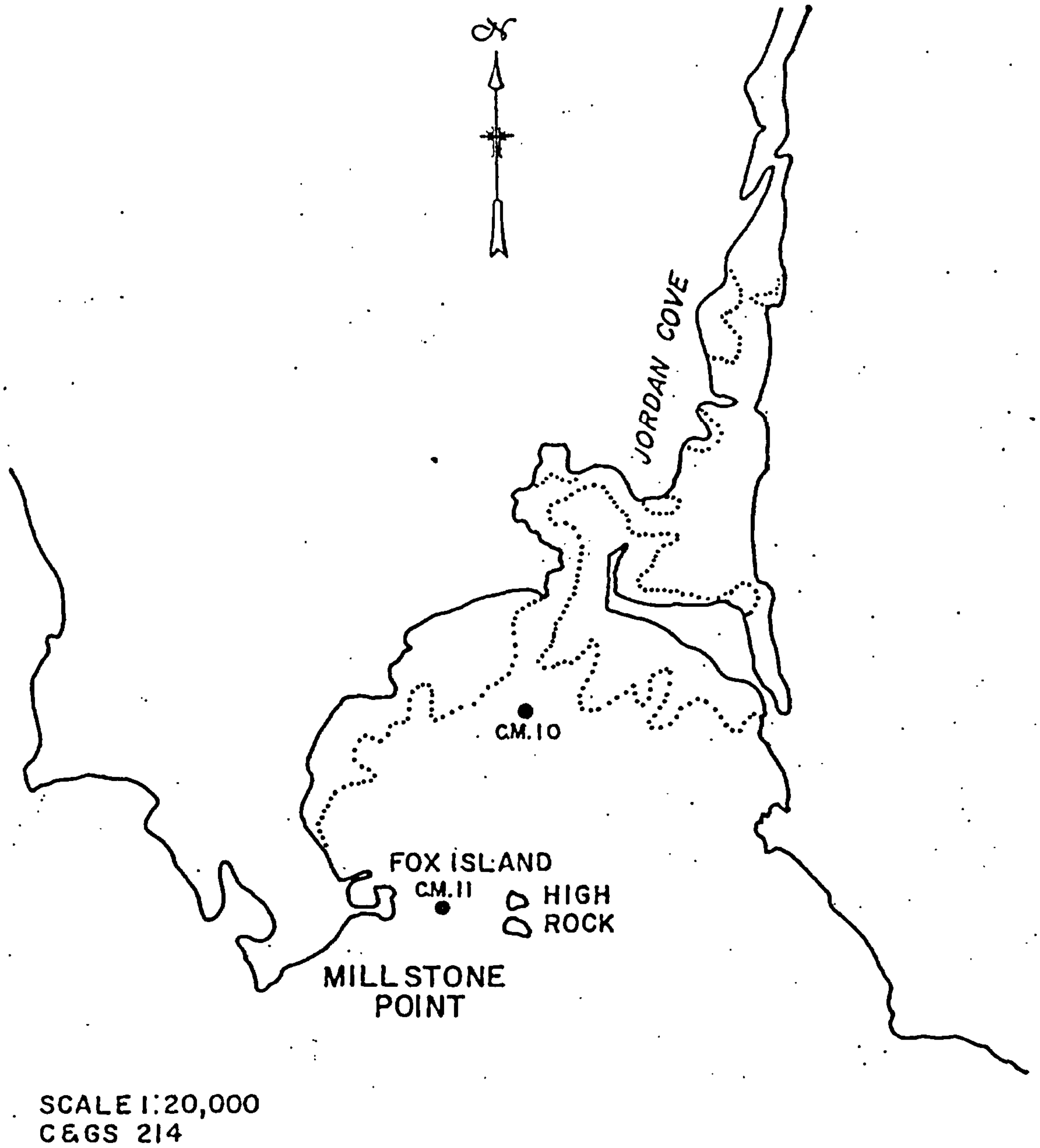


FIGURE 4.2-7
APPROXIMATE LOCATION OF FIELD SURVEY STATIONS SHORT-TERM SURVEY-JORDAN COVE AND FOX ISLAND FEBRUARY 1974
MILLSTONE NUCLEAR POWER STATION

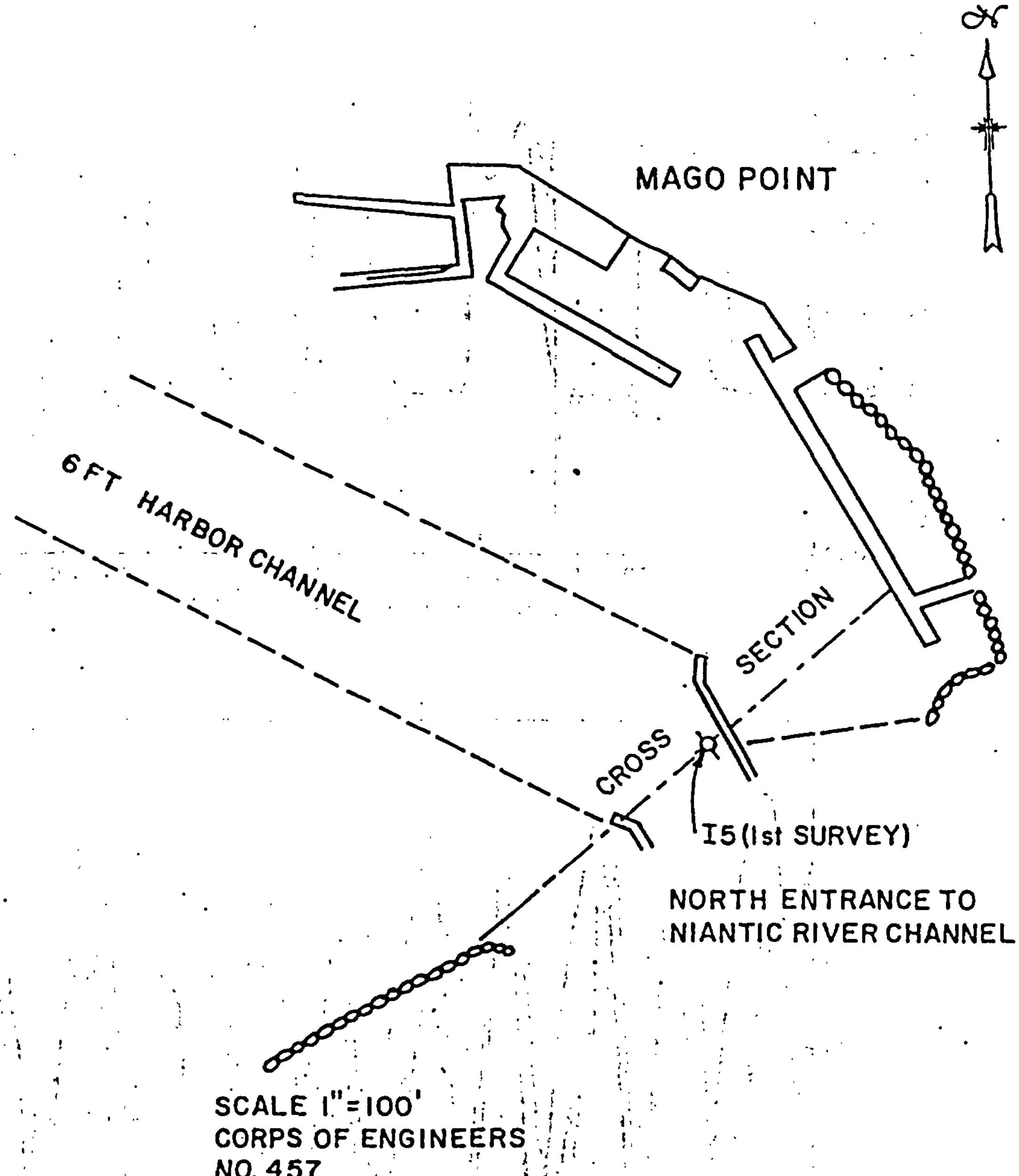


FIGURE 4.2-8

APPROXIMATE LOCATION FOR CROSS-SECTION

MILLSTONE NUCLEAR POWER STATION

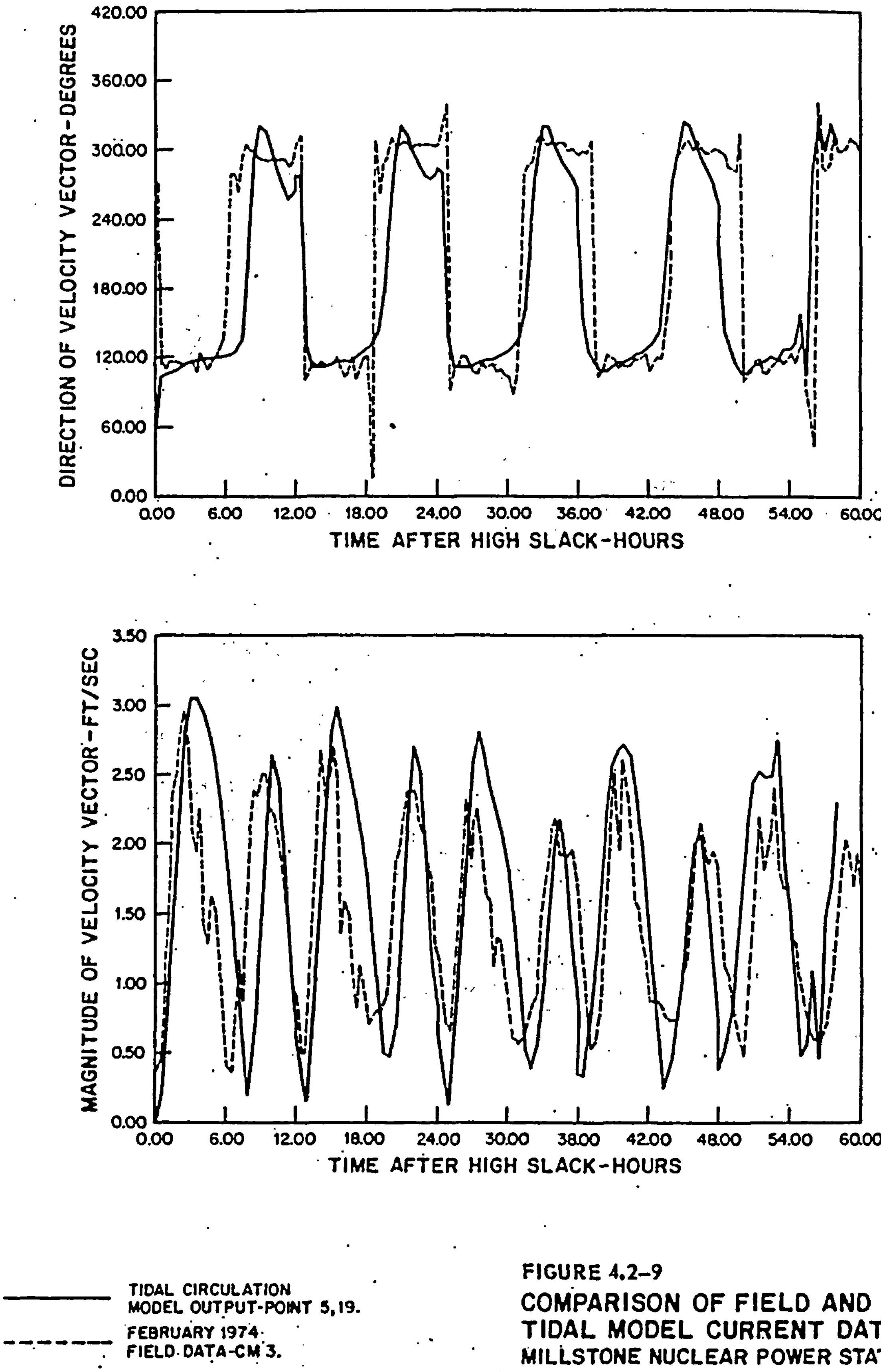
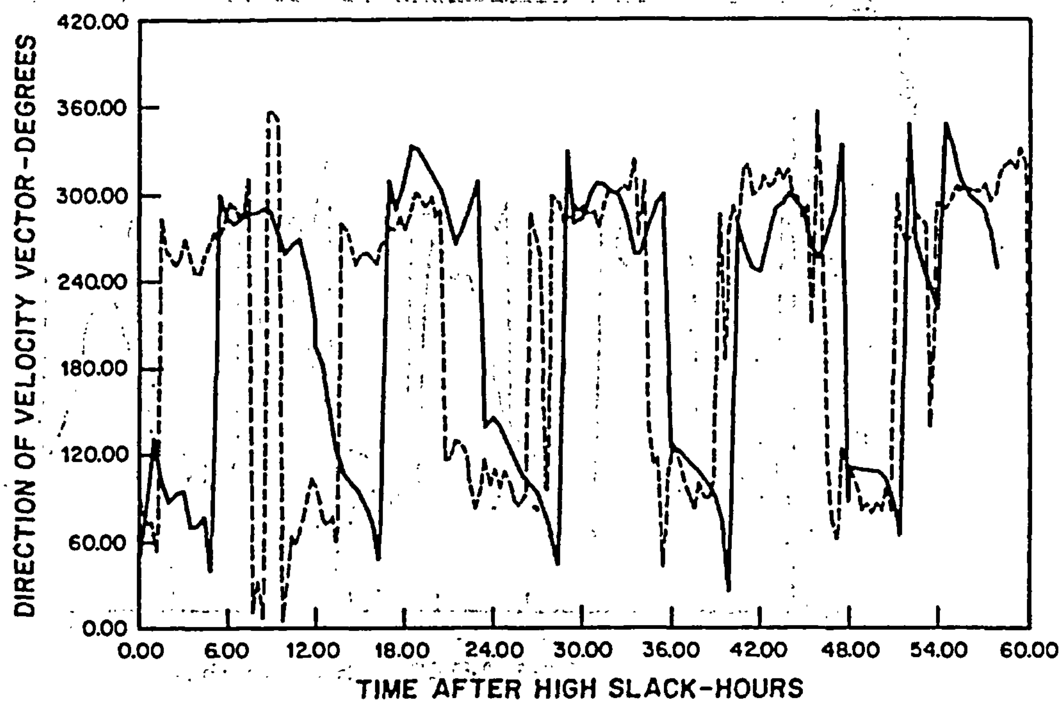


FIGURE 4.2-9

COMPARISON OF FIELD AND TIDAL MODEL CURRENT DATA

MILLSTONE NUCLEAR POWER STATION



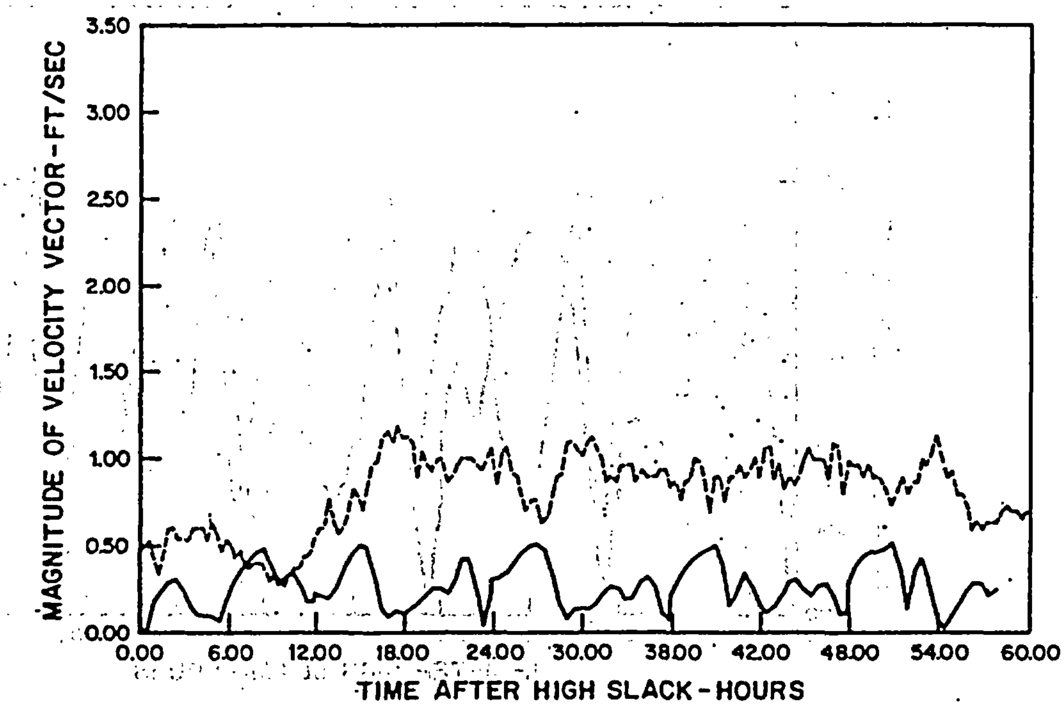


FIGURE 4.2-10

COMPARISON OF FIELD AND TIDAL MODEL CURRENT DATA

MILLSTONE NUCLEAR POWER STATION

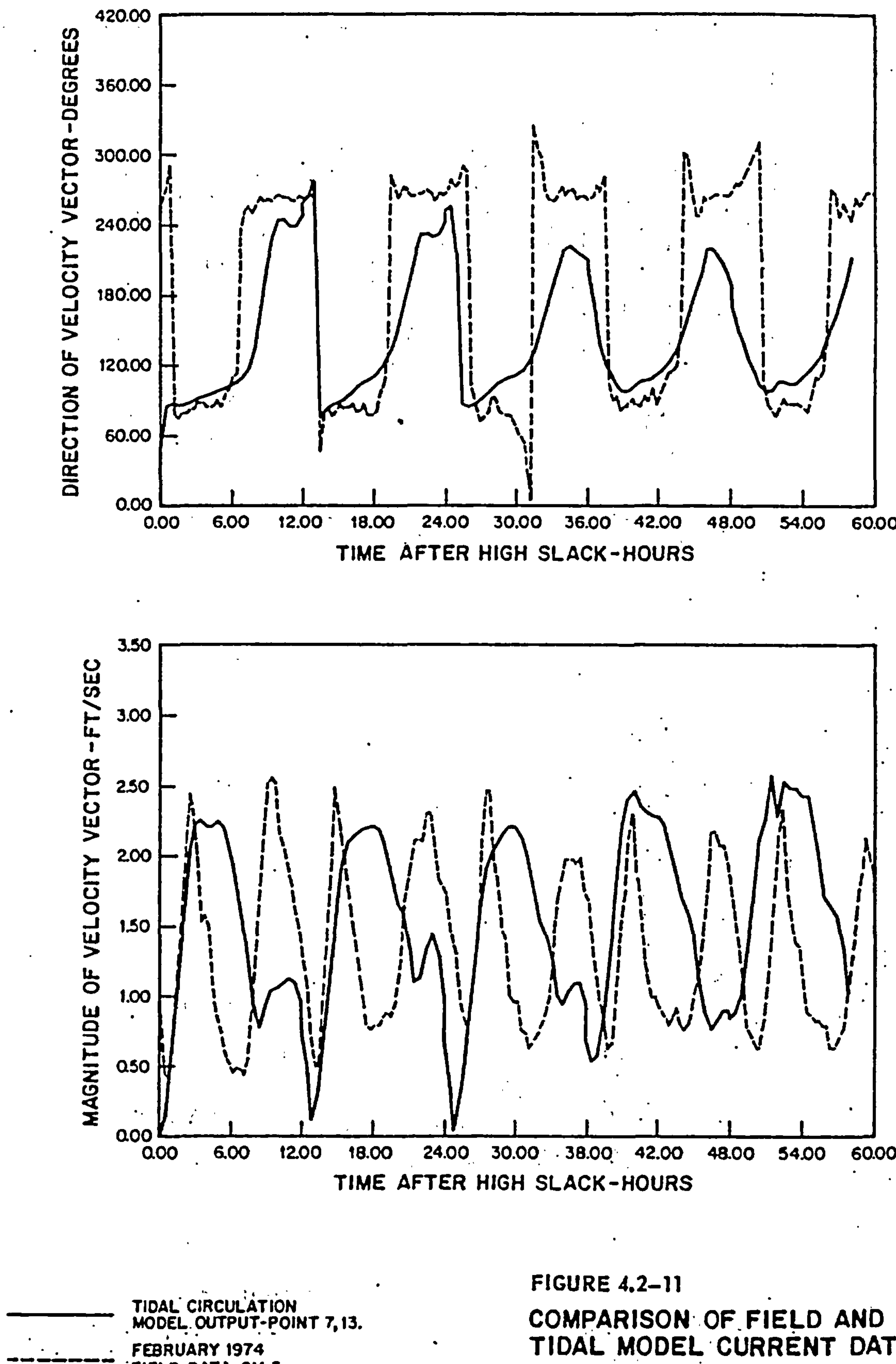


FIGURE 4.2-11

COMPARISON OF FIELD AND TIDAL MODEL CURRENT DATA
MILLSTONE NUCLEAR POWER STATION

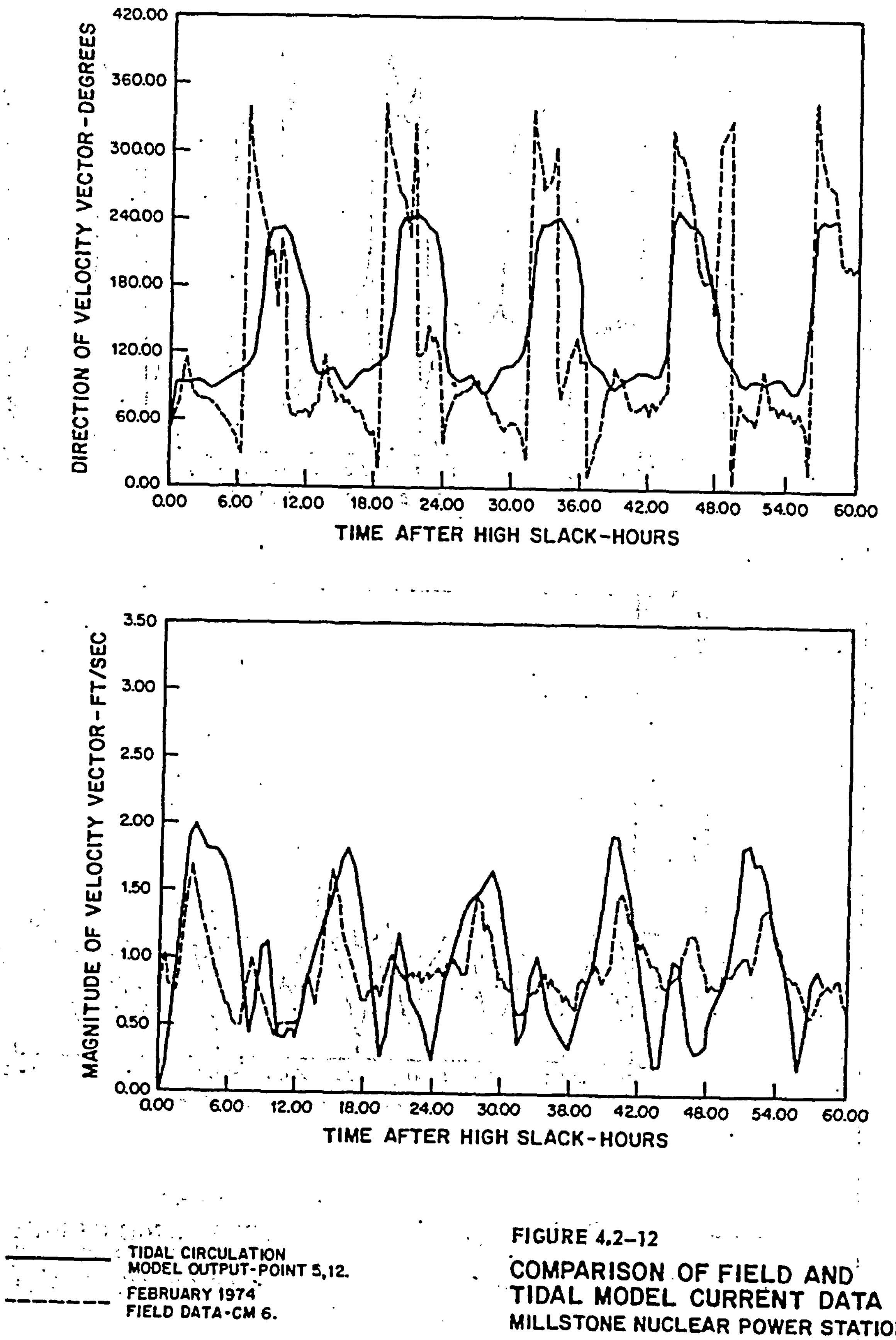


FIGURE 4.2-12

COMPARISON OF FIELD AND TIDAL MODEL CURRENT DATA

MILLSTONE NUCLEAR POWER STATION

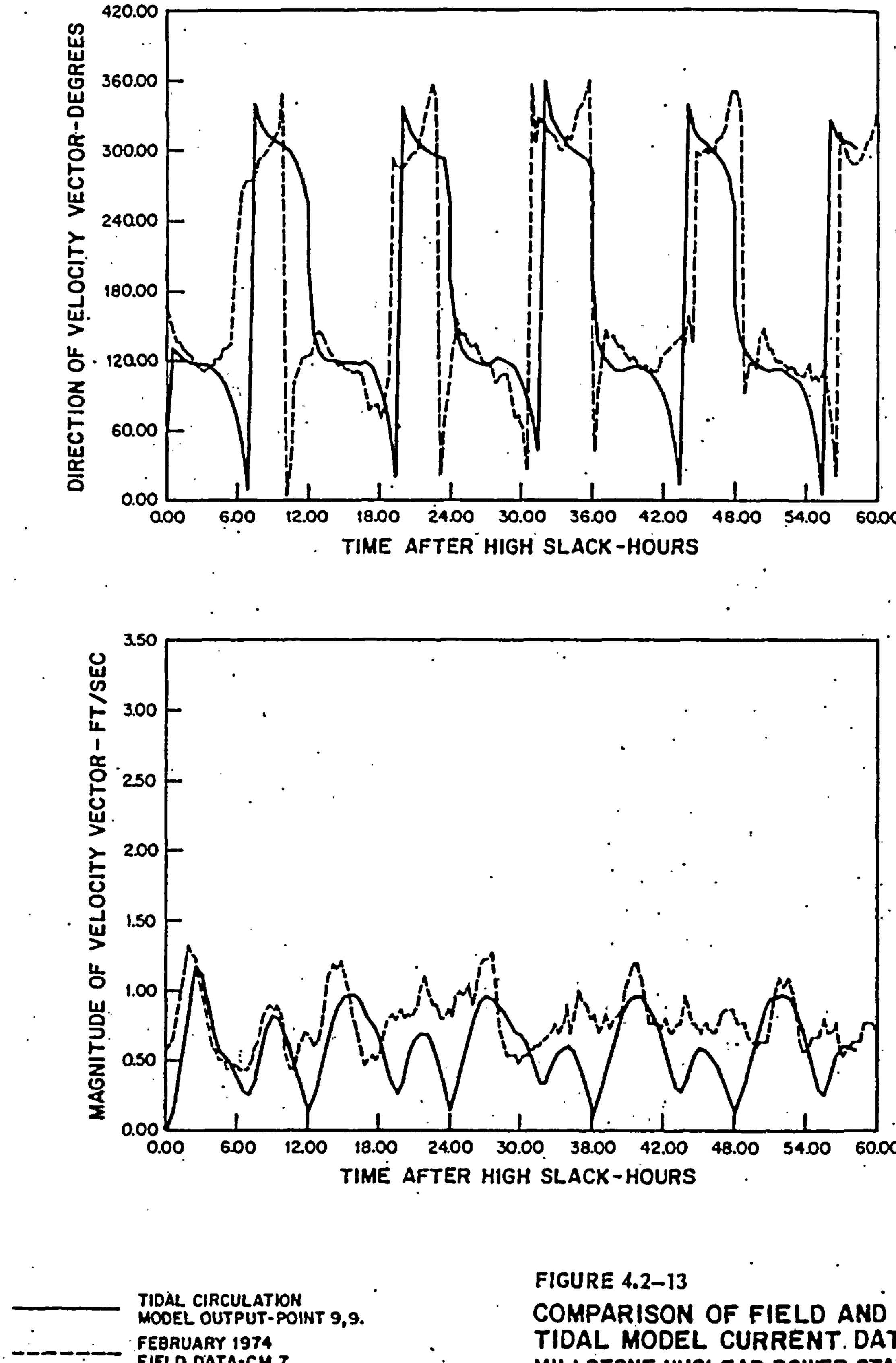


FIGURE 4.2-13

COMPARISON OF FIELD AND TIDAL MODEL CURRENT DATA

MILLSTONE NUCLEAR POWER STATION

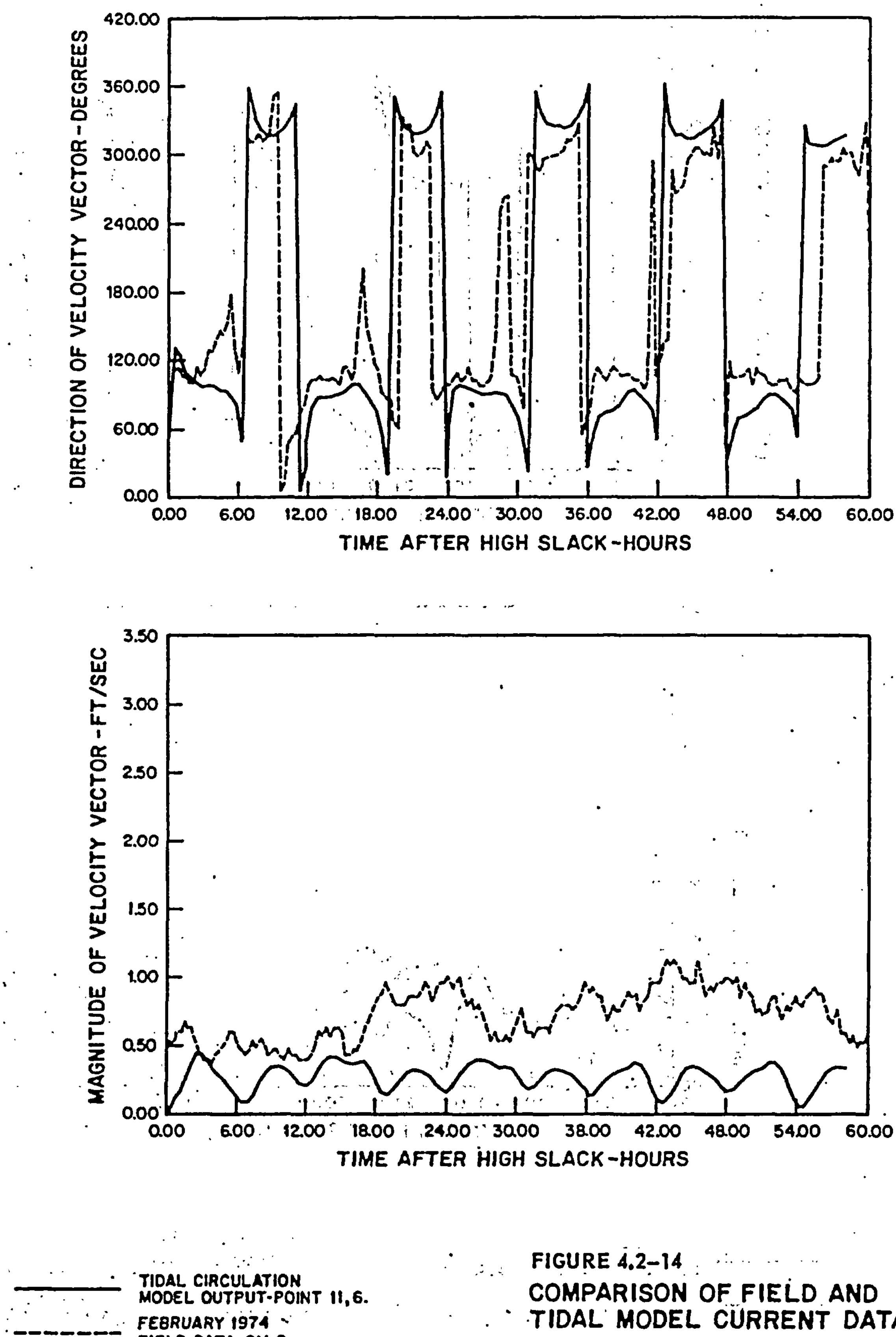
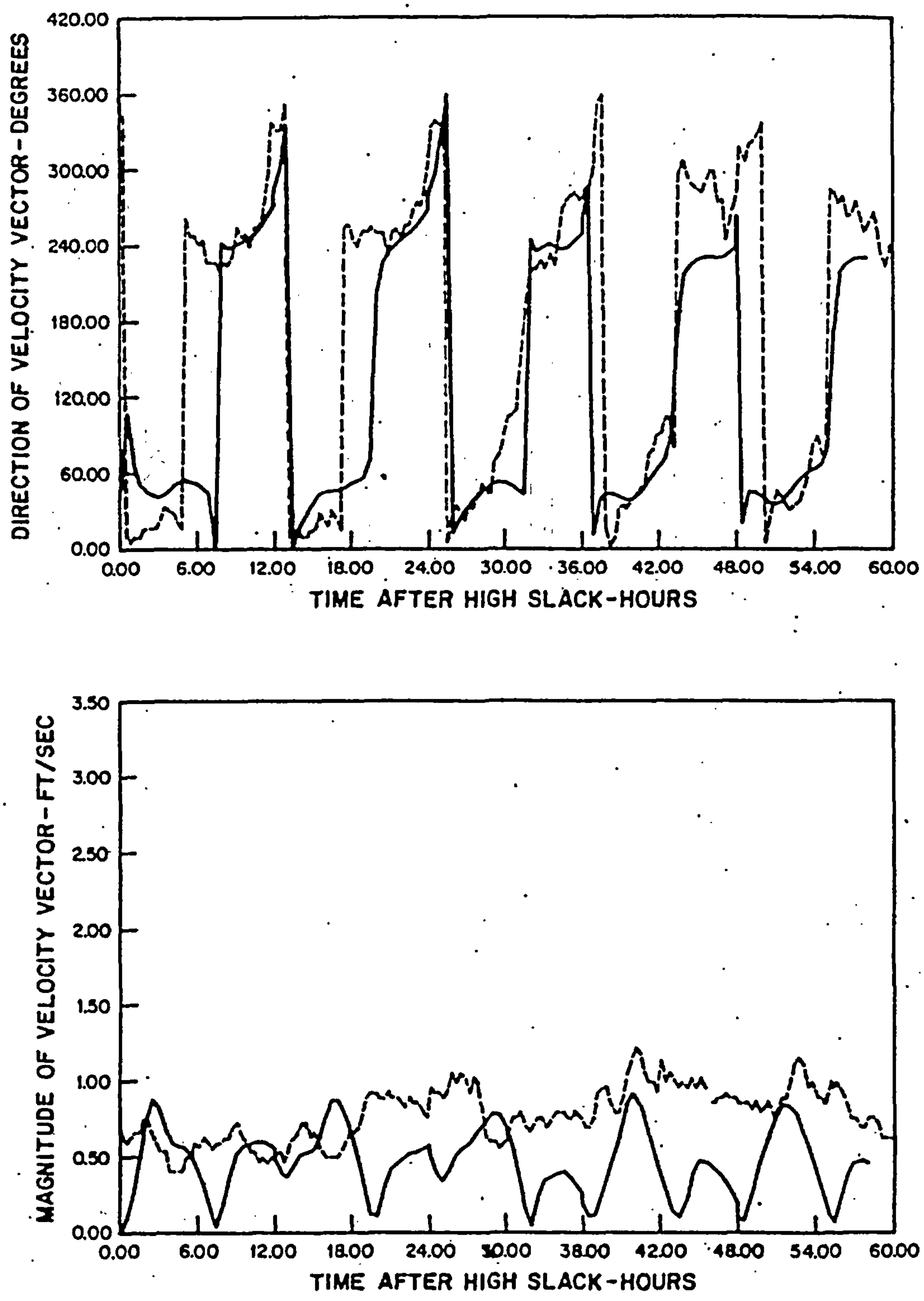


FIGURE 4.2-14

COMPARISON OF FIELD AND TIDAL MODEL CURRENT DATA

MILLSTONE NUCLEAR POWER STATION



TIDAL CIRCULATION MODEL OUTPUT-POINT 8, 4.

FEBRUARY 1974 FIELD DATA-CM 9.

FIGURE 4.2-15

COMPARISON OF FIELD AND TIDAL MODEL CURRENT DATA

MILLSTONE NUCLEAR POWER STATION

TABLE 4.3-1. TAXONOMIC LIST OF ORGANISMS APPEARING ON EXPOSURE PANELS IN THE MILLSTONE POINT AREA FROM MAY, 1968, THROUGH DECEMBER, 1975

CHLOROPHYTA
- *Bryopsis plumosa*
- *Chaetomorpha aerea*
- *Chaetomorpha* spp.
- *Cladophora* sp.
- *Codium fragile*
- *Enteromorpha clathrata*
- *Enteromorpha compressa*
- *Enteromorpha intestinalis*
- *Enteromorpha linza*
- *Enteromorpha prolifera*
- *Enteromorpha* spp.
- *Ulva lactuca*
- Unidentified green film (Chlorophyceae)

RHODOPHYTA
- *Achrochaetium* sp.
- *Agardhiella tenera*
- *Antithamnion* sp.
- *Callithamnion baileyi*
- *Callithamnion byssoides*
- *Callithamnion* spp.
- *Ceramium diaphanum*
- *Ceramium rubrum*
- *Ceramium* spp.
- *Champia parvula*
- *Chondria baileyana*
- *Chondria* sp.
- *Cystoclonium purpureum*
- *Daysa pedicellata*
- *Gracilaria confervoides*
- *Gracilaria foliifera*
- *Gracilaria* spp.
- *Grinellia americana*
- *Herposiphonia tenella*
- *Lomentaria baileyana*
- *Lomentaria* spp.
- *Polysiphonia nigra*
- *Polysiphonia nigrescens*
- *Polysiphonia* spp.
- *Porphyra umbilicalis*
- *Porphyra* spp.
- *Rhodomela subfusca*
- *Rhodymenia palmata*
- *Rhodymenia* spp.

TABLE 4.3-1. (continued)

PHAEOPHYTA
Desmarestia viridis
Ectocarpus sp.
Elachistea sp.
Fucus evanescens
Fucus spp.
Laminaria agardhii
Laminaria spp.
Petalonia fascia
Punctaria latifolia
Punctaria sp.
Pylaiella littoralis
Pylaiella spp.
PORIFERA
Scypha ciliata (grantia)
Scypha spp.
Halichondria bowerbanki
Halichondria panicea
Halichondria spp.
Leucosolenia botryoides
Leucosolenia spp.
Renierinae
CNIDARIA
Actinaria
Unidentified Anthozoan
Campanularia sp.
Diadumene leucolena
Obelia sp.
Sertularia pumila
Sertularia spp.
Tubularia sp.
Metridium dianthus
Metridium senile
Unidentified Hydroid
PLATYHELMINTHES
Stylochus ellipticus
Leptoplana augusta
Leptoplana spp.
Leptoplanidae
RHYNCHOCOELA
Unidentified Rhynchocoela
Nermertea
ECTOPROCTA (Bryozoa)
Encrusting
Callopora aurita
Cryptosula pallasiana
Electra crustulenta
Electra monostachys
Electra pilosa
Schizoporella unicornis
Tegella unicornis

TABLE 4.3-1. (continued)

ECTOPROCTA (Bryozoa continued)
Filamentous
Bowerbankia gracilis
Bugula simplex
Bugula turrita
Bugula spp.
Crisea eburnea
ANNELIDA
Ampharetidae
Amphitrite sp.
Capitellidae
Cirratulidae
Cirratulus grandis
Euchone rubrocincta
Eulalia viridis
Eulalia spp.
Eumida sp.
Glyceridae
Harmothoe imbricata
Hydroides dianthus
Hydroides sp.
Lepidonotus squamatus
Marphysa sanguinea
Marphysa sp.
Nereis pelagica
Nereis succinea
Nereis virens
Nereis spp.
Nephytys sp.
Notomastus latericeus
Phyllodoce arenae
Phyllodoce sp.
Phyllodocidae
Podarke obscura
Polydora ciliata
Polynoidae
Sabella microphthalma
Sabellidae
Serpula vermicularis
Serpulid tubes
Terebella lapidaria
Terebellidae
Spirorbis tubes
Mudworm tubes
Platynereis megalops
SIPUNCULA

TABLE 4.3-1. (continued)

MOLLUSCA
<u>Gastropoda</u>
Anachus avara
Cerithiopsis greenii
Crepidula fornicata
Crepidula plana
Crepidula spp.
Hermaea sp.
Ilyanassa obsoleta
Ilyanassa spp.
Littorina obtusata
Littorina saxatilis
Littorina spp.
Mitrella lunata
Nucella lapilla
Urosalpinx cinerea
Unidentified nudibranch
<u>Pelecypoda</u>
Anomia simplex
Anomia spp.
Crassostrea virginica
Modiolus modiolus
Mytilus edulis
Saxicava arctica (Hiatella arctica)
Teredo bartschi
Teredo navalis
Teredinidae
ARTHROPODA
Aeginella
Ampithoidae
Ampithoe rubricata
Ampithoe spp.
Caprella geometrica
Caprella sp.
Caprellidae
Chelura terebrans
Corophium cylindricum
Elasmopus laevis
Gammarus annulatus
Gammarus locusta
Gammarus sp.
Gammaridae
Grubia compta
Jassa falcata
Melita dentata
Melita nitida
Microdeutopus sp.
Unidentified copepods
Unciola irrorata

TABLE 4.3-1. (continued)

ARTHROPODA (continued)

<u>Cirripedia</u>

Balanus amphitrite niveus
Balanus balanoides
Balanus crenatus
Balanus eburneus
Balanus improvisus
Balanus spp.

<u>Limnoridae</u>

Limnoria lignorum
Limnoria tripunctata
Limnoria tuberculata
Limnoria spp.
Limnoria tunnels

<u>Decapoda</u>

Brachyura
Carcinus maenas
Eurypanopeus depressus
Panopeus herbstii
Unidentified crabs

<u>Isopoda</u>

Idotea baltica
Idotea phosphorea
Jaera marina
Tanais cavolini

ECHINODERMATA

Asteriidae
Asterias forbesii

CHORDATA

Ascidia sp.
Amaroucium sp.
Botryllus schlosseri
Ciona intestinalis
Molgula citrina
Molgula manhattensis
Molgula spp.
Styella partita

TABLE 4.3-2. TAXONOMIC GROUPS APPEARING AT EACH EXPOSURE PANEL SITE IN THE MILLSTONE POINT AREA FROM MAY, 1968, THROUGH DECEMBER, 1975

WP = White Point; FN = Fox Island-North; MH = Millstone Harbor; IN = Intake; EF = Effluent; GN = Giants Neck

Phylum	Total Number of Groups	WP	FN	MH	IN[(b)]	EF[(c)]	GN[(a)]
Chlorophyta	10	7	8	10	6	6	8
Rhodophyta	22	16	10	5	11	6	12
Phaeophyta	8	5	5	3	3	0	3
Porifera	5	3	4	2	2	1	3
Cnidaria	7	5	3	6	5	3	3
Platyhelminthes	2	1	2	2	2	1	1
Annelida	27	18	17	12	10	8	10
Rhynchocoela	1	0	0	0	0	1	0
Sipuncula	1	0	0	0	0	0	1
Mollusca	19	9	15	8	9	8	10
Arthropoda	30	19	14	17	15	15	20
Ectoprocta	11	6	6	4	7	2	8
Echinodermata	1	1	0	0	1	0	0
Chordata	7	4	4	4	3	2	2
Total	151	94	88	73	74	53	81
Percent of Total		62	58	48	49	35	54

(a) First sampled in February, 1969
(b) First sampled in June, 1969
(c) First sampled in August, 1973

TABLE 4.3-3 RESULT OF CHI-SQUARE CONTINGENCY TABLE ANALYSIS TO DETERMINE SIGNIFICANCE OF RELATIONSHIP OF OCCURRENCE AND ABUNDANCE OF SPECIES ON EXPOSURE PANELS TO SITE IN THE MILLSTONE POINT AREA WHERE THEY OCCURRED

Species	Site Relationship
Chlorophyta	
Bryopsis plumosa	Predominantly at Millstone Harbor through 1974; occurred more often at Fox Island-North in 1975.
Codium fragile	Found predominantly at Fox Island and Millstone Harbor.
Ulva lactuca	Heaviest coverage at Intake through 1974; now found equally at all sites, although not heavy.
Rhodophyta	
Rhodymenia palmata	Occurred only at Giants Neck, although sporadically, through 1974; did not occur at Giants Neck in 1975, but did occur once each at Fox Island-North, Millstone Harbor, and Intake.
Phaeophyta	
Laminaria agardhii	Occurred primarily at White Point early in study. By 1974 it occurred everywhere except the Intake and Effluent. In 1975, coverage was heaviest at the Intake; no occurrence at Effluent.
Porifera	
Halichondria bowerbankia	Common everywhere except Effluent.
Cnidaria	
Diadumene leucolena	Predominantly at Effluent; did not appear in 1975.
Obelia sp.	Predominantly at White Point, Fox Island-North, and Millstone Harbor; did not appear in 1975.
Tubularia sp.	Predominantly at Effluent; did not appear in 1975.
Annelida	
Lepidonotus squamatus	Through 1974, predominantly at White Point and Fox Island-North; in 1975, predominantly at Millstone Harbor and Fox Island-North.
Nereis succinea	Predominantly at Effluent.
Phyllodoce sp.	Through 1974, predominantly at White Point; none found at White Point in 1975 and only rarely at other sites.
Mollusca	
Crepidula fornicata	Predominantly at Effluent.
Crepidula plana	Through 1974, predominantly at Effluent; in 1975, predominantly at Intake.
Mytilus edulis	Rarely found at Effluent and Giants Neck sites.
Teredo navalis	Heaviest attack at Effluent through most of 1975; disappeared at end of 1975, but increased at White Point and Giants Neck.
Arthropoda	
Chelura terebrans	Heaviest at Millstone Harbor.
Balanus crenatus	Fluctuates but heaviest at Intake.
Balanus eburneus	Doesn't appear at Giants Neck after 1973.
Limnoria lignorum	Heaviest at Giants Neck.
Limnoria tripunctata	Heaviest at Millstone Harbor.
Limnoria tuberculata	Heaviest at Fox Island-North.
Ectoprocta	
Cryptosula pallasiana	Not found at Effluent through 1974; appeared at Effluent in 1975 but heaviest at Fox Island-North and Giants Neck.
Bugula turrita	Has not occured at Intake.
Chordata	
Botryllus schlosseri	Rare at Intake, Effluent, Giants Neck; diminishing at White Point, Fox Island-North, and Millstone Harbor.

TABLE 4.3-4. DETERMINATION OF RELATIONSHIP BETWEEN NUMBER OF SPECIES OCCURRING ON EXPOSURE PANELS AT SITES IN THE MILLSTONE POINT AREA DURING EACH SAMPLING YEAR AND THE YEAR IN WHICH THE SPECIES OCCURRED

WP = White Point; FN = Fox Island-North (Millstone Environmental Lab); MH = Millstone Harbor; IN = Intake; EF = Effluent; GN = Giants Neck

Year	WP	FN	MH	IN[b]	EF[c]	GN[a]
1968	29	26	23			
1969	37	36	30	22		29
1970	39	37	35	24		35
1971	39	42	30	30		35
1972	47	51	38	12		40
1973	50	45	45	34	20	53
1974	63	59	45	52	48	54
1975	51	58	51	47	46	51
Correlation Coefficient	0.8990	0.9506	0.9552	0.7378		0.9292
Result of t-Test	5.0290	7.5033	7.9075	2.4441		5.6203
Significance	.99<p<.999	.999<p	.999<p	.9<p<.95		.99<p<.999

(a) First sampled in February, 1969
(b) First sampled in June, 1969
(c) First sampled in August, 1973

TABLE 4.3-5 ANNUAL ALGAL SPECIES DIVERSITY INDEXES CALCULATED FROM SPECIES OCCURRING ON EXPOSURE PANELS LOCATED IN THE MILLSTONE POINT AREA FROM MAY, 1968, THROUGH DECEMBER, 1975

WP = White Point; FN = Fox Island-North; MH = Millstone Harbor; IN = Intake; EF = Effluent; GN = Giants Neck

Year	WP[(a)]	FN[(a)]	MH[(a)]	IN[(c)]	EF[(d)]	GN[(b)]
1968	1.97	1.99	1.75			
1969	1.96	2.37	1.86	2.09		2.24
1970	2.42	1.97	2.84	1.94		1.98
1971	3.26	2.52	2.74	2.00		2.01
1972	2.76	3.27	2.71	(e)		2.66
1973	3.27	2.70	2.93	1.12	0.00	2.75
1974	3.41	3.06	2.21	2.54	3.20	3.01
1975	3.26	3.30	3.40	2.81	3.24	2.24

(a) Panels first put on station in May, 1968
(b) Panels first put on station in February, 1969
(c) Panels first put on station in June, 1969
(d) Panels first put on station in August, 1973
(e) Due to wave conditions, etc., the panel rack was lost for most of 1972.

TABLE 4.3-6. ANNUAL ANNELID SPECIES DIVERSITY INDEXES CALCULATED FROM SPECIES OCCURRING ON EXPOSURE PANELS LOCATED IN THE MILLSTONE POINT AREA FROM MAY, 1968, THROUGH DECEMBER, 1975

WP = White Point; FN = Fox Island-North; MH = Millstone Harbor; IN = Intake; EF = Effluent; GN = Giants Neck

Year	WP[a]	FN[a]	MH[a]	IN[c]	EF[d]	GN[b]
1968	0[e]	0.00	0.00			
1969	0.00	0.00	0.00	0[e]		0.00
1970	1.34	0.99	1.00	0.00		0.96
1971	0.87	1.08	0.96	0.81		0.00
1972	1.68	1.58	1.49	0[e][f]		0.82
1973	2.21	1.73	1.58	0.85	0.45	1.40
1974	2.69	2.58	2.19	2.48	1.36	0.82
1975	2.69	2.43	2.02	2.26	2.05	2.49
Correlation Coefficient	0.9584	0.9723	0.9582	0.8546		0.7731
Result of t-Test	8.23	10.20	8.31	3.68		2.72
Probability Level	.999<p	.999<p	.999<p	.98<p<.99		.95<p<.98

(a) Panels first put on station in May, 1968
(b) Panels first put on station in February, 1969
(c) Panels first put on station in June, 1969
(d) Panels first put on station in August, 1973
(e) Zero means no annelid species recorded as opposed to 0.00 which indicates only one species taken
(f) Due to wave conditions, etc., the panel rack was lost for most of 1972

TABLE 4.3-7. MEAN ANNUAL PERCENTAGE OF ATTACK OF EXPOSURE PANELS BY THE MOLLUSCAN BORER, *Teredo*, IN THE MILLSTONE POINT AREA FROM MAY, 1968, THROUGH DECEMBER, 1975

WP = White Point; FN = Fox Island-North; MH = Millstone Harbor; IN = Intake; EF = Effluent; GN = Giants Neck

Year	WP[a]	FN[a]	MH[a]	IN[c]	EF[d]	GN[b]
1968	14	1	0			
1969	48	34	<1	7		<1
1970	23	15	1	17		10
1971	23	29	0	48		38
1972	45	20	<1	<1[e]		19
1973	20	13	<1	58	69	9
1974	75	22	3	66	89	37
1975	49	8	<1	22	72	55

(a) Panels first put on station in May, 1968
(b) Panels first put on station in February, 1969
(c) Panels first put on station in June, 1969
(d) Panels first put on station in August, 1973
(e) Due to wave conditions, etc. the panel rack was lost for most of 1972.

TABLE 4.3-8. MEAN ANNUAL NUMBER FOR EACH SPECIES OF THE ARTHROPOD BORER, *Limnoria*, OCCURRING ON LONG-TERM EXPOSURE PANELS IN THE MILLSTONE POINT AREA FROM JUNE, 1971, THROUGH DECEMBER, 1975

Sites[b]	1971[a]	1972	1973	1974	1975
White Point					
Limnoria lignorum	86	90	34	13	44
Limnoria tripunctata	914	1,808	249	335	3,637
Limnoria tuberculata	85	101	27	8	24
Fox Island-North					
Limnoria lignorum	188	144	173	35	27
Limnoria tripunctata	1,439	2,400	1,435	1,317	2,412
Limnoria tuberculata	263	132	70	46	38
Millstone Harbor					
Limnoria lignorum	50	3	5	2	2
Limnoria tripunctata	3,064	4,242	2,258	3,208	4,004
Limnoria tuberculata	137	190	58	62	[illegible]
Intake					
Limnoria lignorum	292	0	0	13	<1
Limnoria tripunctata	198	0	0	2	9
Limnoria tuberculata	43	0	0	0	0
Effluent					
Limnoria lignorum			0	0	0
Limnoria tripunctata			0	14	770
Limnoria tuberculata			0	0	0
Giants Neck					
Limnoria lignorum	891	134	147	38	212
Limnoria tripunctata	241	128	247	45	409
Limnoria tuberculata	41	27	20	0	<1

(a) Counts of individual *Limnoria* did not begin until May, 1971
(b) Rack or panel missing at (1) White Point - July and August, 1973
(2) Intake - December, 1971; January through September, 1972; December, 1973; January through March, 1974; March through May, 1975
(3) Giants Neck - March and April, 1972; January and February, 1973; March, May, June, and July, 1974

TABLE 4.3-9. MEAN ANNUAL NUMBER OF *Limnoria* TUNNELS IN LONG-TERM EXPOSURE PANELS IN THE MILLSTONE POINT AREA FROM MAY, 1968, THROUGH DECEMBER, 1975

WP = White Point; FN = Fox Island-North; MH = Millstone Harbor; IN = Intake; EF = Effluent; GN = Giants Neck

Year	WP [a]	FN [a]	MH [a]	IN [c]	EF [d]	GN [b]
1968	404	577	1,246			
1969	1,059	1,647	2,568	34		924
1970	1,334	2,887	3,125	60		1,798
1971	1,060	1,581	3,062	260		1,310
1972	2,827	4,367	6,675	0 [e]		395
1973	407	2,460	3,754	0	2	317
1974	566	1,977	4,592	16	27	168
1975	4,750	3,258	6,733	13	1,566	811

(a) Panels first put on station in May, 1968
(b) Panels first put on station in February, 1969
(c) Panels first put on station in June, 1969
(d) Panels first put on station in August, 1973
(e) Due to wave conditions, etc., the panel rack was lost for most of 1972

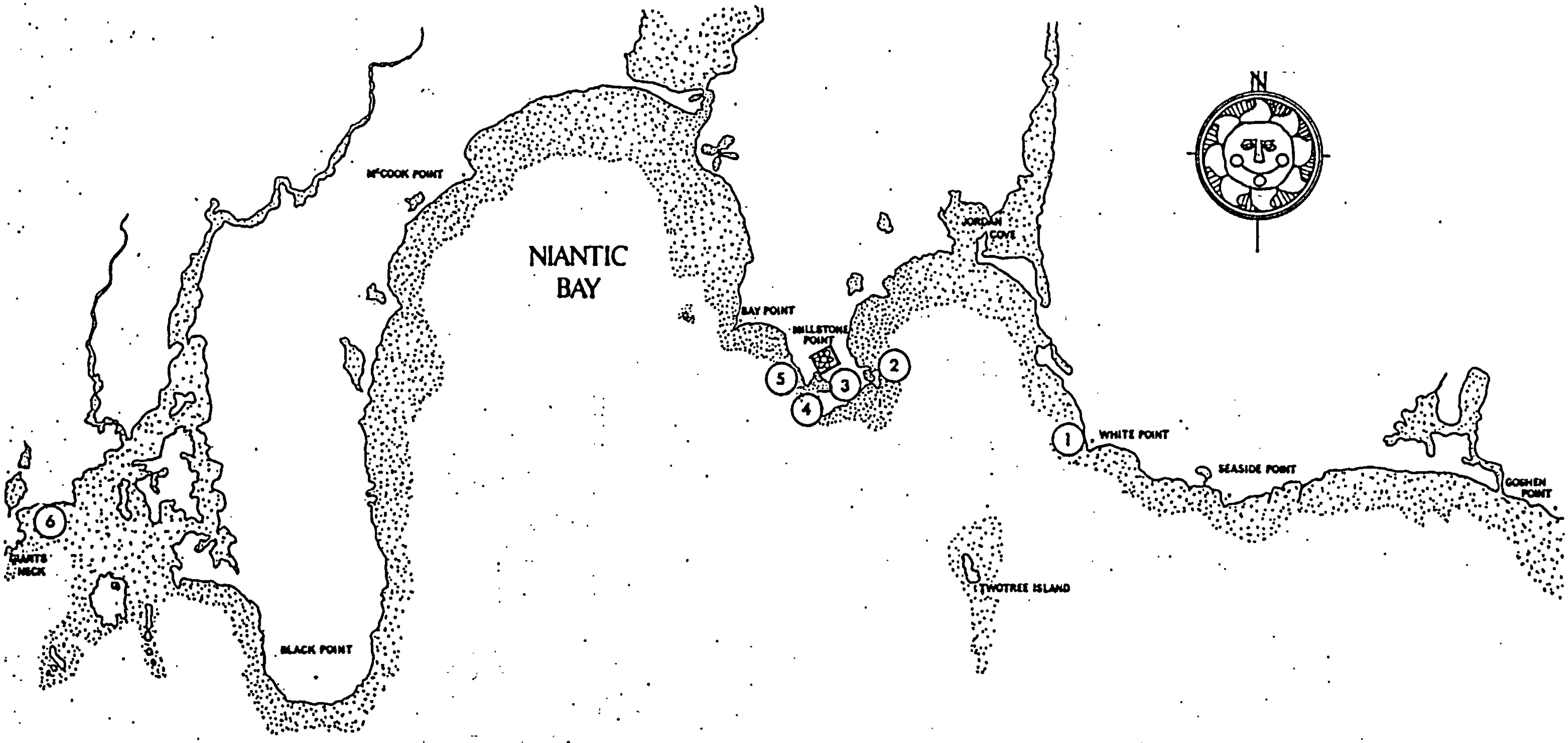


FIGURE 4.3-1. LOCATIONS OF EXPOSURE PA(STATIONS AROUND MILLSTONE POINT

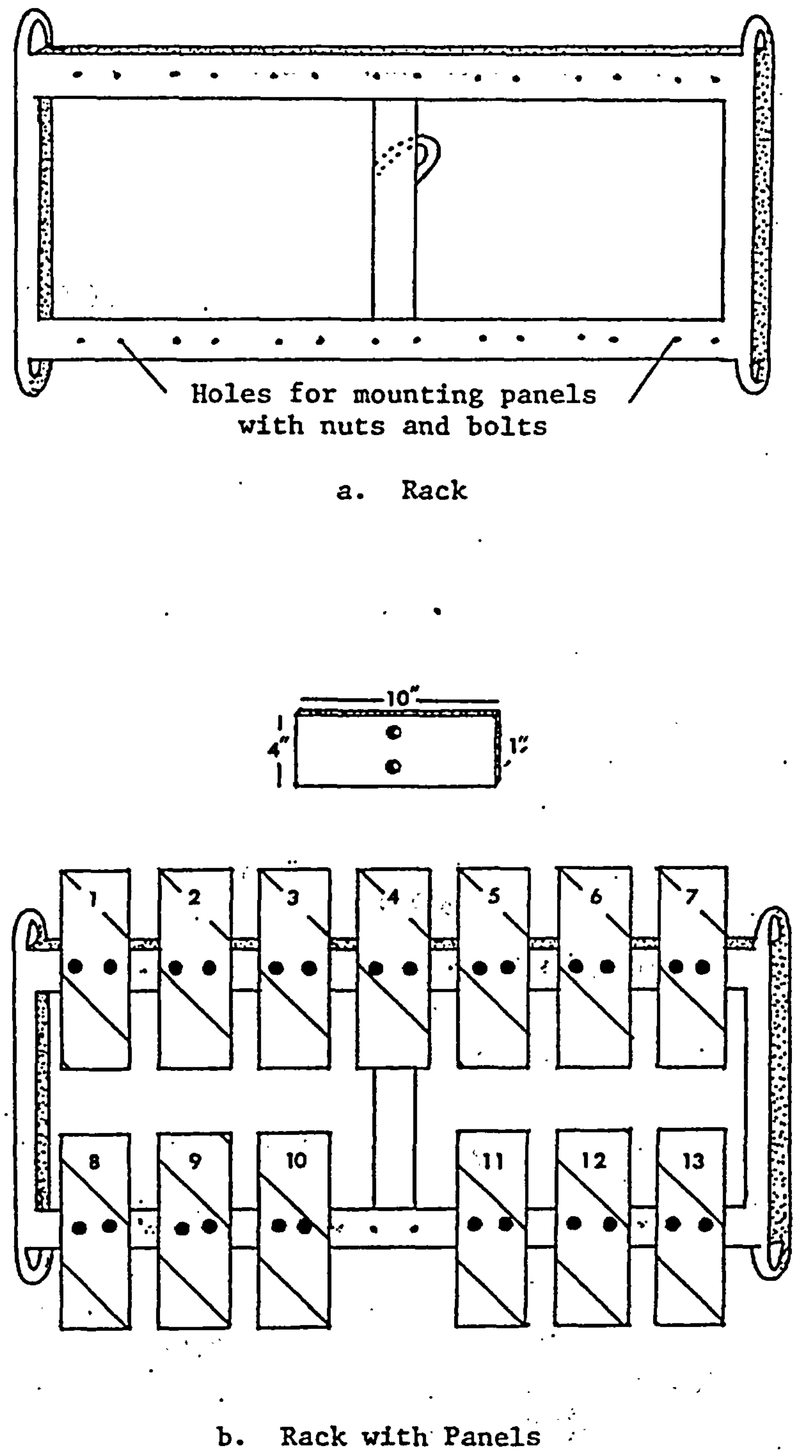


FIGURE 4.3-2. EXPOSURE PANEL RACK USED FOR SAMPLING BORER AND FOULING ORGANISMS

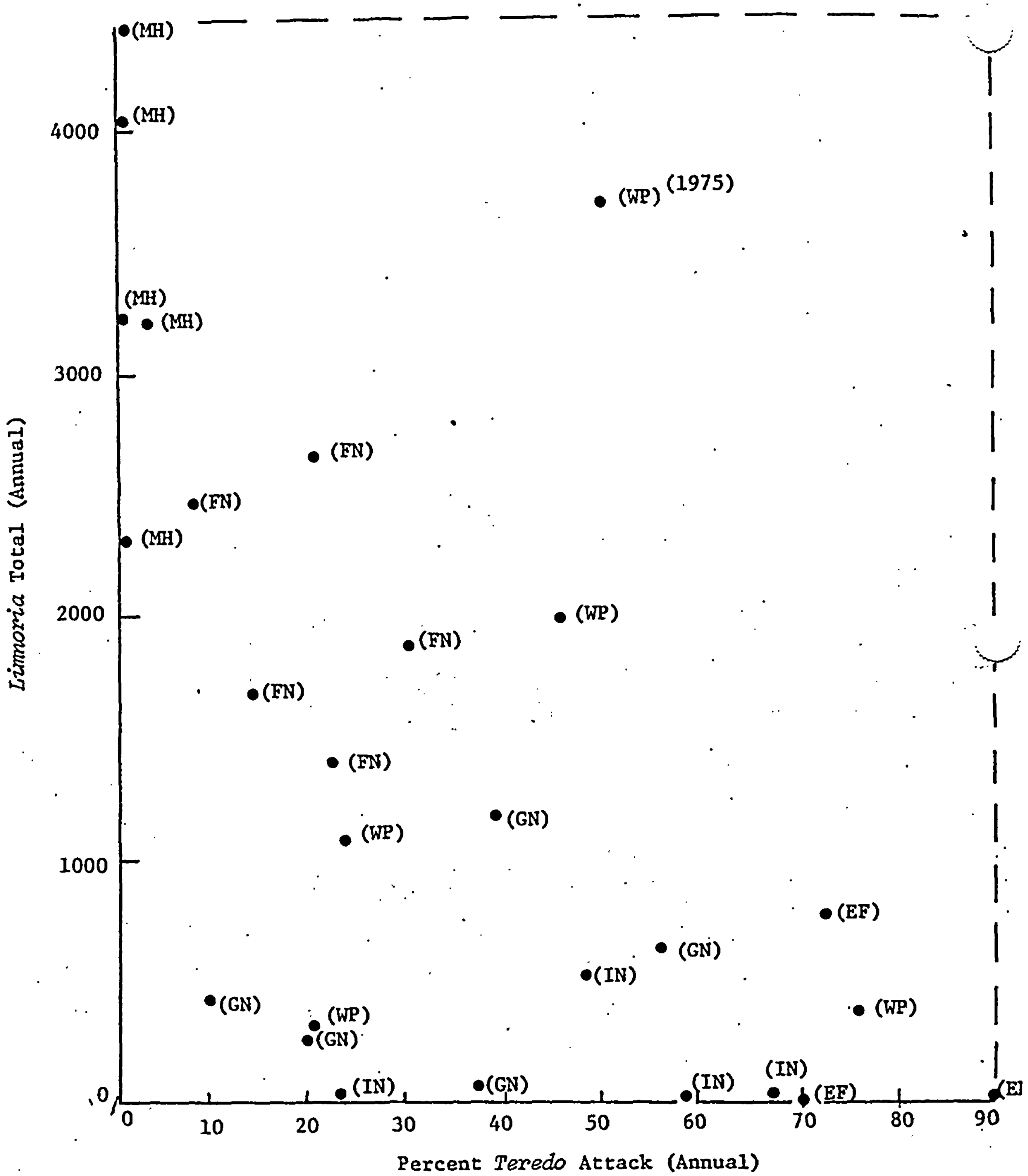


FIGURE 4.3-3. RELATIONSHIP BETWEEN *Teredo* INFESTATION AND *Limnoria* ATTACK ON MILLSTONE POINT EXPOSURE PANELS

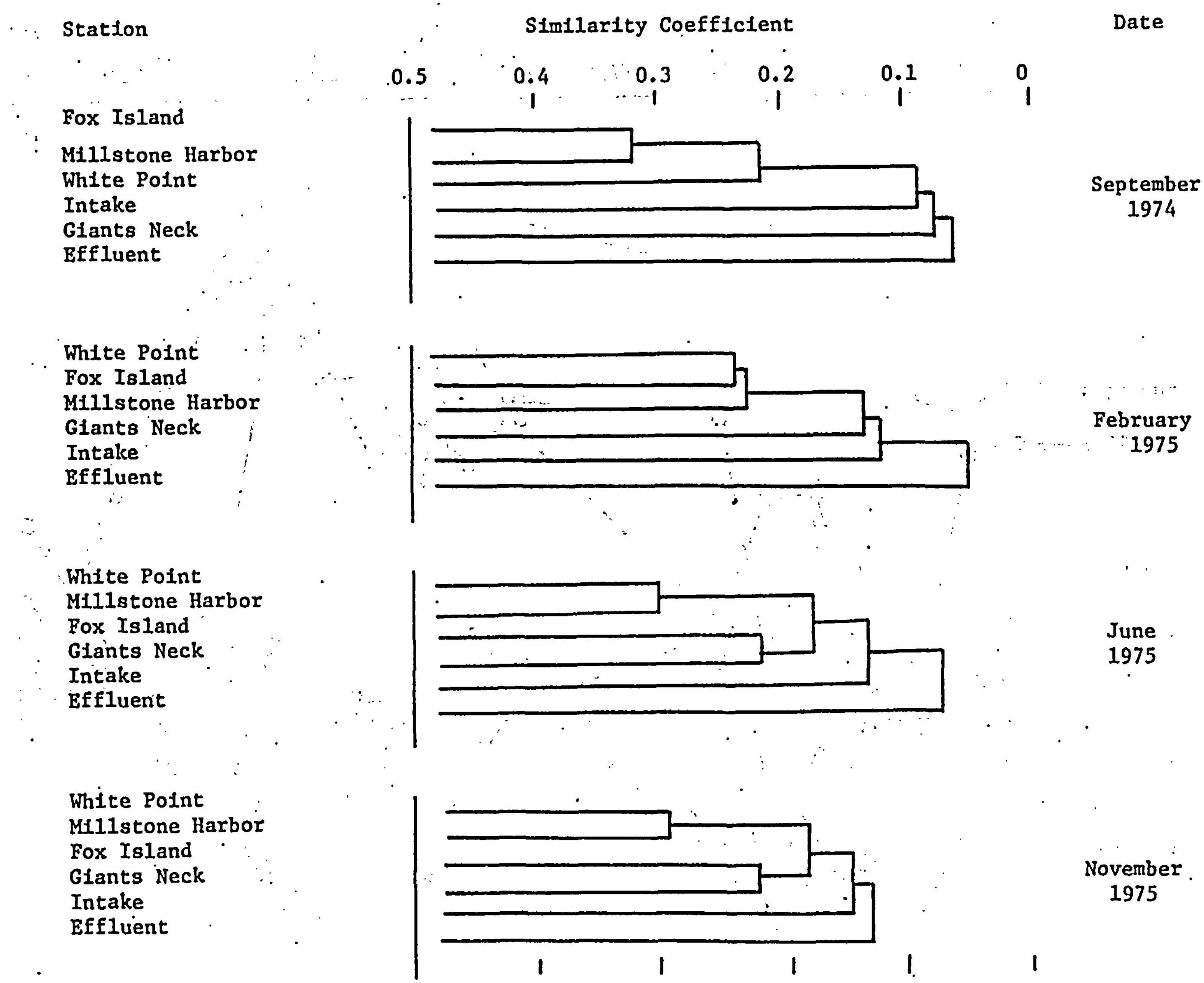


FIGURE 4.3-4. SELECTED DENDROGRAMS OF RELATIVE SIMILARITY OF 12-MONTH EXPOSURE PANEL SPECIES COMPOSITION DATA

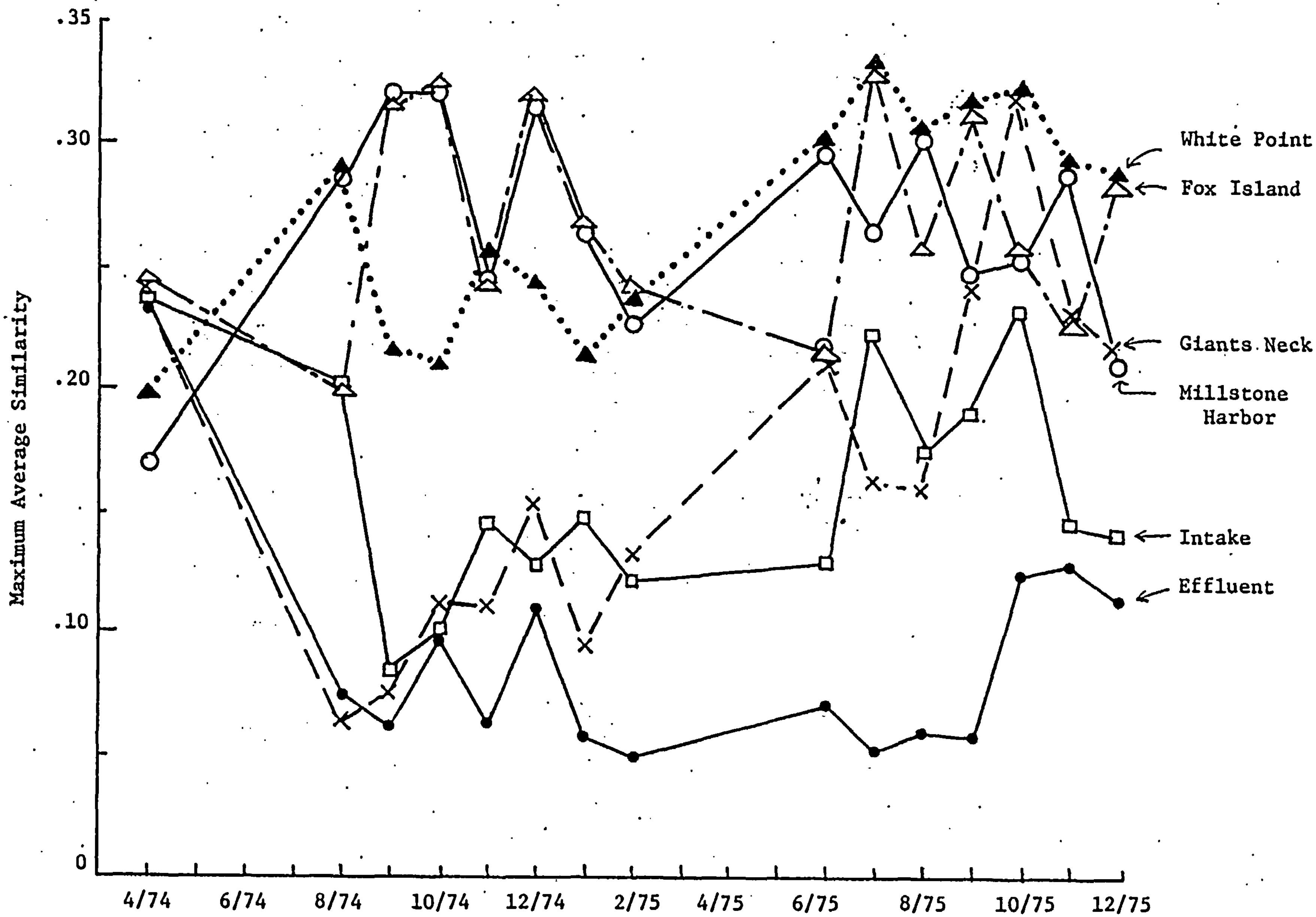


FIGURE 4.3-5. RELATIVE SIMILARITY OF AN EXPOSURE PANEL STATION WITH RESPECT TO OTHER STATIONS

TABLE 4.4-1. AVERAGE PERCENT COVERAGES (TO NEAREST FIVE PERCENT) BY SELECTED SPECIES FOR EACH SITE, FOR EACH YEAR, 1969 THROUGH 1975

A = Rare; B = Sparse; C = Common; D = Abundant; E = Very Abundant; tr = trace

Species	1969	1970	1971	1972	1973	1974	1975
Algae				White Point			
Codium fragile			tr		tr	1	5
Enteromorpha spp.[a]			tr			2	tr
Ulva lactuca	tr	tr	5	5	5	tr	tr
Ascophyllum nodosum	55	44	40	50	50	35	35
Fucus spp.[b]	45	35	30	30	30	40	35
Scytosiphon lomentaria			5	tr		1	1
Chondrus crispus		5	10	5	5	15	25
Invertebrates							
Littorina littorea	E	D/E	D	E	C	C/D	D
Mytilus edulis		C	10	15	10	4	5
Balanus balanoides	50	65	70	70	75	65	65
Algae				Fox Island-North			
Codium fragile		5	5	tr	1	1	tr
Enteromorpha spp.		tr	tr	tr		tr	1
Ulva lactuca	5	tr	5	10	5	3	5
Ascophyllum nodosum	5	5	20	20	5	3	10
Fucus spp.	85	70	50	45	50	40	55
Scytosiphon lomentaria			5			tr	tr
Chondrus crispus	5	15	10	5	1	4	1
Invertebrates							
Littorina littorea	D/E	D	D	B	D	D	D
Mytilus edulis		10	15	10	25	30	10
Balanus balanoides	85	80	55	80	45	55	50
Algae				Fox Island-South			
Codium fragile			tr			10	15
Enteromorpha spp.	tr	10	tr	5	20	20	5
Ulva lactuca	tr	20	25	30	20	15	15
Ascophyllum nodosum	50	45	35	25	30	10	15
Fucus spp.	50	60	35	25	20	35	55
Scytosiphon lomentaria			tr	tr	1	1	tr
Chondrus crispus		tr	10	5	1	4	5
Invertebrates							
Littorina littorea	E	D	C	D	B/C	B	B/C
Mytilus edulis		10	15	5	1	1	tr
Balanus balanoides	35	70	75	65	50	40	45

TABLE 4.4-1. (continued)

Species	1969	1970	1971	1972	1973	1974	1975
Algae				Bay Point			
Codium fragile		tr	tr	tr	tr	1	5
Enteromorpha spp.			tr	tr	tr	25	5
Ulva lactuca	10	5	tr	5	5	25	5
Ascophyllum nodosum			5	tr	tr	tr	tr
Fucus spp.	20	5	5	tr	tr	tr	tr
Scytosiphon lomentaria	tr		5	tr	tr	3	tr
Chondrus crispus			20	10	5	15	25
Invertebrates							
Littorina littorea	C/D	D	D	E	D	C	D
Mytilus edulis	C	C	30	20	25	10	15
Balanus crenatus	60	80	60	60	40	65	60
Algae				Giants Neck			
Codium fragile			tr	tr	tr	1	tr
Enteromorpha spp.			tr	5	tr	tr	tr
Ulva lactuca		tr	5	5	1	tr	tr
Ascophyllum nodosum	40	45	35	35	50	35	35
Fucus spp.	60	65	40	50	40	50	50
Scytosiphon lomentaria			tr	tr	1	tr	tr
Chondrus crispus	15	5	10	5	5	10	15
Invertebrates							
Crassostrea virginica		A	A	A	A	A	A
Littorina littorea	C	D	D	D/B	C	D	D
Mytilus edulis		B	10	10	10	5	5
Balanus balanoides	80	55	80	75	70	75	70
Algae				Seaside-East(c)			
Codium fragile						tr	tr
Enteromorpha spp.					tr	tr	
Ulva lactuca					1	2	1
Ascophyllum nodosum					10	20	5
Fucus spp.					35	40	45
Scytosiphon lomentaria						tr	
Chondrus crispus					10	10	10
Invertebrates							
Littorina littorea					D	C	D
Mytilus edulis					5	3	5
Balanus balanoides					65	60	55

TABLE 4.4-1. (continued)

Species	1969	1970	1971	1972	1973	1974	1975
Algae				Seaside-West[c]			
Codium fragile						1	1
Enteromorpha spp.					1	tr	tr
Ulva lactuca						3	5
Ascophyllum nodosum					1	4	5
Fucus spp.					20	20	35
Scytosiphon lomentaria					tr	tr	
Chondrus crispus					10	10	20
Invertebrates							
Littorina littorea					D	D	D/E
Mytilus edulis					10	5	5
Balanus balanoides					70	55	60

(a) *Enteromorpha* spp. also represents a collective category for six different species listed in Table

(b) *Fucus* spp. represents a collective category

(c) Seaside-East and Seaside-West tables have only three years' data included in their operational average, since they weren't acquired until 1973

TABLE 4.4-2. ALGAL SPECIES COLLECTED FROM THE INTERTIDAL ROCKY SHORE TRANSECTS AT MILLSTONE POINT FROM 1971 THROUGH 1975

Species	1971	1972	1973	1974	1975
CHLOROPHYTA					
Chaetomorpha aerea	X				X
Chaetomorpha linum			X	X	
Chaetomorpha sp.		X	X		
*(Cladophora albida v. refracta)**					X
Cladophora gracilis	X				
Cladophora sp.	X	X	X	X	
Codium fragile		X	X	X	X
Enteromorpha clathrata				X	X
Enteromorpha compressa				X	X
Enteromorpha erecta				X	X
Enteromorpha intestinalis	X				X
Enteromorpha linza	X			X	X
*Enteromorpha minima**					X
Enteromorpha spp.		X	X	X	X
Monostroma grevillei	X				
*Monostroma pulchrum**					X
Monostroma spp.	X			X	X
Rhizoclonium tortuosum				X	
Spongomorpha arcta				X	X
Spongomorpha lanosa	X				
Spongomorpha sp.			X		
Ulva lactuca	X	X	X	X	X
PHAEOPHYTA					
*Asperococcus echinatus**					X
Ascophyllum nodosum	X	X	X	X	X
Chordaria flagelliformis	X		X	X	X
Dictyosiphon foeniculaceus	X				
Ectocarpus confervoides				X	X
Ectocarpus siliculosus				X	X
*(Ectocarpus tomentosoides)**					X
Ectocarpus sp.	X			X	
Elachistea fucicola				X	X
*Fucus edentatus**					X
Fucus evanescens	X			X	X
*Fucus spiralis**					X
Fucus vesiculosus	X	X	X	X	X
Fucus spp.				X	X
Laminaria agardhii				X	X
Laminaria sp.	X	X	X		
Petalonia fascia	X		X	X	X
Punctaria latifolia			X	X	X
Pylaiella littoralis				X	X
*Ralfsia verrucosa**					X
Scytosiphon lomentaria	X	X	X	X	X
*Sphacelaria cirrosa**					X
Sphacelaria spp.*					X
Stilophora rhizoides		X			

TABLE 4.4-2. (continued)

Species	1971	1972	1973	1974	1975
<u>RHODOPHYTA</u>					
Acrochaetium spp.*					X
Agardhiella tenera	X		X	X	X
Ahnfeltia plicata				X	X
Antithamnion cruciatum				X	X
Asparogopsis hamifera			X	X	X
Bangia fuscopurpurea		X	X	X	X
Callithamnion baileyi				X	X
*Ceramium diaphanum**					X
(*Ceramium fastigiatum*)*					X
Ceramium rubriforme	X			X	
Ceramium rubrum				X	X
Ceramium sp.		X	X		
Champia parvula					X
Chondria sedifolia					X
Chondrus crispus	X	X	X	X	X
Corallina officinalis				X	X
Cystoclonium cirrhosum				X	
Dumontia incrassata	X	X		X	X
Gelidium crinale					X
Gigartina stellata			X	X	X
(*Gymnogongrus norvegicus*)	X				
Hildenbrandia spp.*					X
*Lomentaria baileyana**					X
Polysiphonia denudata				X	
Polysiphonia elongata					X
Polysiphonia fibrillosa				X	X
Polysiphonia flexicaulis				X	X
Polysiphonia harveyi				X	X
Polysiphonia lanosa			X	X	X
Polysiphonia nigra				X	
Polysiphonia nigrescens					X
Polysiphonia novae-angliae				X	X
Polysiphonia sp.	X	X	X	X	
(*Porphyra leucosticta*)*					X
Porphyra umbilicalis	X	X	X	X	X
Porphyra sp.		X			
(*Rhodochorton purpureum*)*					X
Rhodymenia palmata	X				X
*Spermothamnion turneri**					X
Trailliella intricata				X	X
Total Algae Species Collected	26	17	23	49	59

( ) indicate that identification is pending confirmation from an outside source
* = Newly identified in 1975

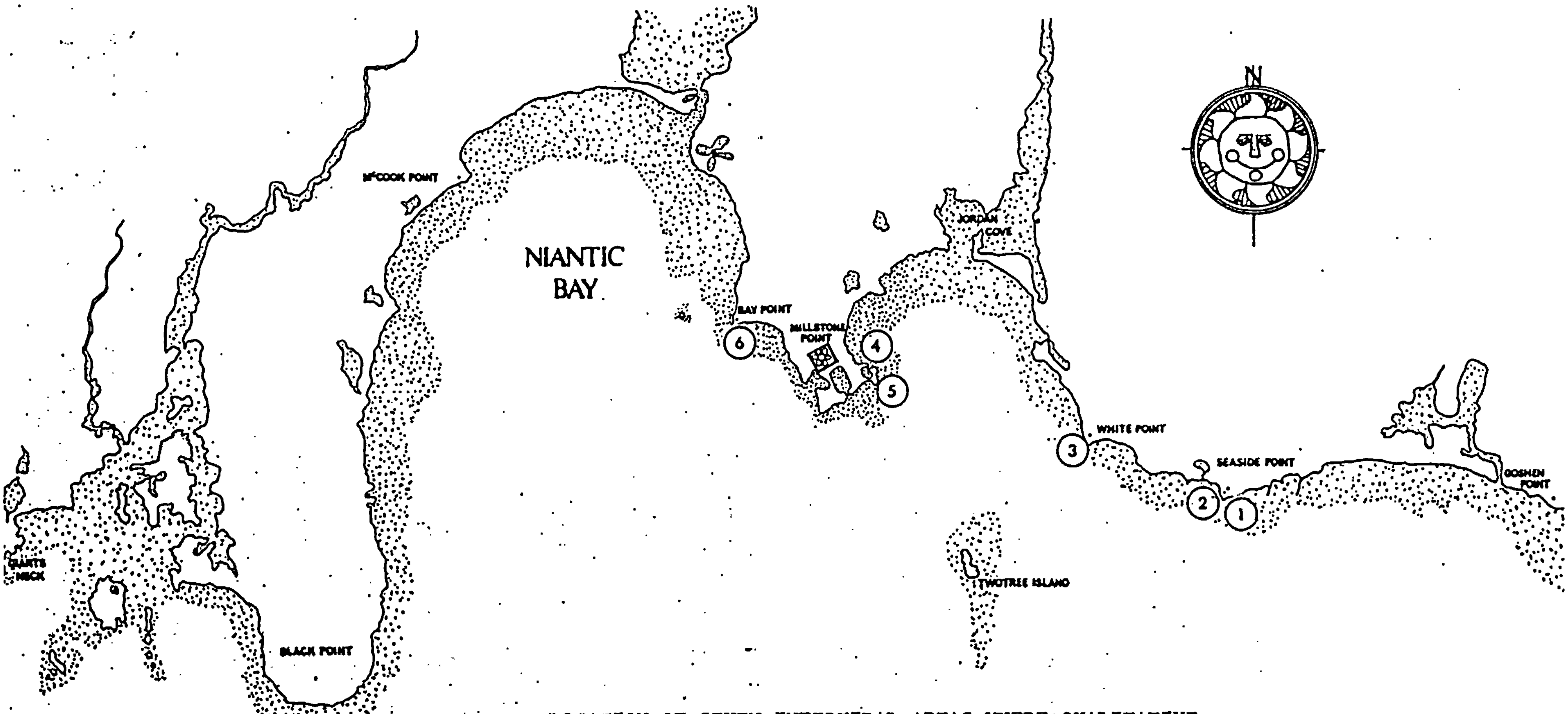


FIGURE 4.4-1. LOCATION OF SEVEN INTERTIDAL AREAS WHERE QUALITATIVE OBSERVATIONS WERE MADE ON THE FLORA AND FAUNA

1. Seaside-East, 2. Seaside-West, 3. White Point,

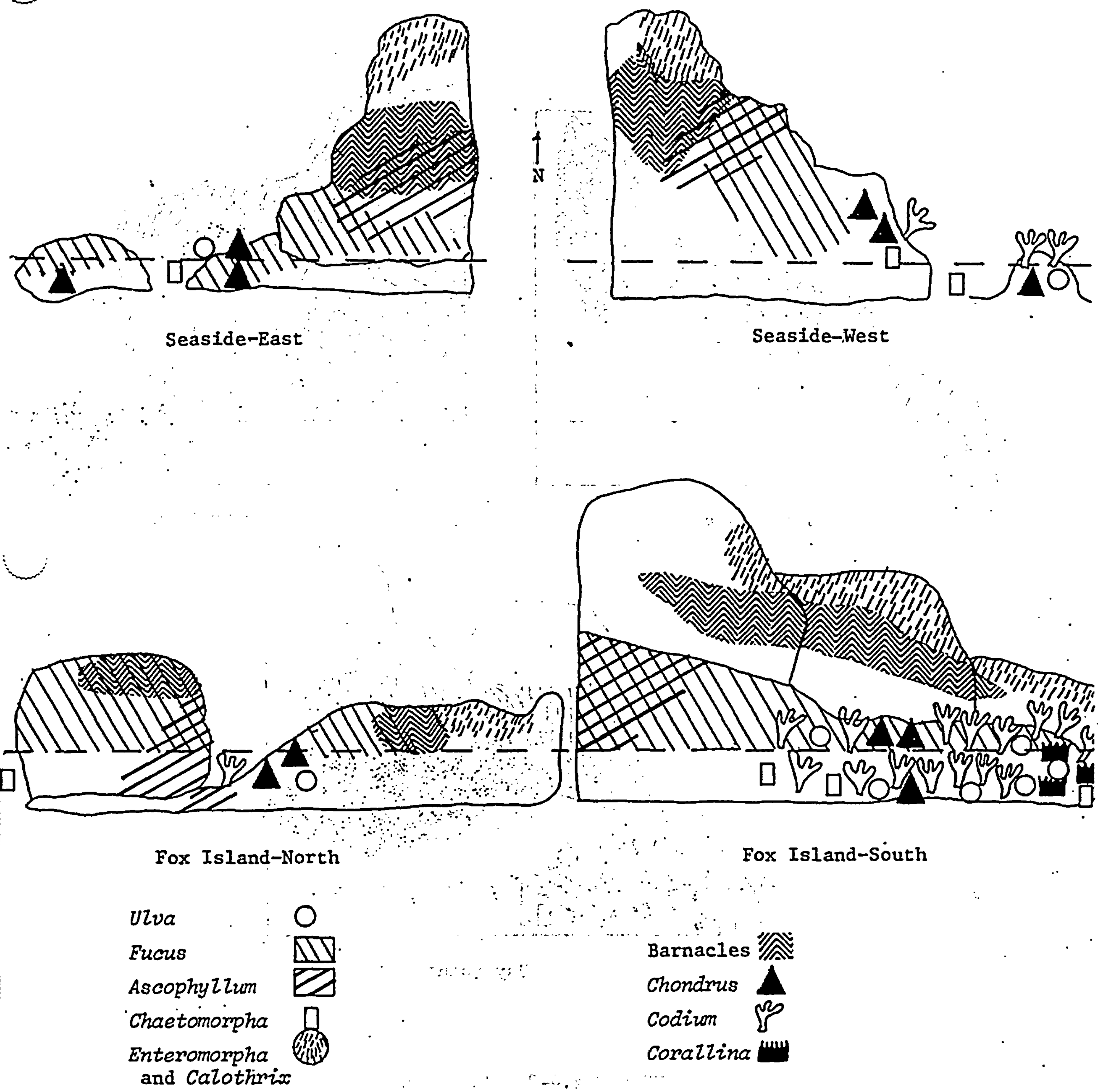


FIGURE 4.4-2. COMMUNITY ZONATION OF THE INTERTIDAL TRANSECT AREAS

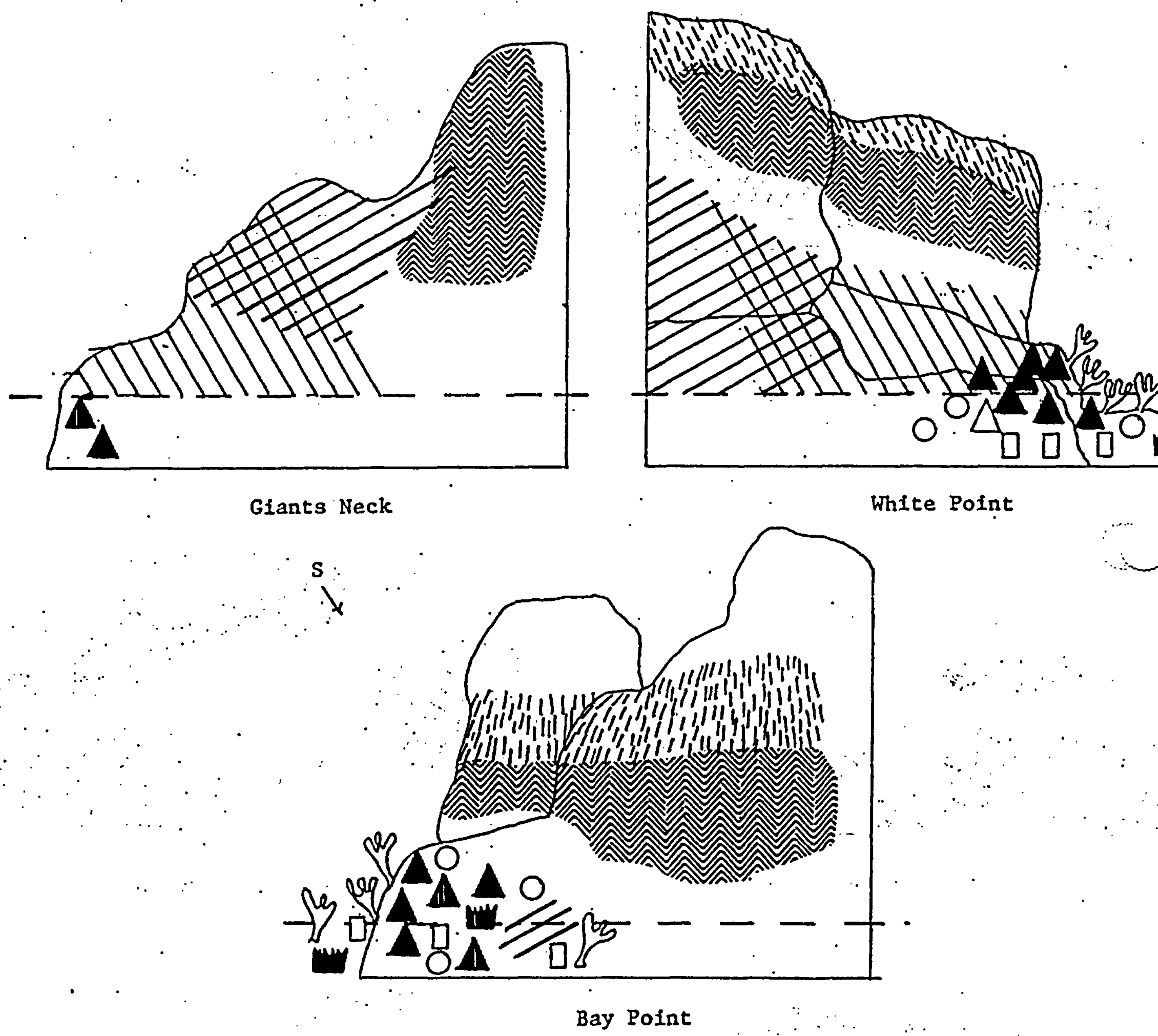


FIGURE 4.4-2. (continued)

TABLE 4.5-1. TAXONOMIC LISTING OF INVERTEBRATES IDENTIFIED FROM THE SUBTIDAL SAND STATIONS FOR JUNE, 1974, THROUGH SEPTEMBER, 1975

JC = Jordan Cove; EF = Effluent; TT = Twotree Island Channel; LR = Little Rock; IN = Intake; BP = Bay Point; NB = Niantic Bay; GN = Giants Neck

	JC	EF	TT	LR	IN	BP	NB	GN
	15'	20'	25'	25'	15'	20'	20'	30'
PORIFERA								
Scypha sp.		X	X					
CNIDARIA								
Edwardsia sp.	X	X	X	X		X	X	X
Metridium senile				X				
RHYCHOCOELA			X		X	X		
ASCHELMINTHES								
Nematoda	X	X	X	X	X	X		X
Stomatopoda					X			
MOLLUSCA								
Acmaea testudinalis						X		
Acteocina canaliculata				X	X		X	
Anachis spp.	X	X	X	X	X	X		X
Anadara transversa				X				X
Anomia squamula			X					
Astarte subaequilatera				X				
Astarte undata				X	X			X
Boreotrophon gunneri				X		X	X	
Cerastoderma pinnulatum			X	X				X
Cerithiopsis greeni		X						
Crepidula convexa				X	X			
Crepidula fornicata		X	X	X	X	X		X
Crepidula plana			X	X	X			
Cumingia tellinoides		X	X					X
Dinocardium robustum				X				
Ensis directus	X	X	X	X	X	X	X	X
Epitonium multistratum		X						
Eupleura caudata	X							
Haminoea solitaria				X	X			
Hydrobia totteni		X		X				X
Lacuna vincta		X	X		X	X		X
Lyonsia hyalina	X	X	X	X				X
Mellanella intermedia								X
Mercenaria mercenaria	X					X		
Mitrella lunata	X	X	X	X	X	X		X
Mysella planulata	X	X	X	X	X	X		X
Mytilus edulis		X	X	X	X		X	X
Nassarius trivittatus		X	X	X		X	X	
Nucula delphinodonta	X	X		X	X	X		X
Nucula proxima	X	X	X	X	X		X	X
Odostomia seminuda	X	X	X	X	X	X	X	X
Pandora gouldiana		X		X	X	X		X
Periploma fragile				X				
Petricola pholadiformis			X					
Pitar morrhuana	X	X		X	X	X	X	X

TABLE 4.5-1. (continued)

	JC 15'	EF 20'	TT 25'	LR 25'	IN 15'	BP 20'	NB 20'	GN 30'
Lunatia duplicatus				X		X		
Lunatia heros			X					
Lunatia triseriata	X	X	X	X	X		X	X
Polinices immaculatus		X						
Retusa obtusa		X	X	X	X			
Solemya velum	X	X			X			X
Solen viridis	X	X		X		X		
Tellina agilis	X	X	X	X	X	X	X	X
Turbonilla interrupta	X	X	X	X	X	X	X	X
Urosalpinx cinerea		X	X	X		X		
Yoldia limatula				X	X		X	
ANNELIDA								
Oligochaeta				X				
Ampharetidae				X			X	
Arabellidae	X			X				
Arabella iricolor		X	X		X	X		X
Driloneris spp.								X
Notocirrus spiniferus					X			
Capitellidae		X		X		X		X
Cirratulidae	X		X	X	X	X	X	X
Cirratulus grandis		X						
Eunicidae								
Marphysa belli	X							
Marphysa sanguinea		X						
Flabelligeridae			X		X		X	X
Pherusa spp.								
Glyceridae								
Glycera americana	X	X	X	X	X	X	X	X
Lumbrinereidae		X						
Lumbrineris tenuis			X	X		X		
Lumbrineris sp.	X				X	X	X	X
Ninoe nigripes			X		X		X	X
Maldanidae								
Clymenella torquata			X	X	X	X	X	X
Clymenella zonalis				X				
Clymenella spp.		X		X	X		X	X
Maldanopsis elongata	X				X			
Nephtyidae								
Nephtys bucera				X	X	X		
Nephtys incisa			X	X			X	
Nephtys picta	X	X	X	X	X	X	X	X
Nereidae				X	X		X	X
Nereis arenaceodonta	X	X	X					
Nereis succinea			X					
Nereis spp.						X		
Onuphidae								
Diopatra cuprea		X		X				X
Ophellidae			X		X			
Ammotrypane aulogaster				X				
Orbiniidae		X		X	X			

TABLE 4.5-1. (continued)

	JC	EF	TT	LR	IN	BP	NB	GN
	15'	20'	25'	25'	15'	20'	20'	30'
Oweniidae			X			X	X	X
Owenia fusiformis	X	X		X	X			
Paraonidae			X		X			
Aricidae jeffreysii	X					X		X
Paraonis sp.		X		X				
Pectinariidae								
Pectinaria gouldii				X	X			
Phyllodocidae								
Eteone lactea	X				X			
Eteone spp.						X		
Eumida spp.				X		X		X
Phyllodoce arenae	X		X	X				X
Phyllodice maculata					X			
Phyllodoce mucosa					X			
Phyllodoce spp.		X						
Polynoidae	X	X	X	X		X		X
Lepidonotus sublevis								X
Lepidonotus spp.				X		X		
Sabellariidae								
Sabellaria vulgaris	X	X	X	X	X	X		X
Sabellidae			X					
Sabella microphthalma				X				X
Scalibregmidae								
Scalibregma inflatum			X	X		X		
Serpulidae								
Hydroides dianthus		X		X				
Signalionidae								
Pholoe minuta		X		X	X		X	X
Sthenelais sp.	X	X	X	X		X		X
Spionidae			X			X		
Syllidae		X	X				X	
Eusyllinae (subfamily)						X		
Exogene spp.	X			X		X		X
Terebellidae	X	X		X				X
Aphitrite spp.			X					
Pista cristata			X			X		
ARTHROPODA								
Acanthohaustorius millsi		X						
Aeginella longicornis								X
Ampelisca abdita	X	X	X	X	X	X		X
Ampelisca agassizi	X	X		X	X	X		X
Ampelisca macrocephla		X		X	X	X	X	X
Ampelisca vadorum	X	X	X	X	X	X		X
Ampelisca verrilli	X	X	X	X	X		X	X
Amphithoe valida		X				X		
Anoplodactylus lentus		X		X				

TABLE 4.5-1. (continued)

	JC 15'	EF 20'	TT 25'	LR 25'	IN 15'	BP 20'	NB 20'	GN 30'
Balanus balanoides		X						
Byblis serrata				X				
Calliopius laeviusculus						X		
Callipallene brevirostris	X	X						X
Caprella geometrica								X
Caprella linearis			X	X				X
Caprella longicornis								X
Carcinas maenas	X	X						X
Chirodotea caeca		X						
Cirolana concharum	X	X						
Copepoda			X					
Corophium acherusicum				X				
Corophium acutum	X	X	X		X	X		X
Corophium bonelli				X				X
Corophium insidiosum	X	X	X	X	X			X
Crangongx pseudogracilis					X			
Cyathura polita	X		X	X		X		
Dexamine thea	X							
Diastylis sculpta		X	X					
Diastylis quadrispinosa		X		X	X	X		
Edotea triloba	X		X	X		X		X
Elasmopus levis		X	X					X
Erichsonella filiformis		X		X		X		X
Erichthonius brasiliensis								X
Gammarus oceanicus			X					
Gammarus palustris						X		
Gammarus trigrinus					X			
Gammarus spp.				X				
Grapsidae			X					
Harpinia propinqua		X	X	X		X		X
Heteromysis formosa								X
Idotea baltica					X			
Lembos websteri			X	X				
Hyale nilssoni				X	X			
Jassa falcata	X	X	X	X	X	X		
Jaera marina				X				
Leptocheirus pinguis	X	X	X	X	X	X		X
Leptochelia savignyi		X	X			X		
Listriella barnardi		X			X			
Lysianopsis alba		X						X
Marinogammarus obtusatus			X		X			X
Marinogammarus stoerensis	X							
Meterythrops robustus				X	X			
Microdeutopus anomalus		X						X
Microdeutopus gryllotalpa		X				X		
Neomysis americana					X			
Nymphoa			X	X				
Orchomenella minuta		X						

TABLE 4.5-1. (continued)

	JC	EF	TT	LR	IN	BP	NB	GN
	15'	20'	25'	25'	15'	20'	20'	30'
Ostracoda		X	X	X				X
Pagurus acadianus						X		
Pagurus longicarpus	X	X	X	X	X	X		X
Pagurus pollicarus							X	
Pentamera pulcherrima		X						X
Phoxocephalus holbolli		X	X		X	X		X
Pleusymtes glaber		X			X	X		
Tanais cavolinii	X	X				X		
Tanystylum orbiculare								X
Tortanus discaudatus						X		
Trichophoxus epistomus		X	X		X	X		
Unciola dissimilis						X		X
Unciola irrorata	X	X	X	X	X	X	X	X
Unciola serrata	X	X	X			X		
Crab zoea			X	X				
ECHINODERMATA								
Holothuridae				X				
Ophiacantha spp.						X		
Ophioderma brevispinum	X	X						
Opioderma sp.								X
Thyone briareus				X				X
CHORDATA								
Styelidae		X				X		X
Molgula sp.		X						

Depth at mean low water

TABLE 4.5-2. MEAN NUMERICAL YIELDS PER SQUARE METER OF INVERTEBRATES AND COEFFICIENTS OF VARIATION OF SAMPLES AT EACH SUBTIDAL SAND STATION FROM JUNE, 1974, THROUGH SEPTEMBER, 1975

		Jun 1974	Sep 1974	Dec 1974	Mar 1974	Jun 1975	Sep 1975	For Six Sample
Jordan Cove (15' MLW)	Mean	3,453	2,714	624	1,542	1,580	2,306	2,036
	Standard Error	692	377	144	275	281	415	997
	Coefficient of Variation (%)	63.4	44.0	72.9	56.5	56.3	56.9	
Intake (15' MLW)	Mean	2,535	10,103	2,255	1,287	318	2,561	3,172
	Standard Error	694	601	416	191	95	257	3,505
	Coefficient of Variation (%)	86.5	18.8	58.3	47.0	94.8	31.8	
Effluent (20' MLW)	Mean	7,096	4,179	4,217	3,299	956	1,707	3,576
	Standard Error	1,556	618	2,008	403	156	490	2,172
	Coefficient of Variation (%)	69.3	46.7	150.6	39.0	51.5	90.8	
Bay Point (20' MLW)	Mean	2,751	3,414	1,363	764	1,669	1,682	1,941
	Standard Error	386	959	240	239	196	441	968
	Coefficient of Variation (%)	44.4	88.9	55.7	98.8	37.1	83.0	
Niantic Bay[a] (20' MLW)	Mean				10,307	11,963	11,950	
	Standard Error				696	1,504	1,262	[illegible]
	Coefficient of Variation (%)				21.4	39.8	33.4	
Twotree Channel (25' MLW)	Mean	2,535	3,822	1,503	637	1,172	1,491	1,860
	Standard Error	839	1,477	576	194	416	251	1,143
	Coefficient of Variation (%)	104.6	122.2	122.3	96.1	112.0	53.2	
Little Rock (25' MLW)	Mean	5,631	11,084	5,401	1,580	1,745	1,223	4,444
	Standard Error	583	820	-	247	245	173	3,802
	Coefficient of Variation (%)	32.8	23.5	-	49.4	44.5	44.8	
Giants Neck (30' MLW)	Mean	1,924	1,924	1,350	459	1,045	940	1,279
	Standard Error	468	482	441	109	131	148	576
	Coefficient of Variation (%)	77.1	79.8	103.3	75.4	39.7	43.2	

MLW - Mean low water
(a) - This station was added to the program in March, 1975

TABLE 4.5-3. PREDOMINANT GRAIN SIZE (MILLIMETERS) DETERMINED FOR EACH SUBTIDAL SAND STATION FROM JUNE, 1974, THROUGH SEPTEMBER, 1975

JC = Jordan Cove; IN = Intake; EF = Effluent; BP = Bay Point; NB = Niantic Bay; TT = Twotree Channel; LR = Little Rock; GN = Giants Neck

Month	JC 15'	IN 15'	EF 20'	BP 20'	NB 20'	TT 25'	LR 25'	GN 30'
June, 1974	0.297	0.297	0.297	0.7		0.7	<0.09	<0.09
September, 1974	0.297	<0.09	0.297	0.7		<0.09	<0.09	<0.09
December, 1974	0.297	<0.09	0.297	0.7		2.0	<0.09	<0.09
March, 1975	0.297	<0.09	<0.09	0.7	<0.09	0.7	<0.09	<0.09
June, 1975	0.297	<0.09	<0.09	0.5	<0.09	2.0	<0.09	<0.09
September, 1975	0.297	2.0	0.297	0.5	<0.09	2.0	<0.09	<0.09

Depths at mean low water

TABLE 4.5-4. RESULTS OF CHI-SQUARE CONTINGENCY TEST OF SAND GRAIN DISTRIBUTION DATA. GN = Giants Neck; JC = Jordan Cove; WP = White Point; EF = Effluent; TT = Twotree Island Channel; LR = Little Rock; BP = Bay Point; IN = Intake; Int. = Intertidal Station; Sub. = Subtidal Station.

	Size vs Month*	Sandsize vs Year Independent**			
		March 74-75	June 74-75	Sept 73-74	Dec 73-74
GN - Int.	X	0	0	X	X
JC - Int.	0	0	0	0	0
WP - Int.	X	Missing	0	0	X
JC - Sub.	X	X	X	0	0
EF - Sub.	0	X	0	Missing	0
TT - Sub.	0	0	0	0	0
LR - Sub.	0	X	X	0	0
BP - Sub.	0	0	X	0	0
GN - Sub.	0	X at .05	0	Missing	Missing
IN - Sub.	0	0	Missing	Missing	Missing

* Independent when averaged over years

** X = no change in distribution; 0 = change (dependent)

TABLE 4.5-5. TAXONOMIC LISTING OF THE ALGAE AND INVERTEBRATES IDENTIFIED FROM THE INTERTIDAL AND SUBTIDAL ROCK STATIONS FOR JUNE, 1974, THROUGH SEPTEMBER, 1975

	Intertidal			Subtidal	
	White Point	Fox Island South	Giants Neck	Effluent	Giants Neck
CYANOPHYTA					
Oscillatoriaceae		X			
CHRYSOPHYTA	X		X	X	X
Rhabdonema adriaticum		X			
PENNALES					X
CHLOROPHYTA					
Bryopsis plumosa	X			X	
Chaetomorpha atrovirens					X
Chaetomorpha linum	X	X	X	X	X
Cladophora albida			X		
Cladophora gracilis			X	X	
Cladophora spp.		X			X
Codium fragile	X	X	X	X	X
Enteromorpha clathrata			X		
Enteromorpha compressa	X	X	X		
Enteromorpha erecta	X	X	X		
Enteromorpha intestinalis	X		X		
Enteromorpha linza	X	X	X		
Enteromorpha minima	X				
Enteromorpha spp.				X	X
Monostroma sp.	X				
Rhizoclonium tortuosum	X	X			
Spongomorpha arcta					X
Ulothrix flacca		X			
Ulva lactuca	X	X	X	X	X
PHAEOPHYTA					
Ascophyllum nodosum	X		X		
Callithamnion byssoides					X
Desmarestia aculeata	X	X		X	X
Ectocarpus confervoides	X				
Ectocarpus siliculosus		X			
Ectocarpus tomentosus		X	X		
Elachistea fucicola	X	X	X		
Fucus endentatus	X	X			
Fucus evanescens	X	X	X		
Fucus spiralis	X		X		
Fucus vesiculosus	X	X	X		
Fucus spp.				X	X
Laminaria agardhii				X	X
Laminaria spp.	X	X	X		
Petalonia fascia	X		X		
Punctaria spp.			X		
Pylaiella littoralis	X	X			
Scytosiphon lomentaria	X				
Sphacelaria cirrosa		X		X	
Spacelaria spp.			X		X

TABLE 4.5-5. (continued)

	Intertidal			Subtidal	
	White Point	Fox Island South	Giants Neck	Effluent	Giants Neck
RHODOPHYTA					
Agardhiella tenera			X		X
Ahnfeltia plicata	X		X	X	X
Antithamnion cruciatum	X	X	X	X	X
Asparagopis hamifera				X	
Callithamnion baileyi	X	X	X	X	X
Callithamnion roseum			X	X	X
Ceramium diaphanum	X			X	X
Ceramium fastigiatum	X		X		
Ceramium rubrum	X	X	X	X	X
Champia parvula	X	X	X	X	X
Chondria baileyanna				X	
Chondria spp.	X				X
Chondrus crispus	X	X	X	X	X
Corallina officinalis	X	X	X	X	X
Cystoclonium cirrhosum	X	X	X	X	X
Daysa pedicellata				X	
Delesseria sinuosa				X	X
Dumontia incrassata				X	
Gigartina stellata	X				
Hypnea musciformis				X	
Lomentaria baileyana	X			X	
Lomentaria orcadensis			X	X	
Phycodrys rubens				X	X
Phyllophora brodiaei	X		X	X	X
Polyides caprinus	X			X	X
Polysiphonia elongata	X				
Polysiphonia fibrillosa	X	X	X	X	X
Polysiphonia flexicaulis		X			
Polysiphonia harveyi	X			X	X
Polysiphonia lanosa	X	X	X	X	X
Polysiphonia nigra				X	X
Polysiphonia nigrescens	X		X	X	X
Porphyra umbilicalis	X	X			
Rangia fuscopurpurea	X				
Rhodocorton spp. (on *Polyides*)				X	
Rhodymenia palmata				X	X
Spermothamnion turneri				X	X
Spyridia filamentosa				X	
Trailliella intricata	X		X	X	X
Porphyra leucosticta	X				
PORIFERIA					
Halichondria sp.				X	X
Haliclona sp.				X	
Scypha sp.				X	X

TABLE 4.5-5. (continued)

	Intertidal			Subtidal	
	White Point	Fox Island South	Giants Neck	Effluent	Giants Neck
CNIDARIA					
Campanularia spp.				X	X
Edwardsia spp.					X
Eudendrium spp.					X
Halecium spp.					X
Hydrallmenia falcata					X
Metridium senile		X	X	X	X
Obelia spp.				X	X
Sertularia pumila			X	X	X
Thuiaria argentea					X
Thuiaria spp.			X		X
RHYNCHOCOELA	X		X	X	
Tubulanidae		X			
ASCHELMINTHES					
Nematoda	X	X	X	X	X
BRYOZOA					
Aetea anguina					X
Bicellariella ciliata					X
Bugula turrita	X	X	X	X	X
Bugula spp.			X		
Bowerbankia gracilis				X	X
Callopora aurita				X	X
Cellepora dichotoma			X	X	X
Crisia eburnea				X	X
Crisia spp.	X		X		
Cryptosula pallasiana	X	X			X
Electra pilosa	X	X		X	X
Electra spp.					X
Hippothoa hyalina				X	X
Lichenopora verrucaria				X	X
Schizoporella unicornis				X	X
Schizoporella spp.			X		
Tubulipora liliacea			X	X	X
MOLLUSCA					
Acmaea testudinalis	X		X		
Argopecten irradians					X
Anachis spp.	X	X	X	X	X
Anadara transversa				X	X
Anomia squamula					X
Anomia simplex				X	
Cerithiopsis greeni				X	
Corbula contracta					X
Crepidula convexa			X		X
Crepidula fornicata	X	X	X		
Crepidula plana				X	X
Cumingia tellinoides				X	
Diastoma alternatum			X	X	X

TABLE 4.5-5. (continued)

	Intertidal			Subtidal	
	White Point	Fox Island South	Giants Neck	Effluent	Giants Neck
Ensis directus				X	X
Epitonium angulatum				X	
Epitonium multistriatum				X	
Hiatella arctica				X	X
Hiatella striata				X	X
Hydrobia totteni				X	X
Lacuna vincta	X	X	X	X	X
Littorina littorea	X	X	X		
Littorina obtusata	X	X	X		
Littorina saxatilis	X	X	X		
Lyonsia hyalina				X	X
Mitrella lunata	X	X	X	X	X
Modiolus modiolus	X			X	
Mysella planulata				X	
Mytilus edulis	X	X	X	X	X
Nassarius trivittatus				X	
Noetia ponderosa				X	
Nucella lapillus	X				
Nucula proxima				X	X
Odostomia seminula				X	X
Pandora gouldiana					
Petricola pholadiformis				X	
Polinices immaculatus				X	X
Lunatia heros					X
Lunatia triseriata		X		X	
Siliqua costata					X
Tellina agilis				X	X
Turbonilla interrupta				X	
Urosalpinx cinerea	X	X	X	X	X
ANNELIDA					
Oligochaeta	X		X		
Arabellidae	X				
Arabella iricolor				X	
Capitellidae		X		X	X
Cirratulidae					X
Cirratulus spp.				X	
Eunicidae		X			X
Marphysa sanguinea				X	
Flabelligeridae					X
Maldanidae				X	X
Clymenella torquata					X
Nephtyidae				X	
Nereidae					
Nereis pelagica		X		X	
Nereis virens				X	X
Nereis spp.	X		X		
Oweniidae				X	X
Phyllodocidae					
Eulalia viridis	X				
Eulalia spp.		X			
Eumidia sanguinea				X	

TABLE 4.5-5. (continued)

	Intertidal			Subtidal	
	White Point	Fox Island South	Giants Neck	Effluent	Giants Neck
Eumida sp.					X
Eteone spp.		X		X	
Phyllodoce maculata				X	X
Polynoidae		X	X		
Harmothoe sp.					X
Lepidonotus squamatus				X	X
Sabellariidae					
Sabellaria vulgaris		X	X	X	X
Sabellidae					
Fabricia sabella		X	X		
Potamilla neglecta				X	X
Potamilla reniformis				X	X
Sabella microphthalma				X	X
Serpulidae					
Hydroides dianthus				X	X
Sigalionidae				X	X
Sthenelais spp.				X	X
Syllidae				X	X
Autolytus spp.					X
Syllinae				X	
Syllis gracilis		X		X	
Terebellidae	X				
ARTHROPODA					
Insecta	X	X			
Aeginella longicornis			X	X	X
Ampelisca abdita				X	
Ampelisca macrocephala				X	
Ampelisca spp.				X	X
Ampelisca verrilli				X	
Amphithoe longimana				X	
Amphithoe rubricata	X			X	X
Amphithoe spp.				X	
Amphithoe valida	X	X	X	X	X
Anvrida maritima			X	X	
Aronyx liljeborgi				X	
Balanus balanoides	X	X	X	X	
Balanus balanus					X
Calliopius laeviusculus				X	
Callipallene brevirostris				X	
Calocaris spp.					X
Cancer irroratus				X	
Caprella geometrica	X	X	X	X	X
Caprella linearis	X		X	X	X
Carcinus maenas	X	X	X	X	X
Chiridotea coeca				X	
Chironomidae	X	X	X		
Cirolana concharum				X	
Corophium acherusicum					X
Corophium acutum		X	X	X	X
Corophium insidiosum	X	X		X	X
Corophium spp.			X		

TABLE 4.5-5. (continued)

	Intertidal			Subtidal	
	White Point	Fox Island South	Giants Neck	Effluent	Giants Neck
Crangon septemspinosus				X	X
Crangon sp.				X	
Cyathura polita	X				
Cymadusa compta			X		
Dexamine thea			X		
Diastylis polita				X	
Diastylis quadrispinosa				X	
Diastylis sculpta				X	X
Edotea triloba				X	X
Elasmopus levis	X	X		X	X
Erichsonella filiformis	X	X	X	X	X
Erichthonius brasiliensis	X			X	X
Erichthonius rubicornis				X	
Gammarellus angulosus	X	X		X	
Gammarus oceanicus	X				
Gammarus tigrinus		X	X	X	
Gammarus spp.	X	X	X	X	X
Harpinia propinqua				X	
Hyale nilssoni	X	X	X	X	X
Hyale plumulosa	X	X	X		
Idotea baltica	X	X	X	X	
Idotea phosphorea	X	X		X	X
Jaera marina	X	X	X	X	
Jassa falcata	X	X	X	X	X
Lembos websteri	X			X	X
Lemos smithi				X	
Leptocheirus pinguis	X	X		X	X
Libinia sp.				X	X
Limnoria lignorum				X	
Limnoria spp.				X	
Listriella barnardi					X
Lysianopsis alba				X	
Marinogammarus stoerensis	X				
Microdeutopsus anomalus			X	X	
Microdeutopsus gryllotalpa	X		X	X	
Neomysis americana					X
Neopanope texana sayi	X	X	X	X	X
Nymphon sp.				X	
Orchomenella pinguis				X	
Orchomenella minuta				X	
Pagurus longicarpus			X	X	X
Palaemontes sp.					X
Paraphoxus spinosus					X
Pelia mutica				X	X
Phoxocephalus holbolli				X	X
Pleusymtes glaber			X	X	X
Podoceropsis nitida					X
Pontogeneia inermis				X	X
Rhithropanopeus harrisii					X
Scaptognathus spp.				X	

TABLE 4.5-5. (continued)

	Intertidal			Subtidal	
	White Point	Fox Island South	Giants Neck	Effluent	Giants Neck
Stenopleustes gracillis				X	X
Stenothoe minuta					X
Sunampithoe pelagica	X				
Tanais cavolini	X	X	X		
Trichophoxus epistomus				X	X
Unicola irrorata				X	
Crab zoea				X	
ECHINODERMATA					
Amphipholis squamata				X	X
Asterias sp.				X	X
Ophioderma brevispinum				X	X
Strongylocentrotus droebachiensis					X
Thyone briareus					X
CHAETOGNATH		X			
CHORDATA					
Ciona intestinalis			X		
Styelidae	X				
Styela sp.				X	X
Molgulidae			X		
Molgula manhattensis					X
Molgula sp.			X	X	

TABLE 4.5-6. TOTAL DRY WEIGHTS (GRAMS) PER SQUARE METER FOR ALGAE FROM THE SUBTIDAL ROCK STATIONS FROM MARCH, 1973, THROUGH SEPTEMBER, 1975

	Effluent (20' MLW)			Giants Neck[a] (20' MLW)		
Month	Mean	Standard Error	Coefficient of Variation (%)	Mean	Standard Error	Coefficient of Variation (%)
March, 1973	337	116	76.9			
June, 1973	285	49	38.6			
September, 1973	199	8	9.2			
December, 1973	77	22	62.8			
March, 1974	79	16	44.1	2	1	108.1
June, 1974	299	64	47.2	57	11	42.5
September, 1974	77	13	36.9	97	22	51.0
December, 1974	87	20	50.3	110	24	48.4
March, 1975	46	10	46.7	17	3	41.5
June, 1975	179	57	70.9	129	16	27.1
September, 1975	86	6	14.3	128	9	15.3

(a) This station was added to the program in March, 1974
MLW = Mean low water

TABLE 4.5-7. MEAN NUMERICAL YIELDS PER SQUARE METER FOR INVERTEBRATES TAKEN AT SUBTIDAL ROCK STATIONS FROM MARCH, 1973, THROUGH SEPTEMBER, 1975

	Effluent (20' MLW)			Giants Neck[a] (20' MLW)		
Month	Mean	Standard Error	Coefficient of Variation (%)	Mean	Standard Error	Coefficient of Variation (%)
March, 1973	9,542					
June, 1973	52,525	10,722	45.6			
September, 1973	24,746	3,695	33.4			
December, 1973	39,619	15,754	88.9			
March, 1974	28,701	7,958	62.0	2,115	588	62.2
June, 1974	52,253	9,311	39.8	3,702	905	54.6
September, 1974	32,870	7,079	48.2	3,757	350	20.8
December, 1974	31,235	10,540	75.5	5,331	1,208	50.7
March, 1975	20,554	4,039	43.9	1,750	266	34.0
June, 1975	35,770	12,091	75.6	3,517	1,014	64.5
September, 1975	13,850	3,678	59.4	4,064	836	46.0

(a) This station was added to the program in March, 1974
MLW = Mean low water

TABLE 4.5-8. NUMBER OF ALGAE AND INVERTEBRATE SPECIES IDENTIFIED FROM THE SUBTIDAL ROCK STATIONS FROM JUNE, 1973, THROUGH SEPTEMBER, 1975

	Effluent (20' MLW)		Giants Neck (20' MLW)	
Month	Algae	Invertebrates	Algae	Invertebrates
March, 1973	18	33		
June, 1973	24	46		
September, 1973	15	44		
December, 1973	15	59		
March, 1974	16	44	5	43
June, 1974	18	47	15	54
September, 1974	16	53	17	47
December, 1974	24	68	16	50
March, 1975	23	49	12	36
June, 1975	29	74	21	47
September, 1975	29	38	18	47
Mean Number of Species Per Sample Period	21	50	15	46

MLW = Mean low water

TABLE 4.5-9. NUMBER OF TAXONOMIC GROUPS FROM EACH PHYLUM AT EACH INTERTIDAL AND SUBTIDAL ROCK STATION FOR THE PERIOD JUNE, 1974, THROUGH SEPTEMBER, 1975

	Intertidal			Subtidal	
Phyla	White Point	Fox Island-South	Giants Neck	Effluent (20' MLW)	Giants Neck (20' MLW)
Cyanophyta		1			
Chrysophyta	1	1	1	1	1
Pennales					1
Chlorophyta	11	9	11	6	7
Phaeophyta	12	11	11	5	6
Rhodophyta	24	12	17	32	23
Porifera				3	3
Cnidaria		1	3	4	10
Rhynchocoela	1	1	1	1	
Aschelminthes	1	1	1	1	1
Bryozoa	4	3	6	12	16
Mollusca	12	10	12	29	24
Annelida	6	10	6	24	22
Arthropoda	29	22	26	63	40
Echinodermata				4	5
Chaetognatha		1			
Chordata	1		2	3	4
Total Algae	48	34	40	44	38
Total Invertebrates	54	49	57	144	125
Total	102	83	97	188	163

MLW = Mean low water

TABLE 4.5-10. TAXONOMIC LISTING OF INVERTEBRATES IDENTIFIED FROM INTERTIDAL SAND SAMPLES FROM JUNE, 1974, THROUGH SEPTEMBER, 1975

	White Point	Jordan Cove	Giants Neck
ASCHELMINTHES			
Nematoda	X	X	X
MOLLUSCA			
Anachia spp.	X	X	
Gemma gemma			X
Hydrobia totteni		X	
Lacuna vincta			X
Mitrella lunata		X	
Mytilus edulis	X	X	X
Semele proficua		X	
Spisula solidissima	X		
Tellina agilis	X		
Turbonilla interrupta	X		
Urosalpinx cinerea		X	
Veneridae		X	
ANNELIDA	X		
Oligochaeta			
Arabellidae			
Driloneris sp.			X
Caoitellidae			
Cirratulidae	X	X	X
Glyceridae	X		
Lumbrinereidae		X	X
Maldanidae			
Clymenella torguata		X	
Nereidae			
Nereis arenaceodonta	X	X	
Nereis pelagica		X	
Nereis succinea		X	
Nereis virens		X	
Nereis spp.	X		X
Ophelliidae	X		
Orbiniidae		X	
Scoloplos spp.	X		X
Paraonidae		X	X
Paraonis sp.	X		
Pectinariidae			
Pectinaria gouldii			X
Phyllodocidae			
Eteone sp.	X		
Polynoidae		X	
Spionidae			
Polydora sp.		X	X
Syllidae	X	X	
Eusyllinae			
Exogene spp.	X	X	
Syllinae			

TABLE 4.5-10. (continued)

	White Point	Jordan Cove	Giants Neck
Terebellidae		X	X
Sabellidae			
Fabricia sabella	X		
ARTHROPODA			
Insecta		X	X
Acanthohaustorius millsi	X		
Amplisca abdita		X	
Balanus amphitrite	X		
Caprella geometrica	X	X	
Caprella linearis	X		X
Carcinas maenas		X	
Corophium acutum	X		X
Corophium insidiosum	X	X	X
Corophium tuberculatum			X
Corophium spp.	X	X	X
Dexamine thea		X	
Diastylis quadrispinosa			X
Diastylis spp.		X	
Gammarus mucronatus	X	X	
Gammarus oceanicus		X	
Gammarus tigrinus			X
Hyale nilssoni		X	
Idotea baltica	X		
Idotea phosphorea	X		
Jassa falcata	X	X	X
Lembos websteri		X	
Leptocheirus pinguis	X		
Lysianopsis alba		X	
Marinogammarus obtusatus		X	
Philoscia vittata		X	
Pontogeneia inermis		X	
Unciola irrorata			X
Labidocera acutifrons		X	
Jaera marina			X

TABLE 4.5-11. MEAN NUMERICAL YIELDS PER SQUARE METER OF INVERTEBRATES AND COEFFICIENTS OF VARIATION OF SAMPLES AT EACH INTERTIDAL SAND STATION FROM JUNE, 1974, THROUGH SEPTEMBER, 1975

	White Point			Jordan Cove			Giants Neck		
Month	Mean	Standard Error	Coefficient of Variation (%)	Mean	Standard Error	Coefficient of Variation (%)	Mean	Standard Error	Coefficient of Variation (%)
June, 1974	217	50.4	73.63	2,026	233.7	36.49	89	38.2	135.53
September, 1974	2,153	414.1	60.82	1,478	274.7	58.78	204	176.3	273.54
December, 1974	89	50.4	178.81	561	100.8	56.89	25	17.0	210.82
March, 1975	89	27.2	96.42	3,618	551.8	48.23	127	32.9	81.65
June, 1975	612	96.5	49.88	395	133.6	106.93	2,115	523.6	78.30
September, 1974	3,096	463.7	47.36	6,975	1,789.7	72.57	779	191.6	73.84
Mean Number for Six Sample Periods	1,043			2,509			556		

TABLE 4.5-12. NUMBER OF TAXONOMIC GROUPS IDENTIFIED FROM INTERTIDAL SAND STATIONS FROM JUNE, 1974, THROUGH SEPTEMBER, 1975

Month	White Point	Jordan Cove	Giants Neck
June, 1974	6	10	7
September, 1974	15	12	5
December, 1974	5	9	2
March, 1975	4	15	5
June, 1975	10	5	6
September, 1975	8	7	7
Mean Number of Groups Per Sample Period	8	10	5

TABLE 4.5-13. PREDOMINANT GRAIN SIZE (MILLIMETERS) FOR THE INTERTIDAL SAND STATIONS FROM JUNE, 1974, THROUGH SEPTEMBER, 1975

Month	White Point	Jordan Cove	Giants Neck
June, 1974	1.0	1.0	0.5
September, 1974	1.0	0.7	0.297
December, 1974	1.0	<0.09	0.297
March, 1975	1.0	0.125	0.297
June, 1975	0.18	2.0	0.297
September, 1975	1.0	1.0	0.297

TABLE 4.5-14. TOTAL DRY WEIGHTS (GRAMS) PER SQUARE METER FOR ALGAE FROM THE INTERTIDAL ROCK STATIONS FROM JUNE, 1973, THROUGH SEPTEMBER, 1975

	White Point			Fox Island-South			Giants Neck		
Month	Mean	Standard Error	Coefficient of Variation (%)	Mean	Standard Error	Coefficient of Variation (%)	Mean	Standard Error	Coefficient of Variation (%)
June, 1973	607	136	50.2	507	433	191.2	2,610	834	63.9
September, 1973	499	151	67.8	430	298	119.7	384	51	26.5
December, 1973	294	208	141.2	426	154	62.8	2,371	504	47.5
March, 1974	476	151	71.2	284	73	57.7	1,356	734	121.0
June, 1974	670	283	94.5	752	255	75.8	718	74	23.0
September, 1974	752	133	39.5	421	40	21.2	993	229	51.6
December, 1974	346	115	74.1	625	197	70.6	612	358	130.6
March, 1975	392	52	29.8	717	88	27.4	563	212	75.2(n=4)
June, 1975	537	80	33.2	770	357	103.7	1,174	194	36.9
September, 1975	743	41	12.4	1,088	263	54.0	1,215	278	51.2

TABLE 4.5-15. MEAN NUMERICAL YIELDS PER SQUARE METER FOR INVERTEBRATES TAKEN AT INTERTIDAL ROCK STATIONS FROM JUNE, 1973, THROUGH SEPTEMBER, 1975

Month	White Point			Fox Island-South			Giants Neck		
	Mean	Standard Error	Coefficient of Variation (%)	Mean	Standard Error	Coefficient of Variation (%)	Mean	Standard Error	Coefficient of Variation (%)
June, 1973	49,114	12,324	56.0	35,398	5,002	31.6	64,608	8,242	25.5
September, 1973	11,869	1,074	20.2	72,709	49,538	118.0	17,980	3,976	44.2
December, 1973	6,012	2,910	96.8	4,379	3,229	127.7	92,618	7,815	18.9
March, 1974	3,344	852	57.0	47,552	7,207	33.9	30,691	5,240	38.2
June, 1974	83,251	23,786	63.9	109,117	38,193	78.3	36,106	8,195	50.7
September, 1974	6,166	2,424	87.9	509	198	87.0	2,307	1,007	98.0
December, 1974	19,376	9,251	107.0	4,336	3,194	165.0	5,411	1,142	47.0
March, 1975	72,272			2,288	834	81.0	13,424	4,782	71.0
June, 1975	79,315	32,191	91.0	70,989	25,246	80.0	99,670	31,469	71.0
September, 1975	14,314	12,564	196.0	3,603	1,743	108.0	41,286	8,418	46.0

TABLE 4.5-16. NUMBER OF ALGAE AND INVERTEBRATE SPECIES IDENTIFIED FROM THE INTERTIDAL ROCK STATIONS FROM JUNE, 1973, THROUGH SEPTEMBER, 1975

Month	White Point		Fox Island-South		Giants Neck	
	Algae	Invertebrates	Algae	Invertebrates	Algae	Invertebrates
June, 1973	14	19	7	17	10	27
September, 1973	9	16	11	22	7	17
December, 1973	9	13	8	19	10	11
March, 1974	17	34	19	19	17	16
June, 1974	14	23	19	23	8	21
September, 1974	33	39	9	12	17	31
December, 1974	25	20	16	17	28	22
March, 1975	18	8	12	13	20	13
June, 1975	14	15	17	29	11	14
September, 1975	13	13	19	24	5	18
Mean Number of Species Per Sample Period	17	20	14	20	13	19

TABLE 4.5-17. THE MEAN DRY WEIGHT BIOMASS (GRAMS) PER SQUARE METER FOR *Fucus* spp. AND PERCENT OF TOTAL WEIGHT AT EACH INTERTIDAL ROCK STATION FROM JUNE, 1973, THROUGH SEPTEMBER, 1975

	White Point		Fox Island-South		Giants Neck	
Month	Grams	Percent	Grams	Percent	Grams	Percent
June, 1973	454	74	463	91	1,326	51
September, 1973	485	97	405	94	376	98
December, 1973	267	91	320	75	188	8
March, 1974	179	38	26	9	250	18
June, 1974	587	88	548	73	703	98
September, 1974	443	59	382	91	894	90
December, 1974	233	67	563	90	149	24
March, 1975	246	63	693	97	361	64
June, 1975	511	95	616	80	868	74
September, 1975	729	98	900	83	1,207	99
Mean Weight for 10 Sample Periods	413.4		491.6		632.2	

TABLE 4.5-18. CORRELATION OF SAND GRAIN SIZE WITH BENTHIC POPULATION PARAMETERS

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
					Intertidal Data					
LOGNO	.0426	.1057	-.0668	-.3967	-.3313	-.0134	.0411	.4085	.4186	.3714
	(15)	(15)	(15)	(15)	(15)	(15)	(15)	(15)	(15)	(15)
	S= .881	S= .708	S= .813	S= .143	S= .228	S= .962	S= .884	S= .131	S= .120	S= .173
NOSPEC	-.0831	.0780	.0181	-.4124	-.4676	-.1445	.1644	.6145	.5817	.4800
	(15)	(15)	(15)	(15)	(15)	(15)	(15)	(15)	(15)	(15)
	S= .768	S= .782	S= .949	S= .127	S= .079	S= .607	S= .558	S= .015	S= .023	S= .070
DIVINDEX	.0072	.2072	.2025	-.2335	-.7185	-.4252	.1945	.5887	.5192	.5482
	(15)	(15)	(15)	(15)	(15)	(15)	(15)	(15)	(15)	(15)
	S= .980	S= .459	S= .469	S= .402	S= .003	S= .114	S=.485	S= .021	S= .047	S= .034
					Subtidal Data					
LOGNO	-.2972	-.2527	-.1623	-.1563	.1552	.1289	.1877	.2161	.1951	.0742
	(38)	(38)	(38)	(38)	(38)	(38)	(38)	(38)	(38)	(38)
	S= .070	S= .126	S= .338	S= .349	S= .352	S= .448	S= .259	S= .193	S= .240	S= .658
NOSPEC	-.0760	-.1521	-.2066	-.0972	.3051	.4749	.3264	-.1316	-.2461	-.0735
	(38)	(38)	(38)	(38)	(38)	(38)	(38)	(38)	(38)	(38)
	S= .650	S= .362	S= .213	S= .562	S= .063	S= .003	S= .045	S= .431	S= .138	S= .661
DIVINDEX	.2816	.2619	.1075	.2310	.2340	.3141	.0717	-.4818	-.5313	-.3380
	(38)	(38)	(38)	(38)	(38)	(38)	(38)	(38)	(38)	(38)
	S= .087	S= .112	S= .521	S= .163	S=.157	S= .055	S= .669	S= .002	S= .001	S= .038

LOGNO = Logarithm of number of individuals per square meter
NOSPEC = Number of species
DIVUNDEX = Diversity index

TABLE 4.5-19. CORRELATION OF SAND GRAIN SIZE WITH REPRESENTATIVE BENTHIC TAXONOMIC GROUPS

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
					Subtidal Data					
TAXA 1	-.4534	-.5453	-.4629	-.1830	.4373	.5196	.4198	.2545	.0791	.0558
	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)
	S= .012	S= .102	S= .010	S= .333	S= .016	S= .003	S= .021	S= .175	S= .678	S= .770
TAXA 2	-.2583	-.5030	-.5015	-.4885	-.1594	-.0801	-.0146	.4197	.6493	.5621
	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)
	S= .168	S= .005	S= .005	S= .006	S= .400	S= .674	S= .939	S= .021	S= .001	S= .001
TAXA 3	.0628	.4235	.4562	.5366	.3470	.1736	-.0498	-.5567	-.4593	-.5661
	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)
	S= .742	S= .020	S= .011	S= .002	S= .060	S= .359	S= .794	S= .001	S= .011	S= .001
TAXA 4	.2806	.3696	.1774	.2061	-.0137	-.1808	-.2717	-.3642	-.2458	-.1277
	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)
	S= .133	S= .344	S= .348	S= .275	S= .943	S= .339	S= .146	S= .348	S= .190	S= .501
TAXA 5	.1304	.5872	.5673	.5846	-.0205	-.1846	-.2667	-.4275	-.3256	-.3997
	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)
	S= .492	S= .001	S= .001	S= .001	S= .915	S= .329	S= .154	S= .018	S= .079	S= .029
TAXA 6	-.2846	-.3384	-.2551	-.2262	.0727	.2649	.5031	.4754	-.0681	.0701
	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)
	S= .127	S= .067	S= .174	S= .229	S= .703	S= .157	S= .005	S= .008	S= .721	S= .713

TAXA 1 = *Tellina* spp.

TAXA 2 = *Nucula* spp.

TAXA 3 = Terebellidae, *Amphitrite* spp., *Pista cristata*

TAXA 4 = *Lumbrineris* spp., *Ninoe nigripes*

TAXA 5 = *Paraonidae* spp., *Aricidae* spp.

TAXA 6 = *Ampelisca* spp.

TABLE 4.5-20. SUMMARY OF THE NATURE OF THE ASSOCIATION OF VARIOUS TAXA OF BENTHIC INFAUNA WITH VARIOUS PARTICLE SIZE GROUPS

Taxa	Type of Association	Significance
Tellina spp.	Avoidance of large sized fractions preference for intermediate size fractions.	95%
Nucula spp.	Avoidance of large sized fractions preference of small size fractions.	95%
Terebellidae *Amphitrite* spp. *Pista cristata*	Preference for large sized fractions avoidance of small size fractions.	95%
Lumbrineris spp. *Ninoe nigripes*	Preference for large sized fractions avoidance of small sized fractions.	95%
Paraonidae spp. *Aridicea* spp.	Preference for large sized fractions avoidance of small sized fractions.	95%
Ampelisca spp.	Preference for smaller intermediate sized fractions.	95%

LEGEND

SAMPLING STATIONS FOR THE BENTHIC STUDIES

(1) Giants Neck intertidal : rock substrate
(2) Giants Neck intertidal : sand substrate
(3) Giants Neck subtidal : rock and sand substrate (20 and 30 feet mean low water)
(4) Bay Point subtidal : sand substrate (20 feet mean low water)
(5) Intake subtidal : sand substrate (15 feet mean low water)
(6) Little Rock subtidal : sand substrate (25 feet mean low water)
(7) Effluent subtidal : rock and sand substrate (20 feet mean low water)
(8) Fox Island-South intertidal : rock substrate
(9) Jordan Cove intertidal : sand substrate
(10) Jordan Cove subtidal : sand substrate (15 feet mean low water)
(11) Towtree Island subtidal : sand substrate (25 feet mean low water)
(12) White Point intertidal : sand substrate
(13) White Point intertidal : rock substrate
(14) Niantic Bay subtidal : sand substrate (20 feet mean low water)

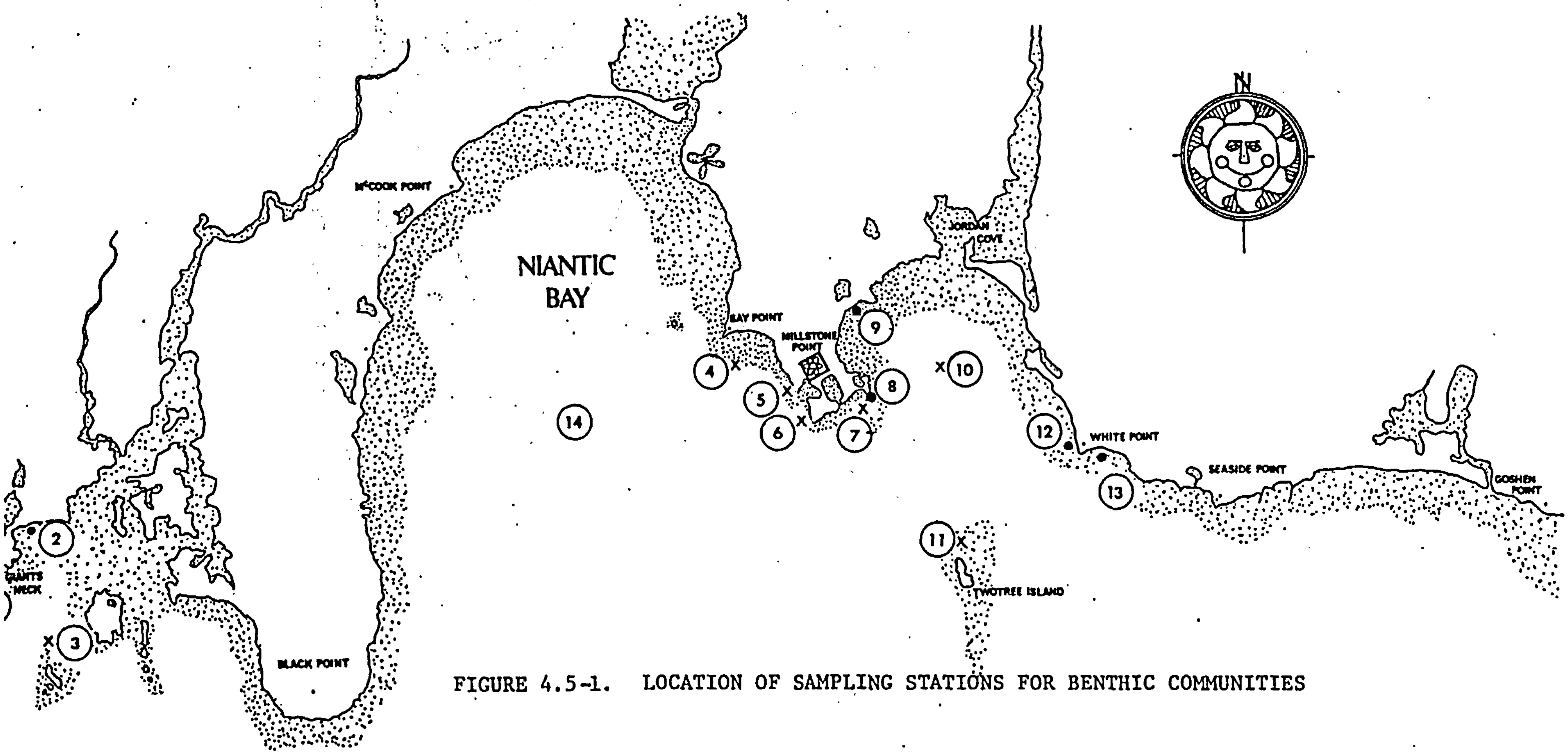


FIGURE 4.5-1. LOCATION OF SAMPLING STATIONS FOR BENTHIC COMMUNITIES

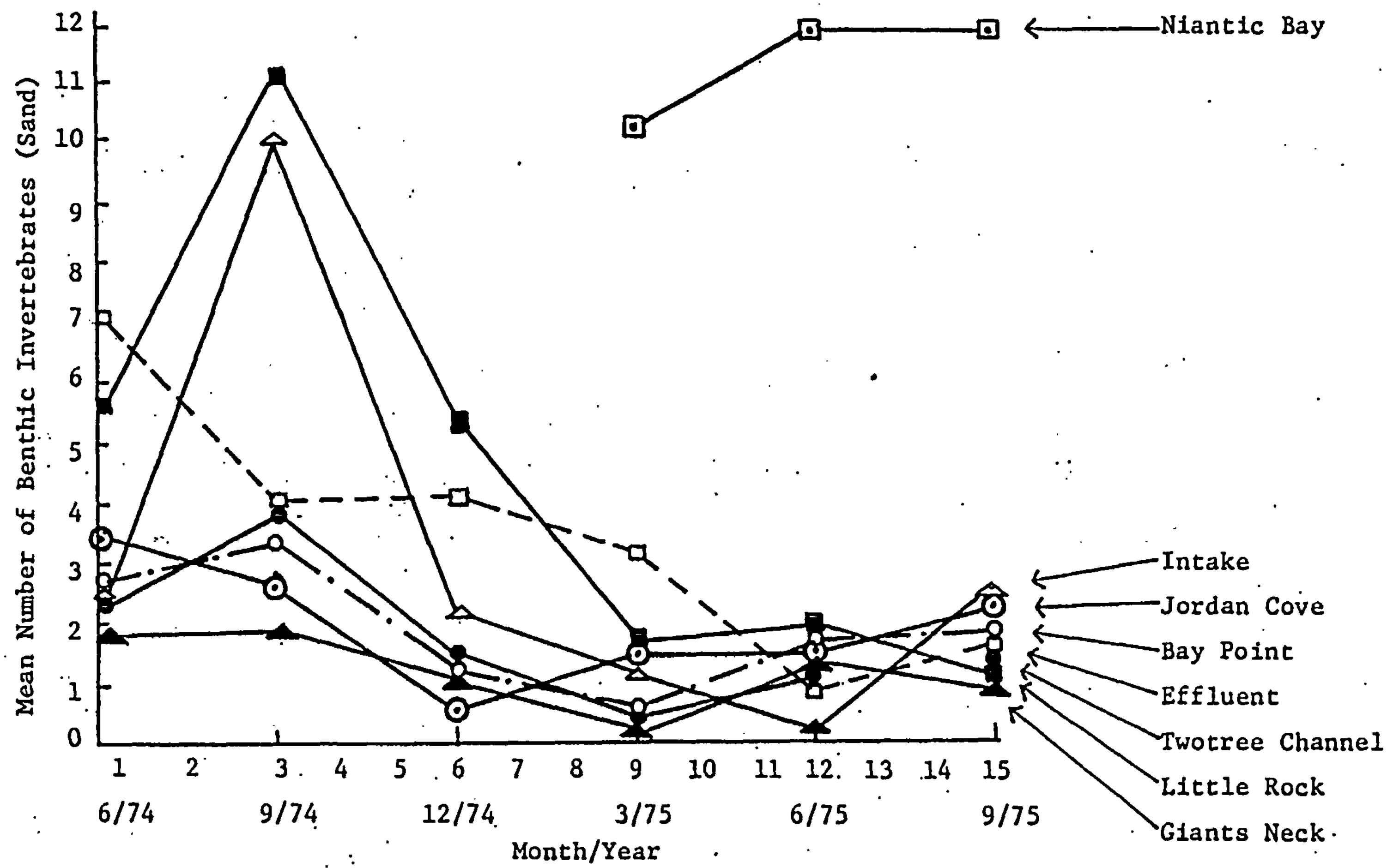


FIGURE 4.5-2. MEAN NUMBER OF INVERTEBRATES AT SUBTIDAL SAND STATIONS

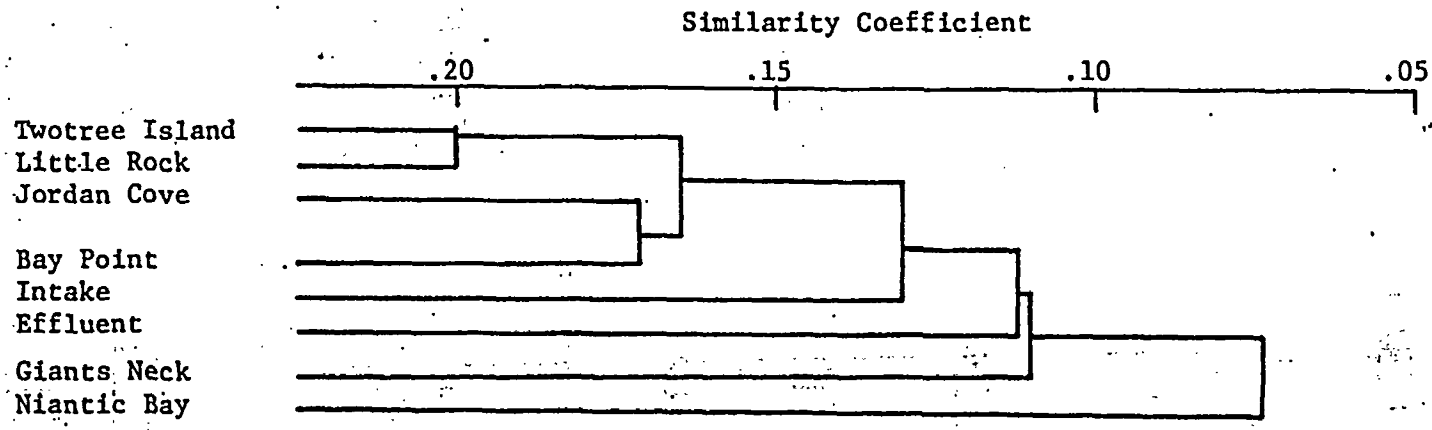


FIGURE 4.5-3. REPRESENTATIVE DENDROGRAM OF RELATIVE SIMILARITY OF SPECIES COMPOSITION AT SUBTIDAL SAND STATIONS (SEPTEMBER, 1975)

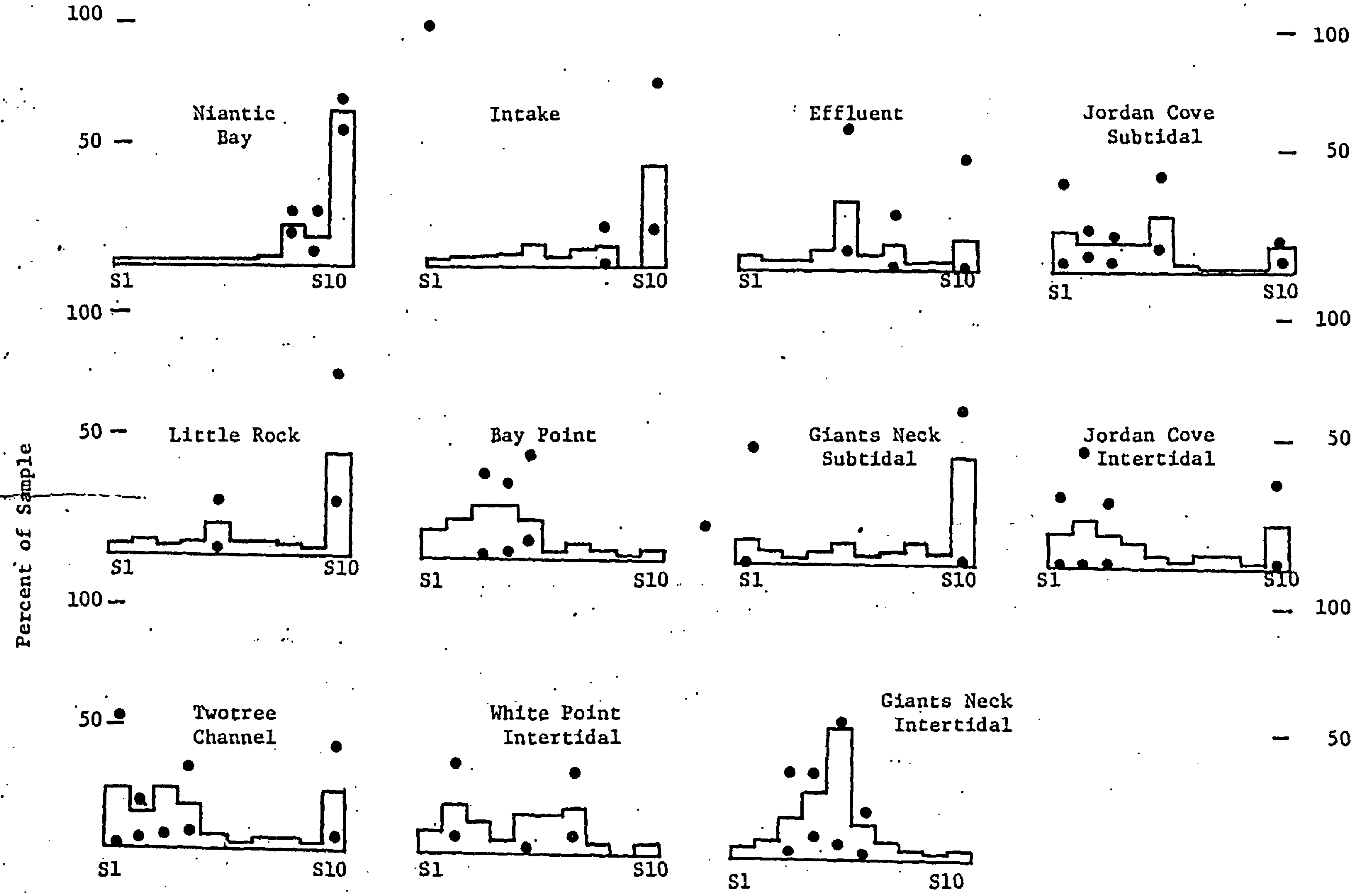


FIGURE 4.5-4. SAND GRAIN SIZE FREQUENCY DISTRIBUTION BY STATION (BASED ON POOLED DATA '73-'75)

● = Range

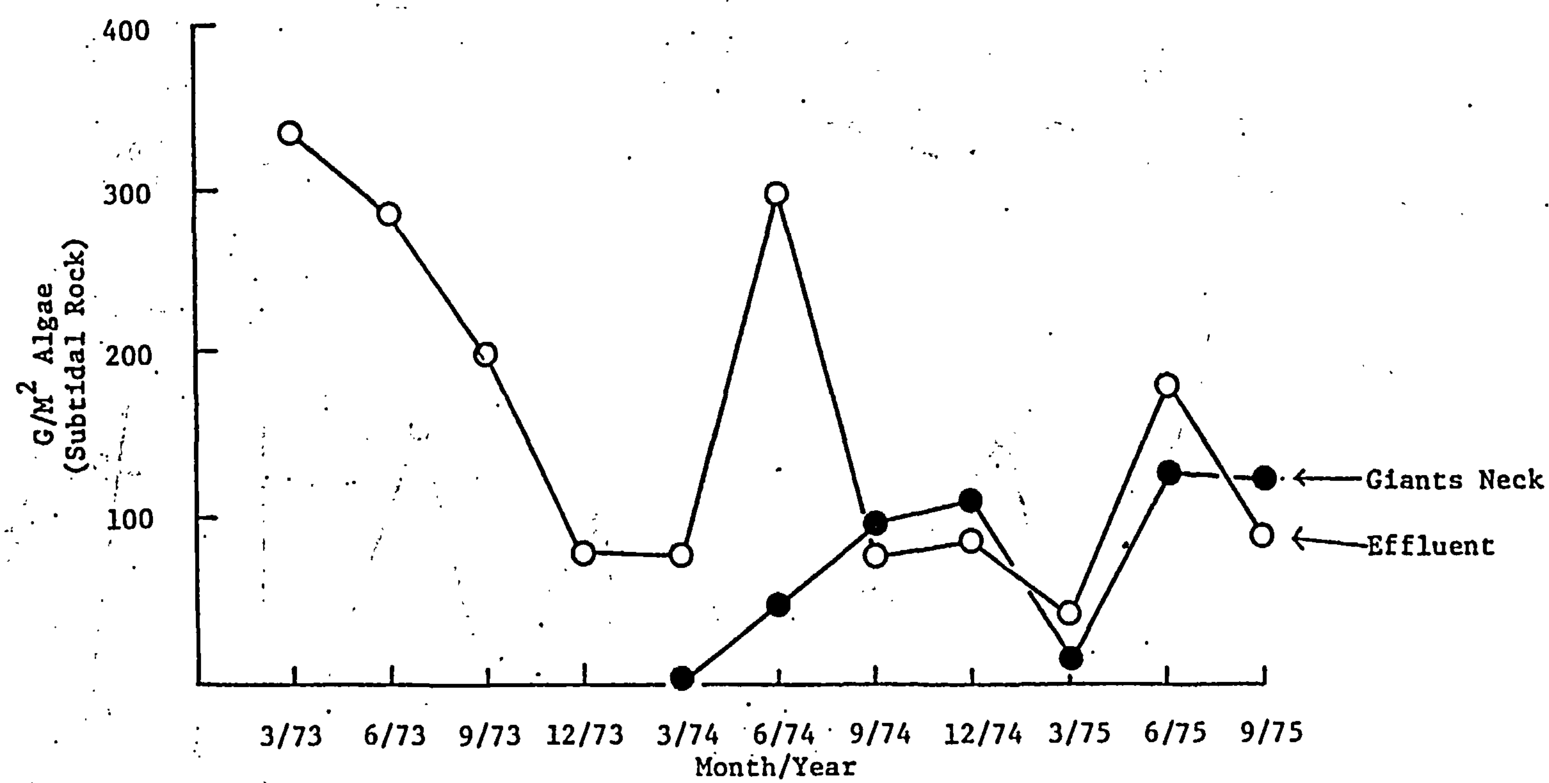


FIGURE 4.5-5. ALGAL STANDING CROPS AT SUBTIDAL ROCK STATIONS

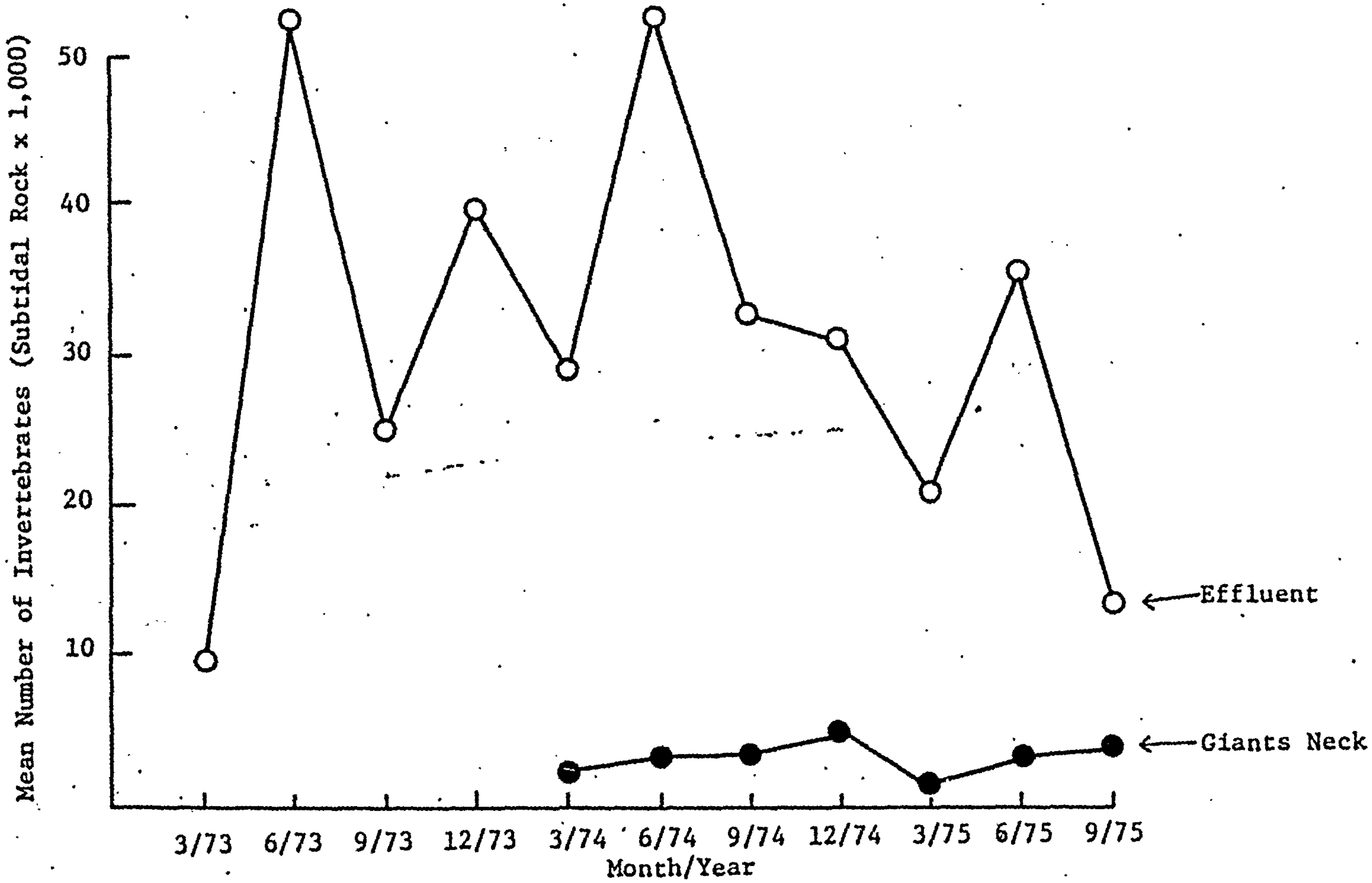


FIGURE 4.5-6. INVERTEBRATE STANDING CROPS AT SUBTIDAL ROCK STATIONS

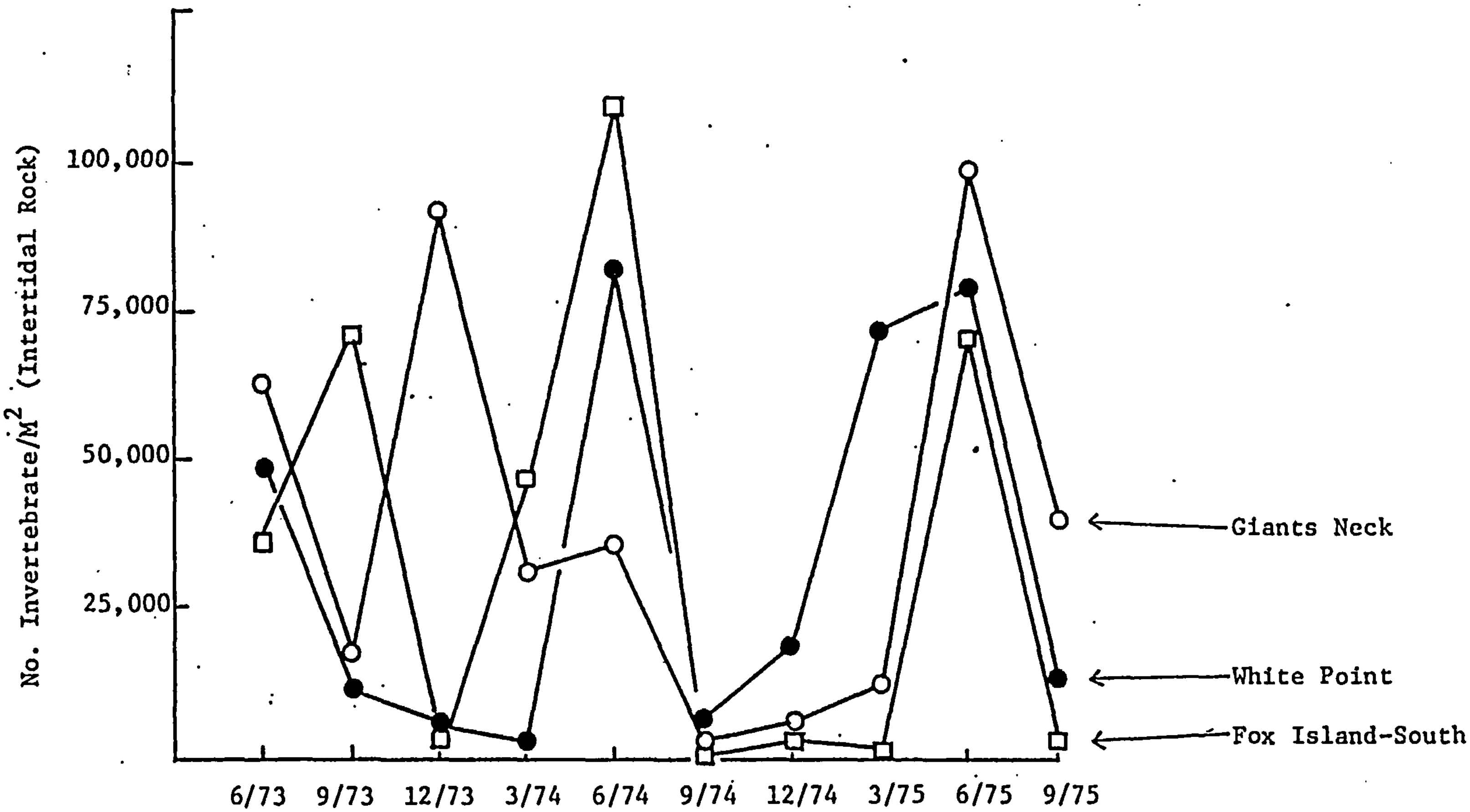


FIGURE 4.5-7. INVERTEBRATE STANDING CROPS AT INTERTIDAL ROCK STATIONS

TABLE 4.6-1. MEAN CARAPACE LENGTHS (MILLIMETERS) FOR ALL LOBSTERS CAPTURED FROM HABITATS

Month	Year 1974	1975
January		65.2
February		67.8
March		65.2
April	68.1	63.7
May	62.7	66.0
June	70.2	61.6
July	63.8	61.8
August	66.1	63.3
September	67.5	67.2
October	65.8	65.1
November	59.8	64.4
December	60.6	62.5

TABLE 4.6-2 . ESTIMATES OF LOBSTER POPULATIONS (JOLLY METHOD) IN THE MILLSTONE POINT AREA FROM OCTOBER, 1973, AND APRIL, 1974, THROUGH JUNE, 1975

Date	Proportion Marked Alpha	Total Marked M	Total Number N	Survival Probability PHI	Number Joining B	Standard Error N	Standard Error PHI-R	Standard Error B	Component SE(N)	Component SE(PHI)-R
Oct., 1973		0.00		.3151						
May, 1974	.0309	16.07	519.64	1.3185	208.74	356.04	.5986	540.13	355.88	.6033
June, 1974	.1154	97.67	846.44	.8059	1831.14	492.17	.3924	1223.15	492.14	.3910
July, 1974	.0455	114.17	2511.67	.8100	1714.11	1355.50	.3331	1935.15	1355.45	.3321
Aug., 1974	.0490	183.20	3737.28	.7371	-545.86	2105.37	.3581	1563.27	2105.25	.3571
Sept., 1974	.0926	204.33	2206.80	1.1952	619.10	1313.29	.6885	1709.93	1312.91	.6892
Oct., 1974	.0923	300.40	3254.33	1.7773	-49.29	1963.22	1.4527	3040.12	1962.99	1.4540
Nov., 1974	.1111	637.00	5733.00	.6072	3104.76	4598.33	.5198	3173.53	4598.51	.5194
Dec., 1974	.0636	419.00	6584.29	.3754	1148.95	4277.05	.2246	1674.68	4276.97	.2236
Jan., 1975	.0534	193.33	3618.10	.6311	1001.46	1958.23	.3197	1868.32	1957.81	.3165
Feb., 1975	.0606	199.00	3283.50	.9577	-1262.29	2137.93	.5976	1775.14	2137.58	.5975
March, 1975	.1324	249.00	1881.33	4.1151	26051.53	1143.05	4.5572	32859.90	1142.39	4.5618
April, 1975	.0370	1251.00	33777.00	.4472	-10096.50	39449.35	.6334	13643.90	39449.33	.6333
May, 1975	.1184	593.00	5007.56			5423.38			5422.59	
June, 1975	.0968									

TABLE 4.6-3. ESTIMATES OF LOBSTER POPULATIONS (JOLLY METHOD) IN THE MILLSTONE POINT AREA, SEPTEMBER, 1975, THROUGH MAY, 1976

I	Proportion Marked Alpha	Total Marked M	Total Number N	Survival Probability PHI	Number Joining B
Sep 1975	.	0.00		.7499	
Oct	.0178	137.97	7764.19	.3320	760.80
Nov	.0742	247.67	3338.55	1.0388	12675.70
Dec	.0358	578.24	16140.53	.3650	255.76
Jan 1976	.0711	437.00	6147.13	1.6696	5307.77
Feb	.0679	1056.86	15571.03	1.2611	-2021.57
Mar	.0904	1592.55	17614.52	.4258	1296.98
Apr	.0932	819.45	8797.09		
May	.1383				

	SE(N)	SE(PHI) -R	SE(B)	Component SE(N)	Component SE(PHI) -R
Oct 1975	3487.32	.0826	1221.86	3487.11	.0808
Nov	94.02	.2576	4384.87	993.07	.2577
Dec	4866.23	.0882	2043.60	4866.03	.0871
Jan 1976	1992.71	.5272	4875.31	1991.70	.5289
Feb	5827.96	.5304	5759.52	5827.59	.5037
Mar	6383.65	.1857	1976.17	6383.52	.1854
Apr	3334.85			3334.16	

TABLE 4.6-4. IMMINENT MOLT AND INTERMOLT STAGE LOBSTERS CAPTURED IN THE MILLSTONE POINT AREA FROM APRIL, 1974, THROUGH DECEMBER, 1975

Month	Year			
	1974		1975	
	Imminent Molt	Intermolt	Imminent Molt	Intermolt
January			8	163
February			3	65
March			1	69
April	7	30	9	95
May	23	73	6	77
June	75	160	45	126
July	21	147	28	112
August	8	108	5	57
September	10	65	7	49
October	31	70	6	32
November	20	89	20	66
December	19	141	0	67

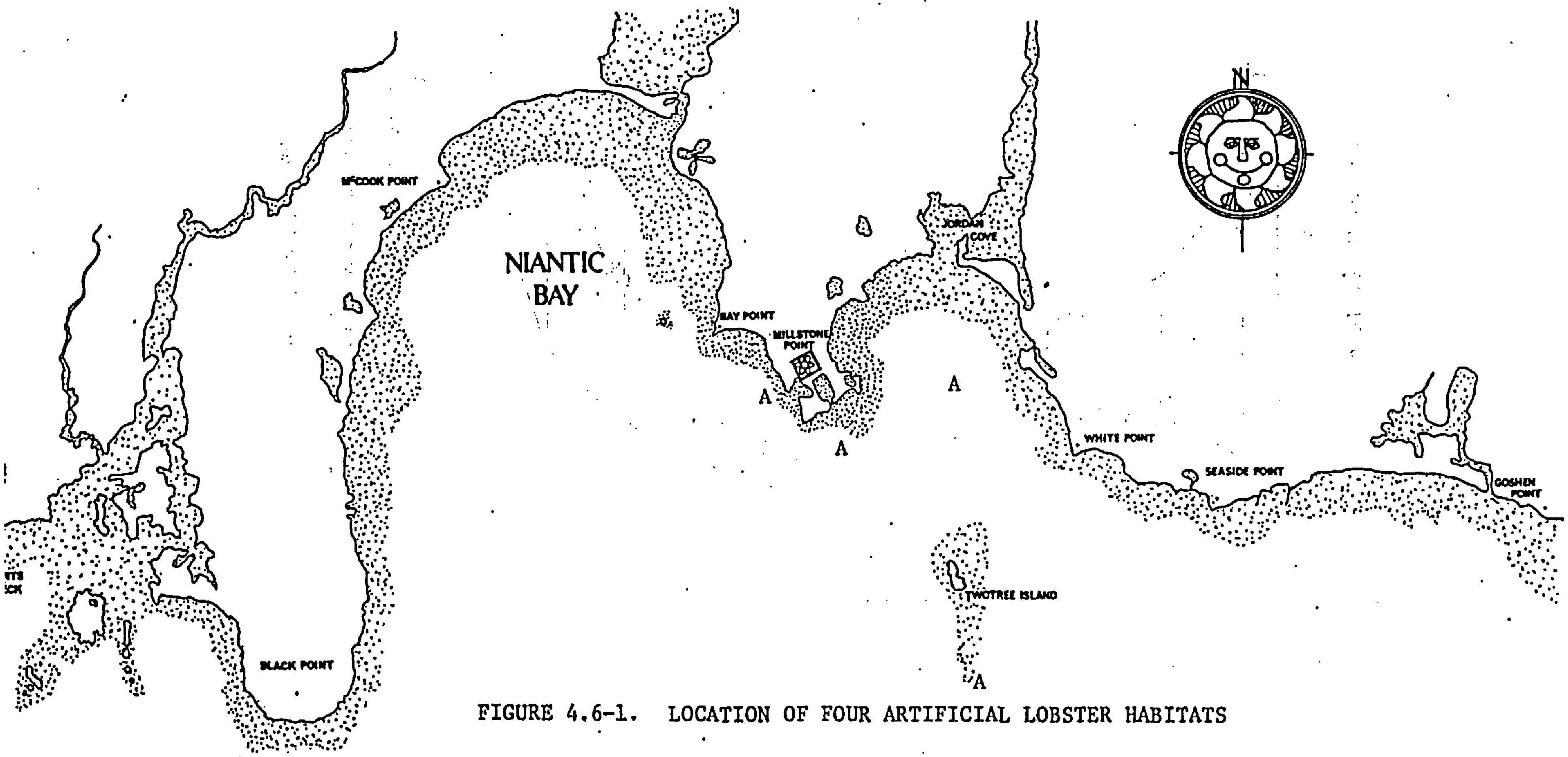


FIGURE 4.6-1. LOCATION OF FOUR ARTIFICIAL LOBSTER HABITATS

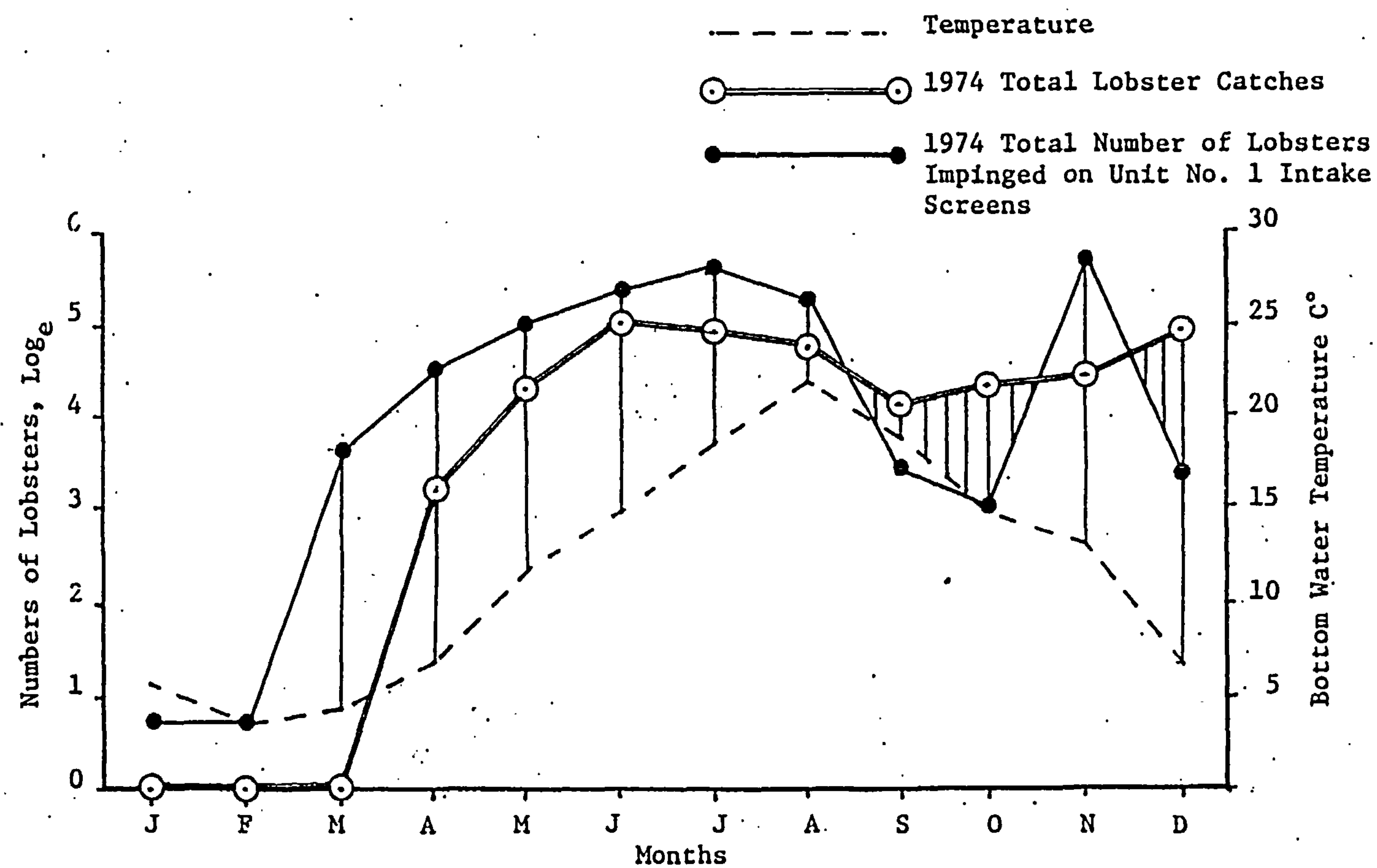


FIGURE 4.6-2. COMPARISON OF WATER TEMPERATURE TO TOTAL LOBSTER CATCHES AND IMPINGED LOBSTERS FOR 1974.

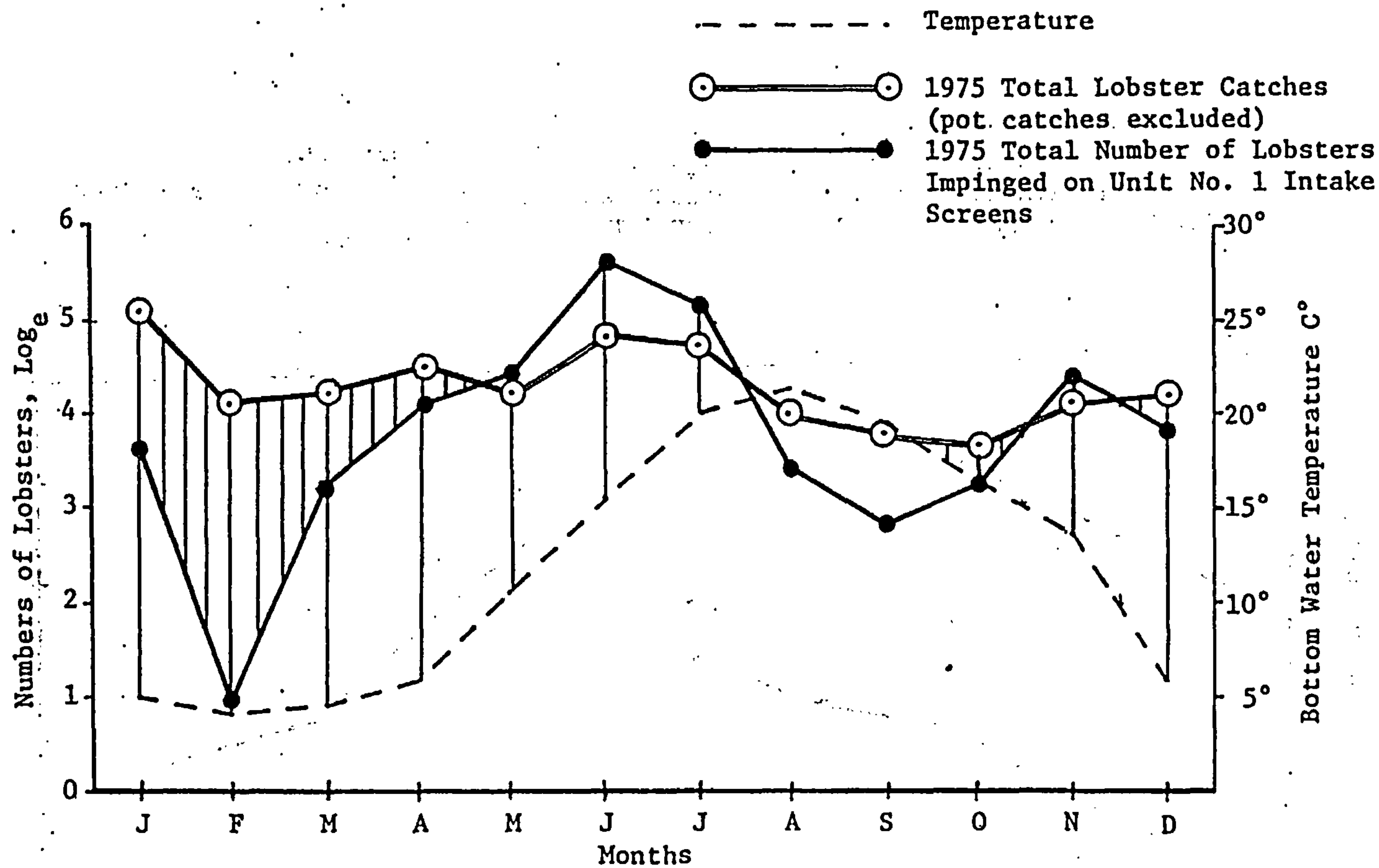


FIGURE 4.6-3. COMPARISON OF WATER TEMPERATURE TO TOTAL LOBSTER CATCHES AND IMPINGED LOBSTERS FOR 1975 (POT CATCHES EXCLUDED).

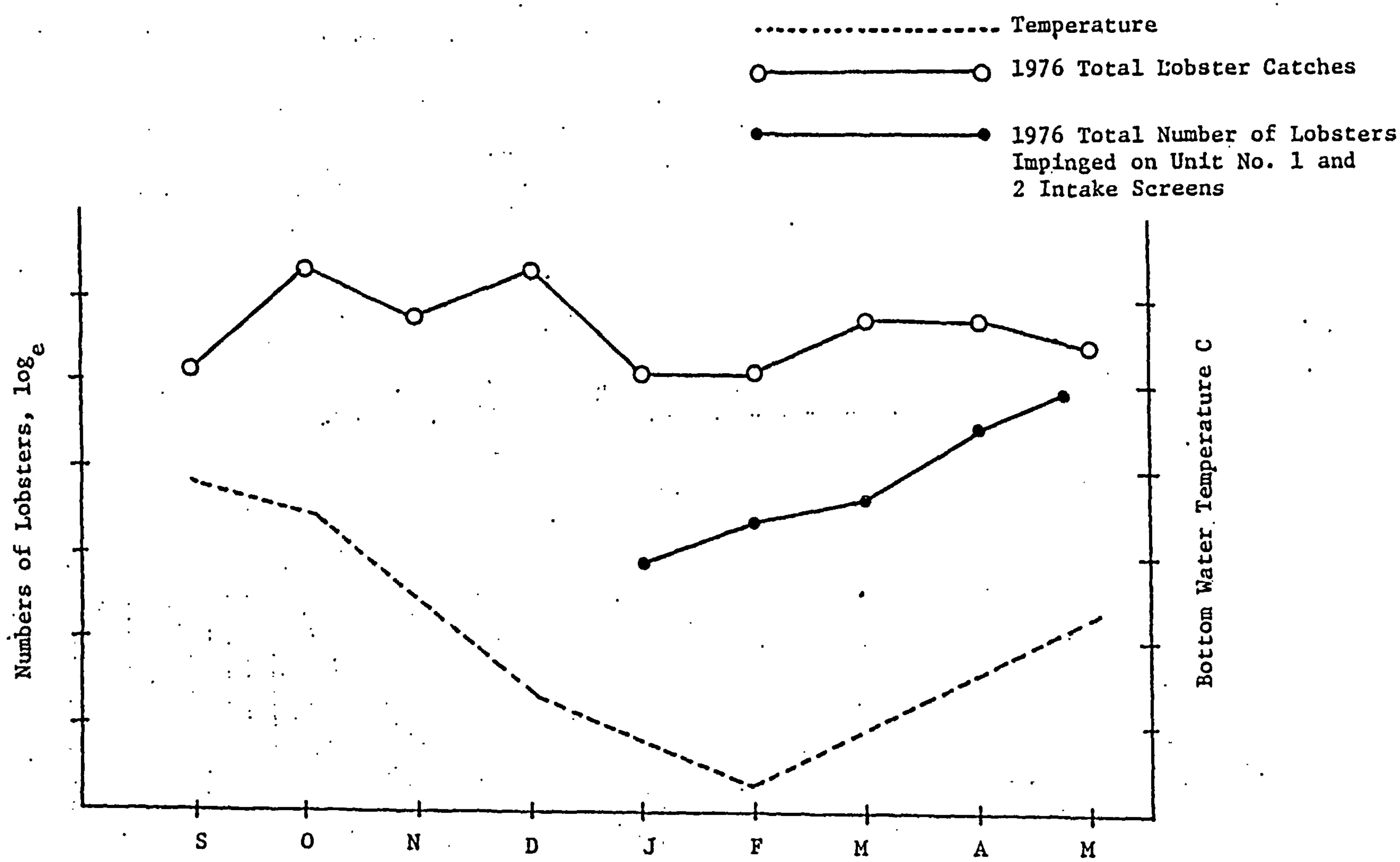


FIGURE 4.6-4. COMPARISON OF WATER TEMPERATURE TO TOTAL LOBSTER CATCHES AND IMPINGED LOBSTERS FOR SEPTEMBER, 1975, THROUGH MAY, 1976

TABLE 4.7-1 TOTAL CHLOROPHYLL (mg/m^3) OBSERVED OFF MILLSTONE POINT FROM MAY 1969 THROUGH OCTOBER 1970

DATE		FLOOD							EBB						
	Depth	1*	2	3	4	5	6	$\overline{X}$	7	8	9	10	11	12	$\overline{X}$
May 1969	S	1.3	0.8	1.9	1.1	1.5	-	1.3	0.8	1.0	0.9	0.8	1.6	1.0	1.0
	M	1.0	1.1	1.0	2.6	0.9	-	1.3	2.5	1.6	2.0	1.6	1.5	0.7	1.6
August 1969	S	7.4	8.2	9.8	6.5	6.6	5.2	7.2	8.9	8.2	9.2	8.0	7.9	8.0	8.3
	M	6.6	7.5	9.8	9.7	6.3	5.5	6.9	7.0	6.7	7.8	6.8	7.8	7.6	7.3
November 1969	S	4.1	5.0	4.5	4.7	5.2	4.7	4.7	3.8	4.0	4.8	4.2	4.9	4.5	4.4
	M	4.1	6.1	5.2	5.1	5.5	4.1	5.0	4.1	4.1	5.7	4.1	3.8	5.7	4.6
February 1970	S	3.2	2.2	2.2	2.4	2.2	2.1	2.4	2.5	2.8	2.6	3.0	2.6	2.2	2.6
	M	2.3	2.4	1.9	2.2	2.2	2.1	2.2	2.5	2.8	3.0	2.8	2.8	2.7	2.8
May 1970	S	1.0	1.5	1.1	0.8	1.6	1.2	1.2	1.3	1.1	1.2	1.2	1.2	1.3	1.2
	M	1.6	0.8	1.1	1.2	1.2	1.4	1.3	1.0	1.2	1.4	1.2	1.2	1.1	1.2
August 1970	S	4.2	5.1	5.1	4.2	5.0	5.0	4.8	3.8	3.9	7.1	4.4	2.2	2.2	3.9
	M	6.5	5.1	5.1	5.4	8.1	7.1	6.2	4.0	2.8	4.7	2.9	2.5	3.7	3.4
October 1970	S	1.9	2.1	2.2	2.7	2.0	2.7	2.3	2.6	1.3	1.7	1.6	1.4	1.6	1.5
	M	2.4	2.7	2.8	2.2	2.8	2.2	2.5	2.1	2.1	2.1	1.6	1.8	1.7	1.9

*Numbers indicate relative locations along the drogue lines.

TABLE 4.7-2 CHLOROPHYLL CONCENTRATIONS IN mg/m^3 AT STATIONS SAMPLED AROUND MILLSTONE POINT, MARCH-JUNE 1972

		STATIONS						
		E	C	D	A	B	F	G
March 16, 1972 (100%)*		.89	.80	.69	.42	.85	1.07	.19
		1.16	.85	.77	.62	.96	.75	.81
		.89	.89	.96	.66	1.00	.50	.89
		1.23	.58	.66	.77	.77	1.07	.89
		1.04	.77	1.00	.77	.90	.58	1.19
	X̄	1.04	.78	.82	.65	.90	.79	.79
April 7, 1972 (100%)		1.43	2.27	.81	1.35	1.35	1.12	1.15
		1.19	1.50	.96	1.15	1.27	1.43	.85
		1.12	1.15	.85	1.46	1.12	1.43	1.04
		1.43	1.58	.81	2.35	1.19	1.19	.62
		1.27	1.93	.81	1.15	1.12	1.30	1.23
	X̄	1.29	1.69	.85	1.49	1.21	1.29	.98
May 25, 1972 (100%)		.46	.46	.39	.42	.62	.42	.54
		.58	.54	.58	.58	.69	.54	.62
		.66	.23	.39	.15	.66	.39	.73
		.39	.66	.73	.54	.50	.42	.66
		.35	.69	.60	.39	.59	.40	.69
	X̄	.49	.52	.54	.42	.61	.43	.65
June 8, 1972 (97%)		1.12	1.31	1.35	.81	1.46	.58	1.08
		1.08	1.96	1.77	1.43	1.08	.92	1.35
		.77	1.16	1.46	1.35	1.43	1.31	1.16
		.89	1.73	1.73	1.23	1.19	1.50	1.31
		.81	1.08	2.89	1.81	1.66	1.23	1.62
	X̄	.93	1.45	1.84	1.33	1.36	1.11	1.30
June 29, 1972 (70%)		.27	.66	.42	.69	.54	.92	1.35
		.23	.62	.81	1.39	.73	.54	.38
		.62	.39	.38	.69	.66	.92	.58
		.15	.39	.62	.73	.81	.81	1.12
		.54	.46	.58	.89	.23	.77	.50
	X̄	.36	.50	.56	.88	.59	.79	.79

*Electric Power Generation Level, Millstone Unit 1.

TABLE 4.7-3. MEAN CHLOROPHYLL-a DETERMINATIONS (Mg/M^3) FOR 1975

		Station 5		8		10		11	
		$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ
Mar, 1975	S	2.29	1.34	2.49	0.47	2.42	0.44	3.19	1.38
	B	4.35	0.66	3.37	1.18	3.90	0.95	3.23	1.08
Jun, 1975	S	2.52	1.05	3.29	0.55	2.17	0.45	1.95	0.59
	B	2.03	0.51	2.24	0.64	1.72	0.25	1.68	0.26
Sep, 1975	S	1.96	0.53	1.99	1.05	2.04	0.43	1.39	0.42
	B	2.31	0.41	1.90	0.38	2.16	0.69	1.83	0.59
Jan, 1976	S	1.52	0.50	1.84	0.46	2.20	0.61	1.90	0.51
	B	2.17	0.29	2.20	0.36	2.19	0.36	2.23	0.60

$\bar{X}$ = Mean chlorophyll-a determination, n=7
σ = Standard deviation
S = Surface water samples
B = Bottom water samples

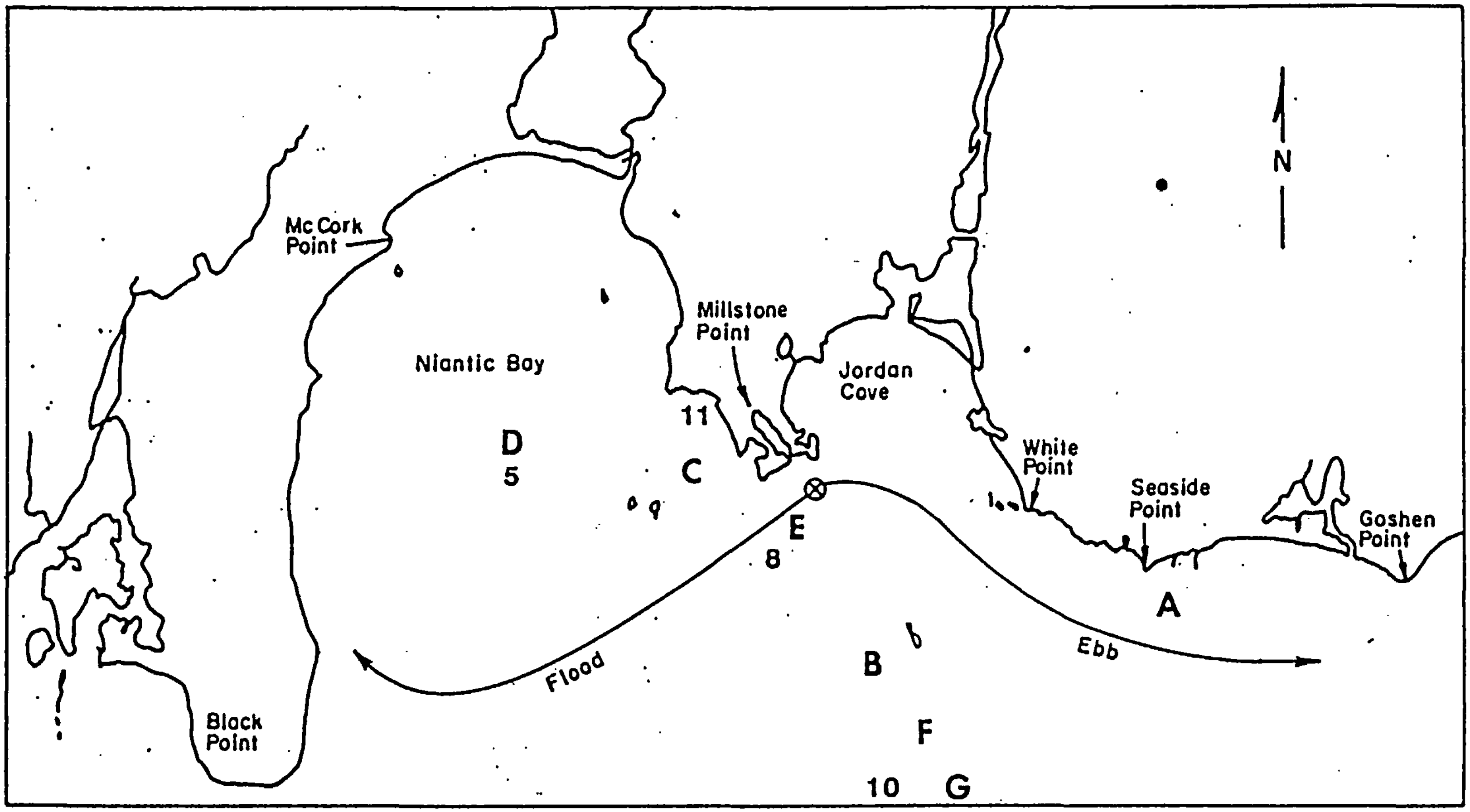


FIGURE 4.7-1 SCHEMATIC REPRESENTATION OF THE GENERAL DIRECTION OF PLANKTON TOWS OFF MILLSTONE POINT, M[illegible] 1969--OCTOBER 1970 AND THE LOCATION OF SAMPLING STATIO[illegible] N 1972 (LETTERED A-G) AND IN [illegible]

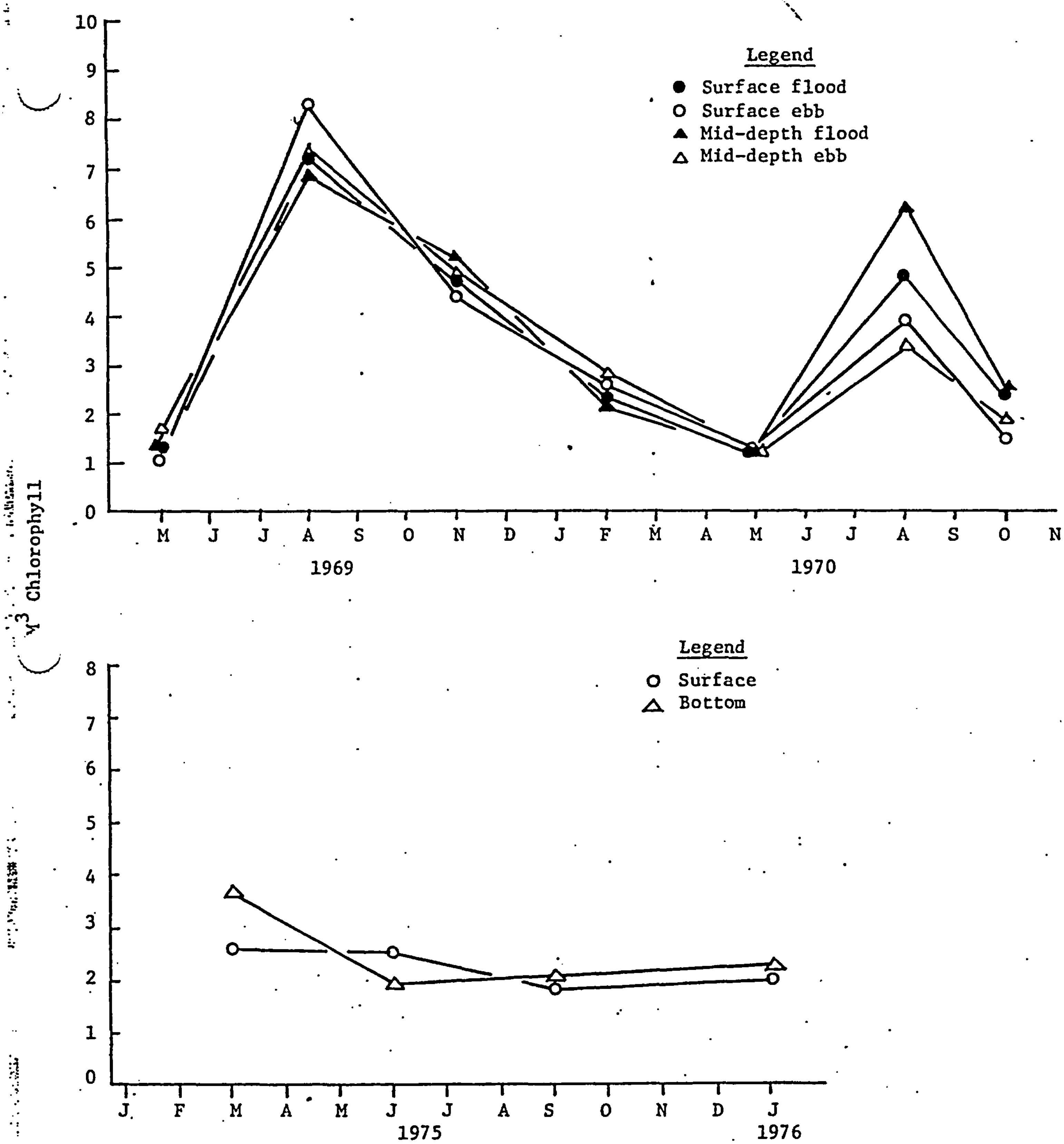


FIGURE 4.7-2 COMPARISON OF MEAN TOTAL CHLOROPHYLL (1969-1970) AND MEAN CHLOROPHYLL-a (1975) LEVELS AS RECORDED IN THE MILLSTONE POINT AREA

TABLE 4.8-1. PHYLOGENETIC LIST OF ZOOPLANKTON COLLECTED IN THE MILLSTONE POINT AREA FROM MAY, 1973, THROUGH MAY, 1975

Phylum: Protozoa
  Class: Ciliophora
    Order: Spirotricha
      Family: Tintinnidae

Phylum: Cnidaria
  Class: Hydrozoa
        Medusoids
        Polyps

Phylum: Aschelminthes
  Class: Nematoda
  Class: Rotifera

Phylum: Chaetognatha

Phylum: Mollusca
  Class: Gastropoda
        Gastropod larvae
        Gastropod eggs
  Class: Bivalvia
    Subclass: Pteriomorphia
    Order: Pteroconchida
      Family: Mytilidae
        Mytilus edulis
        Modiolus demissus
      Family: Ostreidae
        Crassostrea virginica
    Subclass: Tetodesmata
    Order: Heterodontida
      Family: Vereridae
        Mercenaria mercenaria
      Family: Myidae
        Mya arenaria

Phylum: Annelida
  Class: Polychaeta

Phylum: Arthropoda
  Class: Crustacea
    Subclass: Branchipoda
    Order: Cladocera
      Podon sp.
      Evadne sp.
      Penilia avirostra
    Subclass: Ostracoda
    Subclass: Copepoda

TABLE 4.8-1. (continued)

Order: Calanoida
Family: Calanoidae
Calanus finmarchicus
Calanus helgolandicus
Metridia lucens
Family: Paracalanidae
Paracalanus sp.
Paracalanus parvus
Family: Pseudocalenidae
Pseudocalanus elongatus (minutis)
Family: Centropagidae
Centropages typicus
Centropages hamatus
Family: Diaptomidae
Diaptomus sp.
Family: Pseudodiaptomidae
Pseudodiaptomus sp.
Family: Temoridae
Temora longicornis
Eurytemora affinis
Eurytemora sp.
Eurytemora herdmani
Family: Pontellidae
Labidocera acutifrons
Labidocera aestiva
Family: Acartiidae
Acartia tonsa
Acartia clausi
Family: Tortanidae
Tortanus sp.
Tortanus discaudatus
Order: Harpacticoida
Family: Harpacticidae
Harpacticus gracilis
Harpacticus sp.
Alteutha sp.
Order: Cyclopoida
Family: Oithonidae
Oithona sp.
Copepod nauplii
Immature copepods
Subclass: Cirripedia
Cirripedia nauplii
Cirripedia cypris
Cirripedia sp.
Subclass: Malacostraca
Malacostraca nauplii
Malacostraca immature

TABLE 4.8-1. (continued)

Superorder: Eucarida		
Order:	Decapoda	
	Decapod larvae	
Order:	Cumacea	
	Cumaceans	
Order:	Mysidacea	
	Mysids	
Order:	Amphipoda	
	Gammaridea	
	Caprella sp.	
Phylum: Bryozoa		
	Cyphnaute larvae	
Phylum: Echinodermata		
	Echinoderm larvae	
Phylum: Chordata		
Class: Thaliacea		
	Tunicates	
Class: Larvacea		

Reference: Kenneth L. Gosner - Guide to Identification of Marine and Estuarine Invertebrates - Cape Hatteras to the Bay of Fundy (1971), John Wiley & Sons, Inc.

TABLE 4.8-2. MEAN NUMBER OF *Acartia tonsa* PER 10 CUBIC METERS AT STATIONS IN THE MILLSTONE POINT AREA EACH MONTH FROM MAY, 1973, THROUGH DECEMBER, 1975

E = Sampled on ebb tide; F = Sampled on flood tide

		Stations																		
	Month	1	2	3E	3F	4	5	6	7E	7F	8	9E	9F	10	11 (a)	12 (a)	13 (a)	14	15	16
1973	May	0	226	(b)	0	12	7	0	0	0	10	0	(b)	0						
	Jun	14	151	90	338	39	102	50	166	83	341	129	180	105						
	Jul	12,328	1,235	800	673	1,333	2,103	1,294	1,744	2,803	865	3,570	2,340	2,117						
	Aug	12,688	6,673	3,699	3,171	10,463	14,340	10,804	14,652	14,652	25,685	10,751	12,829	10,298						
	Sep	23,004	6,300	4,161	7,351	13,486	14,722	15,949	11,219	24,144	20,770	35,738	23,339	20,014						
	Oct	31,371	584	193	464	534	803	1,575	3,410	620	4,058	3,334	3,412	4,262						
	Nov	29	61	72	100	301	3,106	(b)	89	14	50	5,047	2,843	1,842						
	Dec	1,235	568	3,427	9,025	41,189	5,910	6,539	6,535	(b)	10,605	18,834	5,478	435						
1974	Jan	No Sample in January, 1974																		
	Feb	123	22	28	65	30	66	42	17	40	41	37	113	55	28	32	28			
	Mar	0	0	6	7	23	31	5	13	13	23	4	4	5	0	34	12			
	Apr	0	0	0	0	1	4	2	0	6	0	0	0	0	0	0	11			
	May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	Jun	0	59	0	0	0	0	0	19	0	15	0	0	0	0	0	0			
	Jul	54,608	9,129	144	113	15	172	74	0	65	37	148	73	77	58	0	166			
	Aug	85,834	2,334	1,008	(b)	634	479	1,222	888	304	668	(b)	2,664	1,058	705	215	1,515			
	Sep	41,330	42,011	36,884	70,151	43,325	40,749	31,715	33,712	46,380	60,164	36,133	37,937	9,710	20,724	34,071	49,837			
	Oct	32,823	2,694	26	1,846	6,004	7,703	328	4,908	6,010	10,310	11,620	26,442	3,729	1,618	8,302	3,220	41,214		
	Nov	6,398	2,024	1,106	1,076	3,169	2,488	8,739	9,240	5,528	25,898	2,147	9,835	9,262	13,111	7,777	9,778	6,645		
	Dec	802	667	232	542	695	1,714	1,228	543	675	915	1,160	853	1,025	1,150	1,859	1,638	997		
1975	Jan		152	106	176	138	79	76	92	177	161		149	47	237	64	108	176		
	Feb		0			0	38	44	38	10	9	0				27	15	56	22	47
	Mar	0	0	5	0	0	16	0	4	29	29	0	0	0	12	5	0	23	35	0
	Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jun	249	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	91
	Jul	28,932	24,819		6,571				915	7,205	4,353	3,031	4,468	12,282		1,965	3,233	2,224	13,857	4,553
	Aug	98,541	42,268	15,493	27,565	11,453	33,385	21,790	41,260	21,281	23,030	35,815	6,497	26,406	53,328	21,879	10,963	1,760	35,797	41,323
	Sep	135,005	35,977	15,889	54,713	14,697	61,064	60,314	54,306	63,047	55,246	63,136	480,040	41,317	49,341	56,636	57,686	93,260	40,288	36,066
	Oct	44,068	172	443		19,376	10,711	14,387	20,052	14,756	20,435	29,211	35,035	380	15,652	10,986	158	40,650	3,956	6,092
	Nov	870	988	858	1,063	3,228		1,426	2,179	1,551	3,604	3,596	4,497	1,469	2,518	118	922	3,528	3,773	2,795
	Dec	552	577	266	277	546	736	467	861	946	504		785	473	1,258	1,399	920	732	527	546

(a) Not sampled until February, 1974.
(b) No sample.

TABLE 4.8-3. MEAN NUMBER OF *Acartia clausii* PER 10 CUBIC METERS AT STATIONS IN THE MILLSTONE POINT AREA EACH MONTH FROM MAY, 1973, THROUGH DECEMBER, 1975

E = Sampled on ebb tide; F = Sampled on flood tide

		Stations																		
	Month	1	2	3E	3F	4	5	6	7E	7F	8	9E	9F	10	11[a]	12[a]	13[a]	14	15	16
1973	May	12,755	22,487	(b)	4,202	2,273	2,389	2,144	210	5,974	2,058	1,595	(b)	1,146						
	Jun	4,624	8,887	3,445	5,032	1,942	2,858	925	1,221	671	6,933	1,076	2,068	1,974						
	Jul	2,678	2,162	1,022	744	1,072	368	231	455	513	(a)	417	529	459						
	Aug	18	37	6	5	0	0	12	0	0	0	22	0	0						
	Sep	0	0	0	0	0	0	0	0	0	0	0	0	0						
	Oct	0	0	0	0	0	0	0	0	0	0	0	0	0						
	Nov	0	7	2	0	0	0	(b)	0	0	0	0	0	0						
	Dec	4,835	1,355	6,631	9,797	1,646	517	4,203	2,943	(b)	1,813	3,217	3,404	692						
1974	Jan	Not Sampled in January, 1974																		
	Feb	28,893	9,099	3,283	916	2,010	347	736	304	316	275	298	419	224	1,763	262	1,548			
	Mar	123,854	11,919	3,631	2,998	5,856	895	794	392	1,123	730	684	960	668	1,212	2,192	4,448			
	Apr	190,760	38,121	14,330	8,265	6,079	2,976	1,862	2,640	1,402	6,170	700	8,556	2,368	6,471	6,098	3,735			
	May	101,886	34,574	15,107	7,824	14,686	5,663	5,928	3,627	4,279	2,602	3,486	2,361	1,416	4,675	7,085	7,509			
	Jun	22,778	17,305	10,351	5,961	7,859	10,295	10,717	3,396	4,592	3,884	6,905	6,529	2,233	8,086	8,322	16,078			
	Jul	4,810	9,457	5,281	3,562	5,065	4,792	5,518	777	717	1,964	2,497	4,125	8,577	1,588	4,974	4,980			
	Aug	0	0	0	(b)	0	0	0	0	0	0	(b)	0	0	0	0	0			
	Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	Oct	358	91	0	0	19	0	0	0	0	11	117	0	0	0	0	1,144	0		
	Nov	3,483	753	50	60	293	0	187	59	72	373	11	2	2,051	283	148	217	69		
	Dec	46,239	1,856	631	1,649	624	282	375	39	149	135	365	92	123	480	404	614	153		
1975	Jan		12,547	10,105	1,781	617	477	754	668	729	437		537	80	4,851	798	955	1,130		
	Feb		17,171			1,743	1,917	2,297	1,901	1,007	1,817	399				1,635	2,262	534	1,091	3,671
	Mar	37,337	10,496	1,304	2,005	4,928	2,921	2,693	1,524	2,838	2,245	1,433	1,206	1,823	4,493	1,026	1,436	1,972	4,591	2,429
	Apr	130,931	21,166	30,774	29,283	11,727	1,695	2,227	439	2,253	4,635	951	1,206	698	6,792	2,181	2,330	970	12,717	1,795
	May	66,259	21,444	4,507	10,835	19,353	1,953	868	615	5	1,581	758	599	0	2,003	2,341	1,147	1,883	24,865	716
	Jun	20,075	1,950	5,713	2,175	4,139	1,728	1,656	1,586	1,483	1,223	460	1,836	302	571	2,132	1,668	1,080	2,087	500
	Jul	0	0		0				0	0	0	0	0	0		0	0	0	0	0
	Aug	0	0	162	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
	Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Oct	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0
	Dec	365	165	2	534	2	0	0	14	35	2		5	0	37	0	8	0	2	7

(a) Not sampled until February, 1974

(b) No sample

TABLE 4.8-4. MEAN NUMBER OF *Temora longicornis* PER 10 CUBIC METERS AT STATIONS IN THE MILLSTONE POINT AREA EACH MONTH FROM MAY, 1973, THROUGH DECEMBER, 1975

E = Sampled on ebb tide; F = Sampled on flood tide

	Month	Stations 1	2	3E	3F	4	5	6	7E	7F	8	9E	9F	10	11(a)	12(a)	13(a)	14	15	16
1973	May	147	10,078	(b)	4,413	7,218	11,292	15,396	16,203	16,957	7,619	25,388	(b)	18,077						
	Jun	49	391	138	181	1,052	1,382	974	1,342	1,323	2,241	1,186	1,129	1,211						
	Jul	30	69	27	61	145	241	109	475	126	545	224	459	274						
	Aug	0	0	5	<1	13	6	5	0	2	11	10	21	9						
	Sep	0	0	7	7	50	20	3	49	24	38	22	18	56						
	Oct	0	0	0	0	<1	3	4	6	0	0	15	0	4						
	Nov	0	0	0	0	0	0	(b)	0	0	0	0	0	0						
	Dec	8	0	19	77	33	37	0	0	(b)	98	192	78	9						
1974	Jan	No Sample in January, 1974																		
	Feb	35	133	30	26	62	47	24	56	56	90	63	162	74	86	44	60			
	Mar	28	45	0	57	143	171	140	225	119	258	275	177	329	54	282	85			
	Apr	0	446	1,582	816	317	2,658	438	1,911	1,670	1,109	900	2,307	3,909	725	1,549	1,035			
	May	187	4,222	4,444	5,943	9,151	10,913	6,790	14,288	14,317	13,700	26,151	15,158	23,992	2,186	9,383	4,886			
	Jun	0	5,439	3,253	5,406	1,526	9,532	3,095	11,003	6,401	12,221	23,926	15,806	13,265	8,520	6,392	9,278			
	Jul	447	1,146	1,904	3,286	7,633	10,707	4,537	7,771	17,041	4,425	46,867	25,600	12,866	4,805	10,986	8,798			
	Aug	0	0	0	(b)	0	2	20	12	10	20	(b)	0	2	3	3	20			
	Sep	0	0	0	0	0	0	18	0	0	0	82	0	0	0	0	0			
	Oct	1	0	0	0	0	0	0	60	8	3,570	4	0	44	11	0	376	516		
	Nov	0	2	5	9	3	27	107	102	169	136	159	221	426	20	18	0	231		
	Dec	34	51	14	20	31	51	35	34	89	88	203	541	112	30	104	32	266		
1975	Jan		76	35	55	118	139	73	185	607	277		1,293	554	56	781	285	380		
	Feb		57			172	1,006	436	918	449	704	8,604				962	395	7,623	0	306
	Mar	0	571	11	479	1,035	1,750	320	4,026	2,379	991	3,568	9,504	3,177	17	954	6,905	2,146	1,206	563
	Apr	0	2,177	1,045	4,071	10,808	6,270	4,088	16,099	12,691	13,830	12,819	9,361	28,488	1,591	8,586	3,691	12,447	2,800	4,505
	May	0	262	999	1,090	4,980	8,237	2,356	11,852	1,112	17,553	15,497	9,283	17,807	6,255	7,932	2,992	10,887	890	1,161
	Jun	435	233	543	1,438	5,067	15,325	3,424	18,603	12,056	13,603	37,419	37,789	46,943	1,888	15,909	14,612	79,507	1,324	7,313
	Jul	0	0		50				3	19	183	9	0	95		42	4	9	57	9
	Aug	0	0	0	1	26	0	6	2	124	13	103	32	28	0	77	0	19	0	0
	Sep	0	0	0	0	0	49	0	125	97	3	57	0	25	0	0	216	193	0	46
	Oct	0	0	0	0	0	34	0	131	0	0	0	0	0	0	0	8	0	0	0
	Nov	0	0	0	0	0		0	0	0	0	12	0	0	0	0	0	5	0	0
	Dec	3	0	0	0	0	0	0	0	5	11		17	12	0	0	12	1	4	0

(a) Not sampled until February, 1974.
(b) No sample.

TABLE 4.8-5. MEAN NUMBER OF *Pseudocalanus elongatus* PER 10 CUBIC METERS AT STATIONS IN THE MILLSTONE POINT AREA EACH MONTH FROM MAY, 1973, THROUGH DECEMBER, 1975

E = Sampled on ebb tide; F = Sampled on flood tide

		Stations																		
	Month	1	2	3E	3F	4	5	6	7E	7F	8	9E	9F	10	11(a)	12(a)	13(a)	14	15	16
1973	May	0	7,521	(b)	3,942	598	3,843	5,379	6,492	6,166	1,421	7,975	(b)	10,758						
	Jun	152	827	354	544	1,235	1,584	979	2,237	1,495	3,301	1,713	2,416	1,955						
	Jul	178	436	137	435	829	1,169	879	3,505	1,008	3,268	2,451	2,696	3,189						
	Aug	0	0	15	32	37	14	29	32	68	46	61	55	72						
	Sep	0	0	7	37	28	16	10	36	32	16	19	62	227						
	Oct	0	0	0	0	0	0	0	10	1	0	0	4	0						
	Nov	0	0	0	0	0	0	(b)	0	0	0	0	0	0						
	Dec	27	30	327	0	246	111	104	1,177	(b)	145	713	39	0						
1974	Jan	No Sample in January, 1974																		
	Feb	54	275	98	90	268	137	135	203	297	180	276	371	176	261	207	103			
	Mar	643	219	151	248	508	840	402	787	701	1,038	1,058	638	1,438	371	1,032	473			
	Apr	1,004	930	2,477	1,562	510	2,241	905	2,971	1,910	1,724	2,633	4,088	3,561	1,212	1,529	1,504			
	May	296	1,780	824	1,460	2,052	3,521	1,922	4,340	4,486	3,705	4,228	4,730	4,981	1,288	2,852	2,058			
	Jun	55	1,211	877	1,795	752	1,484	878	4,973	1,798	3,203	2,956	2,876	3,511	1,695	1,192	2,219			
	Jul	0	82	4,146	5,058	4,085	15,184	9,876	5,081	7,051	2,816	5,073	3,830	10,262	6,926	5,361	2,573			
	Aug	0	0	0	(b)	2	0	5	25	2	15	(b)	20	11	15	1	2			
	Sep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
	Oct	0	0	0	0	0	0	0	0	3	195	0	0	0	12	0	196	129		
	Nov	0	0	0	0	0	2	0	0	0	0	0	5	0	0	0	0	0		
	Dec	0	9	3	1	9	24	12	5	3	10	54	64	9	5	25	4	26		
1975	Jan		0	0	16	69	17	3	54	112	33		229	246	35	7	47	44		
	Feb		0			135	437	214	51	186	228	698				234	129	197	251	164
	Mar	0	119	5	133	402	422	204	1,092	1,118	729	1,038	1,162	939	247	902	877	1,309	150	167
	Apr	0	1,413	1,161	1,135	3,066	2,563	930	3,293	2,972	2,280	3,402	5,266	6,046	1,141	1,996	1,031	4,084	2,158	1,474
	May	300	157	563	454	2,094	1,933	551	2,180	66	3,479	2,700	1,497	6,712	1,921	1,537	407	2,376	411	927
	Jun	0	127	284	822	1,677	2,544	425	2,917	2,643	1,370	3,680	2,448	907	472	1,781	3,415	2,160	589	1,590
	Jul	0	0		5				133	35	31	9	14	127		16	41	9	27	0
	Aug	0	0	0	0	0	0	6	0	12	10	0	15	14	0	0	9	6	0	0
	Sep	0	0	0	0	0	0	0	0	0	142	0	0	0	0	0	108	0	0	0
	Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov	0	0	0	3	0		4	0	42	140	35	16	12	0	0	0	0	0	18
	Dec	62	12	4	140	57	154	2	124	244	63		315	265	75	134	197	81	86	35

(a) Not sampled until February, 1974.
(b) No sample.

TABLE 4.8-6. MEAN NUMBER OF *Paracalanus parvus* PER 10 CUBIC METERS AT STATIONS IN THE MILLSTONE POINT AREA EACH MONTH FROM MAY, 1973, THROUGH DECEMBER, 1975

E = Sampled on ebb tide; F = Sampled on flood tide

		Stations																		
Year	Month	1	2	3E	3F	4	5	6	7E	7F	8	9E	9F	10	11[a]	12[a]	13[a]	14	15	16
1973	May	0	451	(b)	1,184	149	353	629	665	2,312	138	1,329	(b)	1,146						
	Jun	0	46	45	97	103	373	190	736	142	799	342	437	394						
	Jul	13	5	17	26	264	173	90	159	200	580	200	271	269						
	Aug	0	74	7	0	34	52	62	25	2	46	104	37	50						
	Sep	0	4	0	32	47	24	30	20	69	99	68	100	31						
	Oct	0	1	0	0	0	3	7	21	8	23	5	5	10						
	Nov	0	0	0	0	8	17	(b)	0	0	0	0	15	2						
	Dec	255	329	1,230	810	1,245	1,219	1,401	2,767	(b)	1,221	3,452	548	43						
1974	Jan	No Sample in January, 1974																		
	Feb	335	403	193	257	609	332	390	340	512	625	695	751	791	761	510	728			
	Mar	567	400	332	338	656	617	334	842	662	1,046	905	533	926	523	906	784			
	Apr	1,399	989	1,311	1,023	623	1,507	1,007	2,054	1,424	1,045	2,902	3,621	2,942	1,080	1,092	1,755			
	May	116	1,120	898	671	1,086	1,790	1,106	2,535	2,343	2,579	1,203	2,195	3,232	757	1,418	1,222			
	Jun	0	419	192	739	438	651	35	1,277	618	1,385	934	1,120	1,067	387	380	1,294			
	Jul	0	0	690	708	569	4,829	4,001	418	1,502	453	328	549	2,604	2,278	1,047	789			
	Aug	0	0	0	(b)	0	4	1	21	2	2	(b)	0	0	0	0	0			
	Sep	0	0	0	0	0	0	0	0	0	0	82	0	31	0	0	87			
	Oct	0	2	0	0	19	0	4	5	15	0	29	130	36	17	7	314	64		
	Nov	0	50	45	125	1	143	175	239	97	0	134	230	534	121	90	113	92		
	Dec	81	40	26	35	29	70	40	26	65	39	86	59	36	22	35	20	58		
1975	Jan		38	0	3	138	40	36	114	187	28		279	256	39	43	54	61		
	Feb		112			387	930	383	332	528	818	1,362				495	404	731	174	340
	Mar	284	486	115	302	697	616	345	3,176	1,605	1,516	2,260	5,635	2,238	583	921	2,334	2,564	661	427
	Apr	495	1,796	1,045	5,380	2,376	2,750	332	1,683	3,585	3,310	2,689	3,207	4,535	2,192	1,763	1,647	1,490	3,092	1,563
	May	150	52	182	182	905	603	220	279		1,028	1,296	556	822	572	280	174	328	137	94
	Jun	0	64	78	34	143	306	45	733	130	49	307	765	201	37	151	159	216	27	45
	Jul	0	0		50				0	0	0	0	0	0		0	9	0	0	0
	Aug	0	0	14	0	0	0	141	284	87	43	491	4	451	0	385	0	13	11	431
	Sep	0	165	0	0	13	226	21	125	161	118	215	1,511	133	103	123	0	604	24	92
	Oct	0	1	1		0	240	47	0	199	271	199	0	2	422	149	1	181	33	115
	Nov	8	6	0	10	34		8	36	21	65	12	65	44	30	0	19	3	36	27
	Dec	56	55	62	109	122	61	81	167	333	65		221	128	171	119	168	318	131	61

(a) Not sampled until February, 1974.
(b) No sample.

TABLE 4.8-7. MEAN NUMBER OF *Evadne* sp. PER 10 CUBIC METERS AT STATIONS IN THE MILLSTONE POINT AREA EACH MONTH FROM MAY, 1973, THROUGH DECEMBER, 1975

E = Sampled on ebb tide; F = Sampled on flood tide

		Stations																		
	Month	1	2	3E	3F	4	5	6	7E	7F	8	9E	9F	10	11[a]	12[a]	13[a]	14	15	16
1973	May	0	1,203	(b)	535	226	278	281	280	193	25	399	(b)	441						
	Jun	379	6,553	4,388	4,208	2,148	1,686	3,188	3,023	3,537	4,090	3,652	2,186	772						
	Jul	33	14	9	9	8	17	8	6	13	6	14	12	0						
	Aug	7	124	31	135	121	287	186	115	368	274	181	15	255						
	Sep	4	109	117	162	158	116	138	174	200	90	171	249	49						
	Oct	0	<1	0	7	10	13	29	36	0	10	5	37	20						
	Nov	0	0	0	0	0	0	(b)	0	0	0	0	0	0						
	Dec	0	0	0	0	0	74	0	0	(b)	15	0	0	0						
1974	Jan	No Sample in January, 1974																		
	Feb	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0			
	Mar	0	0	0	0	9	2	0	10	0	0	7	2	0	0	20	2			
	Apr	154	773	402	326	166	420	63	96	240	98	9	76	128	188	174	147			
	May	179	2,278	1,631	2,442	4,088	1,412	2,081	1,143	2,826	967	1,553	385	1,252	1,608	2,524	1,173			
	Jun	0	575	268	1,072	294	308	159	234	305	458	489	98	391	317	201	236			
	Jul	0	0	0	6	55	553	231	0	196	50	187	150	0	292	254	166			
	Aug	58	16	4	(b)	12	3	12	5	0	1	(b)	10	10	3	2	1			
	Sep	0	0	0	0	0	52	0	56	0	0	0	0	19	0	46	0			
	Oct	0	0	0	0	0	0	0	0	0	0	0	35	0	6	0	0	0		
	Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
1975	Jan		0	0	0	0	0	0	0	0	0		0	0	0	0	0	0		
	Feb		0			0	0	0	0	0	0	0				0	0	0	0	0
	Mar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Apr	0	0	0	0	0	0	0	73	1	0	12	48	0	22	0	21	0	0	0
	May	0	0	36	0	170	11	0	0	0	158	0	0	0	0	0	0	0	68	23
	Jun	0	0	0	0	0	0	22	40	0	0	0	0	0	0	0	0	0	0	0
	Jul	0	0		0				0	0	0	0	0	0		0	0	0	0	0
	Aug	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sep	0	0	0	0	0	151	0	0	0	0	0	0	0	0	0	0	0	0	0
	Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0
	Dec	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0

(a) Not sampled until February, 1974.
(b) No sample.

TABLE 4.8-8. MEAN NUMBER OF *Podon* sp. PER 10 CUBIC METERS AT STATIONS IN THE MILLSTONE POINT AREA EACH MONTH FROM MAY, 1973 THROUGH DECEMBER, 1975

E = Sampled on ebb tide; F = Sampled on flood tide

		Stations																		
	Month	1	2	3E	3F	4	5	6	7E	7F	8	9E	9F	10	11[a]	12[a]	13[a]	14	15	16
1973	May	0	150	(b)	114	5	54	185	601	193	0	532	(b)	176						
	Jun	144	1,999	1,713	1,019	1,996	1,602	1,190	1,566	1,714	2,003	2,452	1,231	739						
	Jul	494	314	152	542	56	61	252	223	202	67	98	67	50						
	Aug	114	263	165	292	195	183	318	246	103	273	194	258	713						
	Sep	0	65	10	62	33	13	44	11	41	21	9	60	66						
	Oct	78	0	0	0	0	5	1	0	1	10	5	7	13						
	Nov	0	0	0	0	0	0	0	0	0	0	0	0	0						
	Dec	0	0	0	0	0	0	0	0	(b)	0	0	0	9						
1974	Jan	No Sample in January, 1974																		
	Feb	0	0	0	0	0	0	0	0	0	0	0	0	0						
	Mar	0	0	0	0	0	0	0	0	0	0	0	0	0						
	Apr	0	0	246	171	35	145	10	196	16	95	0	48	32	59	61	38			
	May	161	793	433	1,267	2,200	902	545	915	3,064	388	1,258	413	1,338	343	1,579	305			
	Jun	870	712	505	616	168	385	192	315	506	252	88	377	505	512	70	415			
	Jul	1,751	368	493	603	63	760	808	0	1,110	76	47	0	230	0	51	291			
	Aug	0	33	0	10	1	1	10	11	1	4	(b)	20	3	8	1	5			
	Sep	37	0	72	0	137	0	50	337	0	0	128	0	18	0	0	0			
	Oct	0	4	0	5	0	6	0	0	62	0	29	35	9	4	0	0	0		
	Nov	37	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
1975	Jan		0	0	0	0	0	0	0	0	0		0	0	0	0	0	0		
	Feb		0			0	0	0	0	0	0	0				0	0	0	0	0
	Mar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0	0
	May	0	0	0	0	0	19	0	0	5	0	0	0	0	0	0	0	16	0	0
	Jun	497	21	0	17	0	0	0	86	0	0	0	0	0	0	0	0	0	13	0
	Jul	0	0		25				3	0	0	0	0	0		0	4	0	27	0
	Aug	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0
	Sep	0	0	0	0	0	0	64	175	109	103	0	0	44	0	16	78	97	0	0
	Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dec	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0

(a) Not sampled until February, 1974.
(b) No sample.

TABLE 4.8-9. ANALYSIS OF VARIANCE OF TOTAL ZOOPLANKTON ABUNDANCE BY STATION AND BY MONTH

1973

Station:	3	2	5	10	7	9	6	1	4	8
Mean:	2.5668	2.8081	2.8688	2.9973	3.0264	3.1146	3.1259	3.1718	3.1813	3.2600
Month:	Oct	Jul	Nov	Dec	Jun	Aug	May	Sep		
Mean:	2.4390	2.8581	3.0044	3.0522	3.0570	3.2040	3.2220	3.2829		

1974

Station:	4	6	7	11	3	5	10	13	12	9	8	2	1
Mean:	3.020	3.040	3.042	3.068	3.083	3.084	3.118	3.148	3.152	3.236	3.258	3.347	3.742
Month:	Dec	Feb	Oct	Nov	Mar	Aug	Jun	Apr	May	Jul	Sep		
Mean:	2.468	2.671	3.029	3.101	3.101	3.195	3.398	3.442	3.449	3.482	3.642		

1975

Station:	13	6	4	11	5	12	16	3	10	7	15	14	2	8	9	1
Mean:	2.692	2.793	2.845	2.897	2.907	2.959	2.960	2.967	2.987	3.006	3.025	3.066	3.107	3.122	3.280	3.455
Month:	Dec	Nov	Jan	Oct	Jul	Feb	Mar	May	Jun	Apr	Aug	Sep				
Mean:	2.076	2.498	2.543	2.911	2.914	2.928	2.980	3.224	3.258	3.398	3.405	3.806				

TABLE 4.8-10. RESULTS OF AN ANALYSIS OF VARIANCE FOR TOTAL NUMBER OF EGGS AT EACH STATION Stations arranged in order of increasing means. Underlining shows grouping of means with no significant difference.

Weeks	Level of Significance	Grouping of the Means
May 6 - May 19, 1973	.90	1 3 4 9 6 5 10 2 7 8
May 20 - Jun 2	.95	4 1 10 7 2 8 3 6
Jul 1 - Jul 14	.98	10 8 9 4 2 7 3 6 5 1
Aug 12 - Aug 25	.98	1 6 2 3 7 10 4 9 8 5
Aug 26 - Sep 8	.99	1 10 2 6 5 7 4 9 3 8
Sep 9 - Sep 22	.90	8 6 7 10 9 4 3 5 1 2
Sep 23 - Oct 6	>.999	5 6 8 10 4 7 9 3 2 1
Nov 4 - Nov 19	.90	1 2 3 4 5 6 9 7 10 8
Dec 2 - Dec 15	>.999	2 1 3 8 6 4 5 9 7 10
Dec 16 - Dec 22	>.999	1 2 3 4 7 8 9 10
Feb 10 - Feb 23, 1974	.95	1 4 6 13 5 11 2 8 9 3 10 12
Feb 24 - Mar 9	.95	1 6 4 2 9 7 5 3 10 11 8 13 12
Mar 24 - Apr 6	>.999	1 8 7 5 9 3 2 10 12 4 6 11 13
Apr 7 - Apr 20	>.999	10 8 12 3 7 9 4 5 11 6 13
Apr 21 - May 4	>.999	1 4 3 2 12 8 5 11 7 13 10 6 9
May 12 - May 18	>.999	1 4 2 5 12 9 3 6 11 7 8 13 10

TABLE 4.8-10. Continued

Weeks	Level of Significance	Grouping of the Means
May 19 - Jun 1	>.999	1 4 6 12 8 11 5 7 9 13 3 10 2
Jun 2 - Jun 15	>.999	11 3 6 8 4 7 5 10 9 1 12 13 2
Jul 14 - Jul 27	.99	9 1 3 10 8 5 4 6 13 7 12 11 2
Jul 28 - Aug 10	>.999	4 1 9 10 3 2 5 12 7 6 11 13 8
Aug 11 - Aug 24	>.999	1 4 13 3 9 10 12 2 5 7 11 6 8
Aug 25 - Sep 7	>.999	4 3 2 1 5 13 11 8 9 6 10 12 7
Sep 8 - Sep 21	>.999	4 11 3 13 7 2 6 12 8 5 9 10 1
Sep 22 - Oct 5	>.999	13 4 2 3 12 5 8 11 10 9 6 7 1
Oct 6 - Oct 19	>.999	14 2 11 4 6 13 7 5 12 3 8 9 10 1
Oct 20 - Nov 2	>.999	1 8 11 2 12 14 13 9 5 3 6 7 4 10
Nov 17 - Nov 30	.98	2 3 5 11 12 4 1 13 7 8 9 14 10 6
Nov 31 - Dec 14	.998	1 2 3 6 11 13 12 4 7 10 8 5 14 9
Dec 15 - Dec 28	>.999	2 4 1 11 13 12 3 6 8 5 7 9 14 10
Dec 29 - Jan 3, 1975	>.999	1 4 2 6 13 8 11 12 3 7 14 10 5 9
Jan 4 - Jan 17	>.999	1 2 13 6 4 3 12 8 7 11 14 5 9 10
Jan 18 - Jan 31	>.999	2 8 3 1 4 5 15 16 7 6 10 12 13 11 14 9
Feb 1 - Feb 14	.95	2 4 16 7 12 11 5 6 13 15 8 3 9 14 10
Feb 15 - Feb 28	.995	1 4 16 2 13 15 11 8 5 3 12 6 10 9 14 7

TABLE 4.8-10. Continued

Weeks	Level of Significance	Grouping of the Means
Mar 8 - Mar 21	>.999	16 1 15 3 6 14 11 4 9 5 2 10 8 7 12 13
Mar 22 - Apr 4	>.999	1 2 12 11 7 15 10 5 3 13 9 4 6 8 16 14
Apr 5 - Apr 8	>.999	1 15 2 16 4 3 11 7 6 12 14 9 5 8 13 10
Apr 19 - Apr 25	>.999	1 3 4 16 9 15 11 6 2 7 12 5 14 10 8 13

Arrow (↰) indicates that all stations to the left of the arrow have zero means

TABLE 4.8-11. MEAN DENSITIES OF HADDOCK/COD EGGS, *Melanogrammus aeglefinus/Gadus mrohua*, /M^3

Date	1	2	3 ebb	3 flood	4	5	6	7 ebb	7 flood	8	9 ebb	9 flood	10	11	12	13	14	15	16
5/5/73-5/19/73	.17	0.00		0.00	.08	0.00	0.00	0.00	.03	0.00	0.00	0.00	0.00						
5/20/73-6/2/73	.44	.26	0.0		.09		0.00	.07		1.03			0.00						
6/3/73-6/16/73	.33	.17	0.00	0.00	.25	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
6/17/73-11/19/73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00						
11/20/73-12/1/73	0.00	0.00	0.00		.02	.02	.04	.09	0.00	0.00	.04	0.0	.02						
12/2/73-12/15/73	0.00	0.00	0.00	.02	.06	.07	.04	.09	.08	0.02	.09	.18	.25						
12/16/73-12/22/73	0.00	0.00	0.00		0.00			.04	0.00	.23	.10		.24						
1/30/74-2/9/74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.01	0.00	.01	0.00	.01	.01	.01	0.00	0.00			
2/10/74-2/23/74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.02	.01	.01	.01	.01	.01	0.00	.01	0.00			
2/24/74-3/9/74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.01	.01	.02	.01	0.00	.01	.01	.01	.01			
3/10/74-3/23/74	0.00	0.00	.01	0.00	0.00	0.00	0.00	0.00	.01	.01	0.00	0.00	.01	0.00	0.00	0.00			
3/24/74-4/6/74	0.00	0.00	0.00	0.00	.01	.01	.01	0.00	.01	.01	0.00	.01	.01	0.00	.01	.01			
4/7/74-4/20/74			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.01	.01	0.00	0.00	0.00			
4/21/74-5/4/74	.02	.01	0.0	0.00	0.00	0.00	.02	0.00	0.00	.01	.02	0.00	0.00	0.00	0.00	0.00			
5/5/74-5/18/74	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.08	0.00	.08	0.00	0.00	0.00	0.00	.01			
5/19/74-10/5/74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
10/6/74-10/19/74	2.63	0.00	.01	.01	0.00	.01	.01	.02	.03	.01	.03	0.00	.01	0.00	0.00	.01			
10/20/74-11/2/74	0.00	0.00	0.00	0.00	0.00	0.00	.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
11/3/74-11/16/74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
11/17/74-5/16/75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5/17/75-5/30/75	0.00	0.00	0.00	0.00	0.00	.01	0.00	0.00	0.00	.05	0.00	.03	0.00	.01	0.00	0.00	.01	0.00	0.00

TABLE 4.8-12. RESULTS OF ANALYSIS OF VARIANCE TEST FOR DIURNAL EFFECT ON TOTAL NUMBER OF EGGS FOR OBLIQUE TOWS

Week	Level of Significance	Diurnal Stage with Higher Mean Night or Day
Jun 3 - Jun 16, 1973	>.999	N
Jul 1 - Jul 14	.99	N
Jul 29 - Aug 11	.90	N
Feb 10 - Feb 23, 1974	.98	D
Apr 7 - Apr 20	.99	D
Jun 2 - Jun 15	.99	N
Jun 30 - Jul 13	.99	N
Jul 28 - Aug 10	.998	N
Oct 20 - Nov 2	.95	N
Mar 8 - Mar 21, 1975	.95	N

TABLE 4.8-13. PERCENTAGE OF EACH SPECIES TAKEN IN DAY AND NIGHT OBLIQUE TOWS

Species	Day Oblique Tows			Night Oblique Tows		
	May 1973 - Apr 1974	May 1974 - Apr 1975	May 1975 - Dec 1975	May 1973 - Apr 1974	May 1974 - Apr 1975	May 1975 - Dec 1975
Anchoa hepsetus	.016	.076	.367	.022	.206	.519
Anchoa mitchilli	7.935	3.776	10.761	.814	5.018	8.223
Brevoortia tyrannus	2.191	2.235	.881	2.221	2.335	3.948
Brosme brosme	.087			.009	.004	
Melanogrammus aeglefinus/ Gadus morhua type	.020	.043	.009	.002	.021	
Cynoscion regalis		.525			.185	
Enchelyopus cimbrius	.096	.212	.190	.019	.141	.021
Engraulidae	.070			.015		
Gadidae			.066			.117
Gadus morhua	.014			.003		
Glyptocephalus cynoglossus	.016	.005		.031		
Hippoglossoides platessoides	.055			.031		
Labridae/*Limanda ferruginea* type	80.896	79.450	63.056	87.557	70.568	82.538
Melanogrammus aeglefinus	.100	.011		.003	.032	
Merluccius albidus	.036			.003	.027	
Merluccius bilinearis	.559	.240	.354	.123	.063	.140
Merluccius spp.			.075			.013
Paralichthys dentatus	.017	.059		.001	.059	
Paralichthys oblongus	.096	.051		.342		
Pholis gunnellus	.001					
Pollachius virens	.001			.001		
Peprilus triacanthus		.047	.315		.021	.285
Prionotus carolinus	.001	.018	.023			.933
Prionotus spp.	1.762	2.506	1.860	3.176	2.993	
Scophthalmus aquosus	.305	1.194	2.952	1.834	1.032	.338
Scophthalmus aquosus/ Paralichthys oblongus Type			.077			.028
Scomber scombrus	5.571	9.004	18.433	3.777	16.115	2.526
Stenotomus chrysops	.013	.005	.313	.005	.022	.287
Trinectes maculatus		.004	.077			
Unknown	.108	.487	.022	.007	1.138	.063
Urophycis chuss	.032	.049	.156	.004	.021	.021
Urophycis spp.		.002				
Urophycis chuss/Enchelyopus cimbrius type			.010			

TABLE 4.8-14. RESULTS OF ANALYSIS OF VARIANCE TEST FOR DIURNAL EFFECT ON TOTAL NUMBER OF EGGS FOR SURFACE TOWS

Week	Level of Significance	Diurnal Stage with Higher Mean Night or Day
Jun 3 - Jun 16, 1973	>.999	N
Jul 1 - Jul 14	.95	N
Nov 20 - Dec 1	.95	N (none found in day tows)
Jun 2 - Jun 15, 1974	.998	N
Jun 30 - Jul 13	.90	D
Jul 13 - Aug 10	.98	N
Sep 22 Oct 5	.95	D
Oct 20 - Nov 2	.95	N
Feb 8 - Feb 21, 1975	.95	D
Mar 8 - Mar 21	>.999	N

TABLE 4.8-15. RESULTS OF ANALYSIS OF VARIANCE TEST FOR DIURNAL EFFECT ON TOTAL NUMBER OF EGGS FOR BOTTOM TOWS

Week	Level of Significance	Diurnal Stage with Higher Mean Night or Day
Jun 3 - Jun 16, 1973	>.999	N
Nov 20 - Dec 1	.95	N (none found in day tows)
Feb 10 - Feb 23, 1974	>.999	D
May 5 - May 11	.95	N
Jun 2 - Jun 15	.95	N
Jun 30 - Jul 13	.90	N
Aug 25 - Sep 7	.995	D
Sep 22 - Oct 5	.98	D
Oct 20 - Nov 2	.998	N
Jan 11 - Jan 24, 1975	.90	D
Mar 8 - Mar 21	.998	N

TABLE 4.8-16. RESULTS OF ANALYSIS OF VARIANCE FOR DEPTH EFFECT FOR TOTAL NUMBER OF EGGS FOR DAY STRATIFIED TOWS

Week	Level of Significance	Depth with Higher Mean Surface or Bottom
Apr 21 - May 4, 1974	.95	S
Jun 2 - Jun 15	.95	S
Jun 30 - Jul 6	>.999	S
Sep 8 - Sep 21	.90	S
Nov 3 - Nov 16	.90	S
Dec 29, 1974 - Jan 10 - 1975	.90	S
Apr 19 - Apr 25, 1975	.90	S

TABLE 4.8-17. RESULTS OF ANALYSIS OF VARIANCE FOR DEPTH EFFECT ON TOTAL NUMBER OF EGGS IN NIGHT STRATIFIED TOWS

Week	Level of Significance	Depth with Higher Mean Surface or Bottom
Jun 3 - Jun 16, 1973	.99	S
Feb 10 - Feb 23, 1974	.95	S
Jun 2 - Jun 15	.99	S
Jul 21 - Aug 3	.98	S
Aug 25 - Sep 7	>.999	S
Nov 17 - Dec 14	.90	B
Feb 8 - Feb 21, 1975	.98	B
Mar 8 - Mar 21	>.999	S

TABLE 4.8-18. RESULTS OF ANALYSIS OF VARIANCE FOR TIDAL EFFECT ON TOTAL NUMBER OF EGGS IN DAY OBLIQUE TOWS

Week	Level of Significance	Tidal Stage with Higher Mean Ebb or Flood
May 6 - May 19, 1973	.995	E
Oct 7 - Oct 20	.95	F
Feb 24 - Mar 9, 1974	.95	E
May 12 - May 18	.90	E
May 19 - Jun 1	.95	E
Jun 2 - Jun 18	.95	E
Jun 30 - Jul 6	.95	E
Oct 6 - Oct 17	.90	F
Oct 20 - Nov 2	>.999	F
Dec 29, 1974 - Jan 3, 1975	.90	F
Feb 22 - Mar 7	.90	E

TABLE 4.8-19. RESULTS OF ANALYSIS OF VARIANCE FOR *Anchoa mitchilli* EGGS AT EACH STATION

Stations arranged in order of increasing means. Underlining shows grouping of means with no significant difference.

Weeks	Level of Significance	Grouping of Means[a]
Jun 17 - Jun 30, 1973	.90	4 6 ↰ 8 3 5 7 10 1 2 9
Jul 1 - Jul 14	>.999	10 8 9 4 7 3 5 6 2 1
Jul 29 - Aug 11	>.99	6 ↰ 9 10 3 7 4 2 8 5 1
Jun 2 - Jun 15, 1975	.998	4 6 7 8 9 10 11 12 13 ↰ 5 2 3 1
Jun 16 - Jun 29	.998	11 6 3 8 13 7 10 9 4 12 2 1
Jun 30 - Jul 13	>.999	11 12 6 8 10 3 7 5 9 13 4 2 1
Aug 29 - Sep 7	>.999	2 3 4 5 6 7 8 9 10 11 12 13 ↰ 1

(a) Arrow (↰) indicates that all stations to the left of the arrow have zero means.

TABLE 4.8-20. MEAN DENSITIES OF BAY ANCHOVY EGGS, *Anchoa mitchilli*, /M^3

	Stations																		
Date	1	2	3 ebb	3 flood	4	5	6	7 ebb	7 flood	8	9 ebb	9 flood	10	11	12	13	14	15	16
5/5/73-6/16/73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
6/17/73-6/30/73	15.48	0.55	0.24	0.00	0.00	1.40	0.00	0.90	0.00	0.00	0.69	0.00	3.01						
7/1/73-7/14/73	19.29	20.16	0.96	1.14	1.34	3.03	4.01	0.37	0.87	0.58	0.74	0.39	0.11						
7/15/73-7/28/73	8.97	2.32	0.35	0.70	2.78	2.20	0.56	3.82	0.39	1.41	0.59	6.56	2.35						
7/29/73-8/11/73	0.67	0.10	0.03	0.12	0.07	0.13	0.00	0.09	0.00	0.00	0.00	0.00	0.01						
8/12/73-8/25/73	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.00	0.00	0.03						
8/26/73-12/22/73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
1/30/74-5/18/74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
5/19/74-6/1/74	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
6/2/74-6/15/74	8.75	2.28	1.69	0.31	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
6/16/74-6/29/74	19.36	2.29	0.00	3.20	0.72	0.00	0.09	0.36	0.20	1.67	0.94	0.41	0.33	0.00	1.08	0.13			
6/30/74-7/13/74	36.06	17.44	0.00	3.76	5.95	1.59	0.24	0.57	0.99	0.46	0.42	0.90	0.26	0.62	0.55	0.66			
7/14/74-7/27/74	0.32	0.54	0.00	2.21	0.67	0.02	1.54	0.00	0.42	1.27	0.17	0.12	0.74	1.74	0.97	0.51			
7/28/74-8/10/74	0.01	0.10	0.03	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00			
8/11/74-8/24/74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
8/24/74-9/7/74	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
9/8/74-9/21/74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
9/22/74-10/5/74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			

TABLE 4.8-21. RESULTS OF ANALYSIS OF VARIANCE FOR *Scomber scombrus* EGGS AT EACH STATION

Stations arranged in order of increasing means. Underlining shows grouping of means with no significant difference.

Weeks	Level of Significance	Grouping of the Means[a]
May 6 - May 19, 1973	>.999	1⤶ 4 3 2 5 6 9 10 7 8
May 20 - Jun 2	>.999	3 6⤶ 1 4 7 2 10 8
May 5 - May 11, 1974	.90	10 2 1 7 13 8 5 4 9 11 12 6

(a) Arrow (⤶) indicates that all stations to the left of the arrow have zero means.

TABLE 4.8-22. SPECIES OF FISH LARVAE TAKEN DURING 1974 IN THE .333 mm NET SAMPLES OF DAY OBLIQUE TOWS FROM ALL STATIONS, RANKED BY ORDER OF OVERALL DENSITY

Species	Overall Average Density #/1000 M^3	Percentage of Total Larvae	Cumulative Percent	Overall Monthly Density (#/1000 M^3) J	F	M	A	M	J	J	A	S	O	N	D
Engraulidae	75.61	22.712	22.712					6.2	30.6	671.2	86.5	14.0	3.5	3.0	
Scomber scombrus	54.17	16.270	38.982					648.7	313.5	11.0	-	-			
Tautogolabrus adspersus	41.34	12.417	51.319				3.0	10.5	171.7	391.5	4.0	5.5	3.1		
Tautoga onitis	31.44	9.442	60.841					20.8	163.9	252.5	11.2	6.1	3.1		3.9
Pseudopleuronectes americanus	22.36	6.706	67.547	3.8	61.6	65.3	128.6	37.3	11.3	3.0					
Scophthalmus aquosus	21.38	6.422	73.969	-	-	-	-	42.9	151.0	90.5	5.0	18.7	12.2	7.5	3.0
Peprilus triacanthus	14.50	4.354	78.323						5.8	168.7	10.8	9.5	6.3		
Ammodytes spp.	12.56	3.774	82.097	5.8	41.2	60.9	90.0	41.8	4.5	3.1	3.3				5.9
Enchelyopus cimbrius	10.28	3.087	85.184			-	26.4	91.2	34.8	16.5	-	3.1	3.2		
Myoxocephalus spp.	7.03	2.110	87.294	10.1	51.2	63.3	27.2	12.5							
Clupeidae	6.87	2.064	89.358	-	3.4	4.5	3.3	9.2	44.4	27.3	-	28.2	23.2	15.4	5.3
Prionotus spp.	5.93	1.781	91.139						13.8	137.4	18.3	7.0	6.1		
Lumpenus lumpretaeformis	5.75	1.728	92.867			5.5	25.9	64.4	18.5	-					
Stenotomus chrysops	4.96	1.491	94.358					38.6	11.6	74.6					
Syngnathus fuscus	4.14	1.244	95.602					4.4	29.5	25.9	9.6	5.5	3.1		3.8
Unknown	4.11	1.235	96.837		7.1	9.2	9.2	68.9	38.6	33.7		3.1	3.0	8.2	3.0
Menidia spp.	3.26	.979	97.816					9.3	56.2	50.3	15.9				
Limanda ferruginea	1.53	.459	98.275			-	12.6	23.8	5.7	6.0					
Liparis spp.	1.01	.304	98.579			3.9	15.1	19.3	9.5						
Paralichthys oblongus	.87	.262	98.841					2.9	3.9	25.5	5.3	5.4	6.0		
Gobiidae	.61	.184	99.025						7.6	25.0	35.3	13.2	2.5	4.6	3.2
Cynoscion regalis	.57	.171							4.8	20.1	3.1				
Merluccius bilinearis	.55	.164							10.3	10.9					
Pholis gunnellus	.37	.112		5.9	7.7	3.6		3.5							
Trinectes maculatus	.28	.084							2.8	9.2					
Urophycis spp.	.23	.070							6.8	8.3		4.4	3.9	4.0	
Rissola marginata	.23	.068							2.8	9.1	4.3	5.5	4.2		
Gadus morhua	.18	.053			4.5	3.5	4.0	3.5	3.0					3.1	3.7
Paralichthys dentatus	.14	.042						3.2				3.0	5.0	4.7	3.2
Sphoeroides maculatus	.13	.039							3.2	5.5	3.0	3.0			
Microgadus tomcod	.11	.034			8.4	11.3									
Pollachius virens	.09	.027			11.8	4.3	4.4	3.0							
Pomatomus saltatrix	.05	.016							2.8	9.3					
Hippocampus spp.	.05	.016									9.2	4.4	3.2		

TABLE 4.8-22. (continued)

Species	Overall Average Density #/1000 M^3	Percentage of Total Larvae	Cumulative Percent	J	F	M	A	M	J	J	A	S	O	N	D
								Overall Monthly Density (#/100 M^3)							
Etropus microstomus	.05	.014									9.3	4.4	3.2		
Gadidae	.03	.009			6.9		3.0	4.9		4.2	–	4.8	3.1		
Hippoglossoides platessoides	.03	.008						10.0	3.0						
Anguilla rostrata	.02	.007			3.1		5.1	3.1							
Gasterosteidae	.02	.007			3.4			10.4			3.5				
Centropristes striata	.01	.004								6.2					
Lophius americanus	.01	.004							2.8	3.3					
Brosme brosme	.01	.004							5.2						
Orthopristes chrysoptera	.01	.002								2.8					
Scienidae	<.01	.001													4.0
Hemitripterus americanus	<.01	.001			3.3										
Glyptocephalus cynoglossus	<.01	.001					3.3								
Menticirrhus saxatilis	<.01	.001							3.1						
Bairdiella chrysura	<.01	.001								3.0					
Melanogrammus aeglefinus	<.01	.001								2.8					
Gerridae	<.01	.001							2.5						

TABLE 4.8-23. SPECIES OF FISH LARVAE TAKEN DURING 1975 IN THE .333 mm NET SAMPLES OF DAY OBLIQUE TOWS FROM ALL STATIONS, RANKED BY ORDER OF OVERALL DENSITY

Species	Overall Average Density #/1000 M^3	Percentage of Total Larvae	Cumulative Percent	Overall Monthly Density (#/1000 M^3) J	F	M	A	M	J	J	A	S	O	N	D
Scomber scombrus	447.72	39.827	39.827					305.2	7719.9	13.5					
Engraulidae	210.03	18.683	58.510				2.8	-	201.3	2384.4	281.6	88.8	49.8	5.3	3.1
Scophthalmus aquosus	202.83	18.043	76.553	2.8		3.7		30.0	3060.9	80.0	3.2	39.2	15.1		3.2
Pseudopleuronectes americanus	74.11	6.593	83.146	8.6	46.8	135.0	259.3	106.1	264.9						
Ammodytes spp.	34.74	3.091	86.237	7.7	135.5	198.9	198.2	33.5							22.0
Tautoga onitis	31.18	2.774	89.011					5.3	252.7	210.3	13.6	10.8			
Clupeidae	30.98	2.756	91.767	4.3	19.8	7.9	6.4	3.9	409.6	19.7	2.8	24.0	24.8	79.1	3.8
Tautogolabrus adspersus	24.32	2.163	93.93					56.0	162.6	184.0	4.2		6.4		
Enchelyopus cimbrius	20.56	1.829	95.759			3.2	10.8	75.0	204.1	7.1	2.7				
Peprilus triacanthus	11.39	1.013	96.772						8.3	141.0	44.4	44.5			
Myoxocephalus spp.	9.40	.837	97.609	11.3	15.4	25.7	26.4	14.1							
Unknown	3.96	.352	97.961						3.3	13.4					
Stenotomus chrysops	3.34	.297	98.258						30.6	66.1					
Lumpenus lumpretaeformis	3.22	.286	98.544				13.4	21.8	17.0						
Limanda ferruginea	2.90	.258	98.802			3.1	16.8	21.4	5.0						
Prionotus spp.	2.12	.188	98.99						52.9	61.8	4.1	16.9			
Pholis gunnellus	2.10	.187	99.177	17.4	7.8	5.9	5.6	2.8							
Gobiidae	2.03	.181					2.9		44.8	86.3	17.8				2.8
Syngnathus fuscus	1.59	.142				3.0		5.9	9.2	14.3	13.8	9.5	9.9	2.8	
Liparis spp.	1.44	.128				3.1	13.5	18.9	59.3						
Gadus morhua	.83	.074		3.5	4.6	4.9	6.6	5.0							
Paralichthys oblongus	.80	.071							6.0	24.9	3.4	6.3			
Etropus microstomus	.65	.058								19.4	5.6	12.0			
Menidia spp.	.42	.037						25.8	14.7	16.3	9.6				
Merluccius bilinearis	.38	.034							6.7	14.4	5.5				
Cynoscion regalis	.22	.020					3.6		4.7	11.2					
Paralichthys dentatus	.11	.017		2.8								4.6	12.8	6.1	
Microgadus tomcod	.11	.010		5.8	5.4	3.5	3.1	5.9							
Centropristes striata	.11	.010							2.8	8.4	3.0	12.2			
Urophycis chuss	.11	.009								11.0	3.5	5.7			
Rissola marginata	.08	.007							6.6	5.1	4.0	11.5			

TABLE 4.8-23. (continued)

Species	Overall Average Density #/1000 M^3	Percentage of Total Larvae	Cumulative Percent	Overall Monthly Density (#/1000 M^3) J	F	M	A	M	J	J	A	S	O	N	D
Trinectes maculatus	.07	.006						2.8	2.5	6.8					
Hippocampus spp.	.06	.005							24.0	-	6.6	2.8			
Pollachius virens	.04	.003		3.2	3.3		5.8	3.2							3.4
Sphoeroides maculatus	.03	.003							3.2	3.0					
Gasterosteidae	.02	.002		6.1				3.2	2.9	2.8					3.2
Menticirrhus saxatilis	.02	.002								13.8					
Anguilla rostrata	.01	.001		3.4			5.8								
Hemitripterus americanus	.009	.001		3.2		3.3									
Hippoglossoides plattessoides	.008	.001						3.1							
Lophius americanus	.008	.001							3.2	2.9					
Fundulus spp.	.007	.001								2.8					
Glyptocephalus cynoglossus	.007	.001					2.9	2.7							
Gadidae	.005	<.001				3.7									
Pomatomus saltatrix	.004	<.001									3.2				
Scienidae	.004	<.001								3.1					

TABLE 4.8-24. PERCENTAGE OF SAMPLES CONTAINING EACH OF THE MOST ABUNDANT SPECIES OF FISH LARVAE FOR 1974, 1975, AND FOR BOTH YEARS

Species	Mean % of Sampled 1974 & 1975	% of 1974 Samples	% of 1975 Samples
Pseudopleuronectes americanus	8.95	7.3	10.6
Ammodytes spp.	8.80	6.3	11.3
Myoxocephalus spp.	7.35	5.8	9.9
Scophthalmus aquosus	6.80	8.4	5.2
Clupeidae	6.45	7.6	5.3
Engraulidae	5.15	5.6	4.7
Enchelyopus cimbrius	5.10	4.8	5.4
Tautoga onitis	4.75	5.1	4.4
Syngnathus fuscus	3.90	5.0	2.8
Tautogolabrus adspersus	3.80	4.1	3.5
Lumpenus lumpretaeformis	3.55	3.3	3.8
Peprilus triacanthus	2.95	3.5	2.4
Liparis spp.	2.80	2.5	3.1
Scomber scombrus	2.60	3.0	2.2
Prionotus spp.	2.20	3.0	1.4
Gadus morhua	2.15	1.0	3.3

TABLE 4.8-25. NIGHT/DAY CATCH RATIOS FOR EACH OF THE MOST ABUNDANT SPECIES OF LARVAE TAKEN IN SAME-WEEK NIGHT AND DAY OBLIQUE .333 mm MESH SAMPLES

Species	Night/Day Ratio
Scomber scombrus	2.08
Pseudopleuronectes americanus	1.22*
Clupeidae	1.68*
Ammodytidae	0.88
Engraulidae	4.19
Tautogolabrus adspersus	1.00
Tautoga onitis	1.30
Peprilus triacanthus	0.76
Enchelyopus cimbrius	1.20
Lumpenus lumpretaeformis	0.72
Stenotomus chrysops	1.71
Syngnathus fuscus	2.12
Limanda ferruginea	1.50
Myoxocephalus spp.	1.19
Unknown	1.67
Pholis gunnellus	1.71
Prionotus spp.	2.27
Liparis spp.	2.00
Gobiidae	4.25
Menidia spp.	6.00
Scophthalmus aquosus	0.54

*Species showing a marked increase in night/day catch ratios during the latter weeks of its period of occurrence.

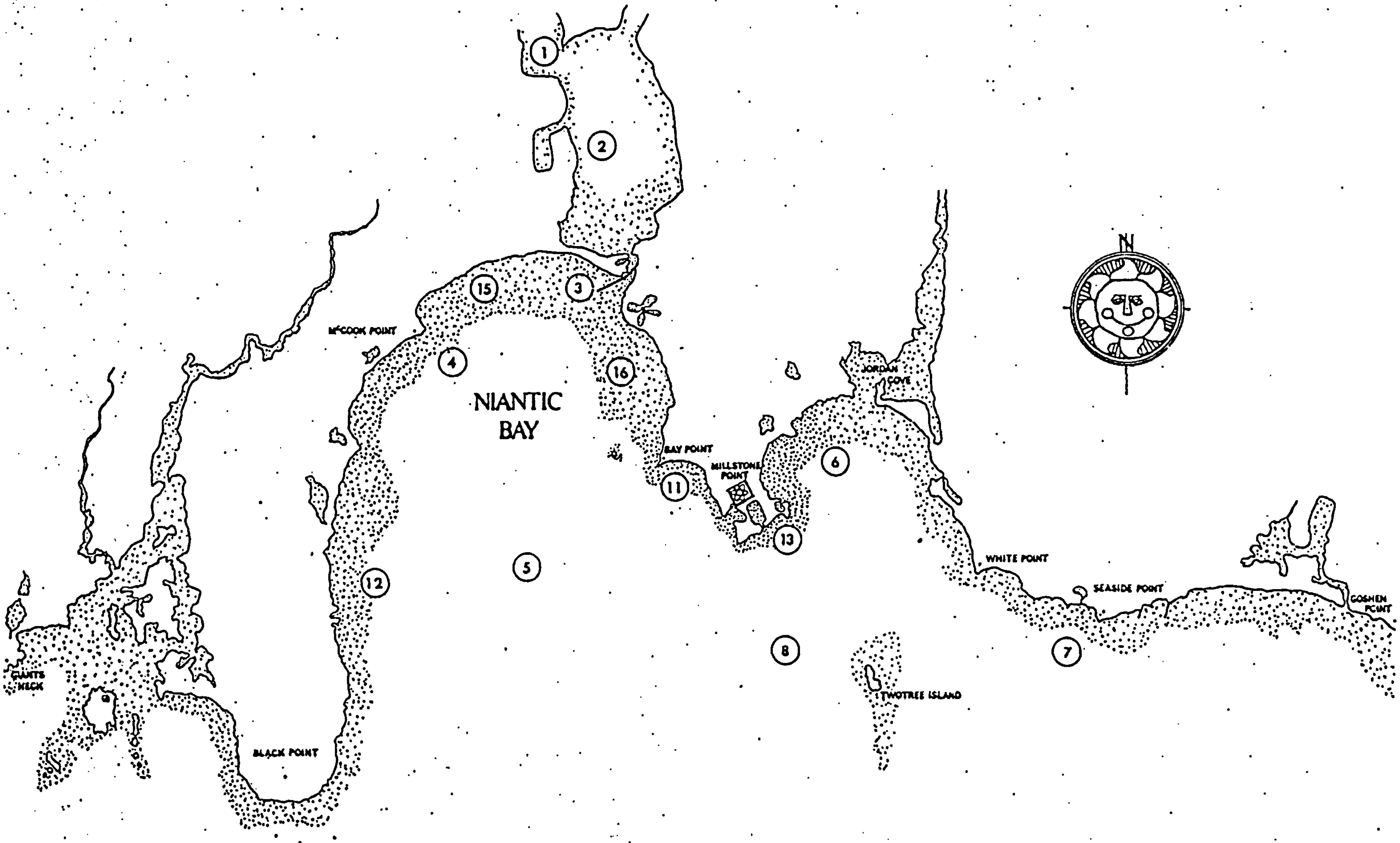


FIGURE 4.8-1. LOCATION OF ZOOPLANKTON SAMPLING STATIONS IN THE MILLSTONE POINT AREA

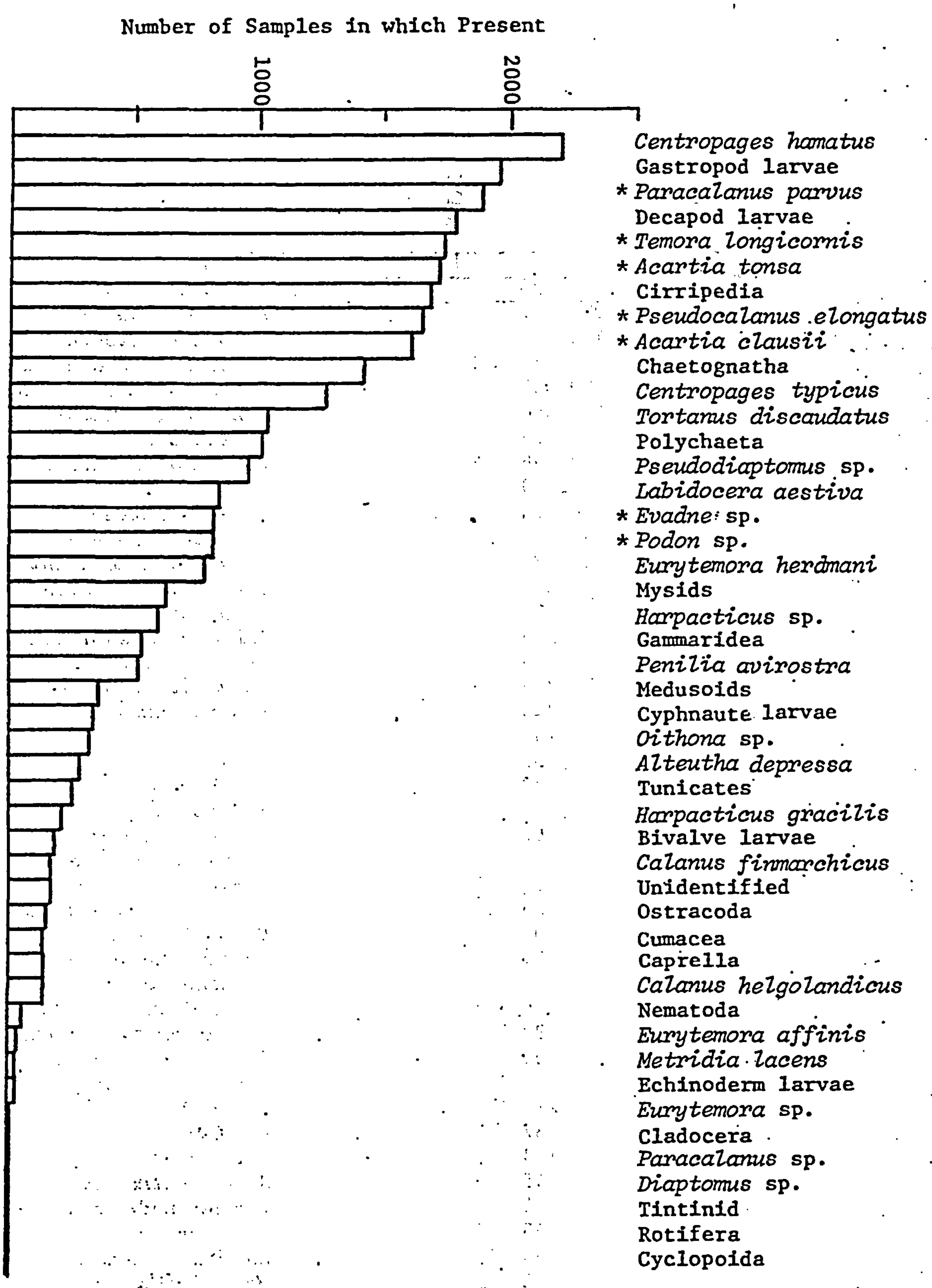


FIGURE 4.8-2. FREQUENCY OF OCCURRENCE OF ZOOPLANKTON SPECIES

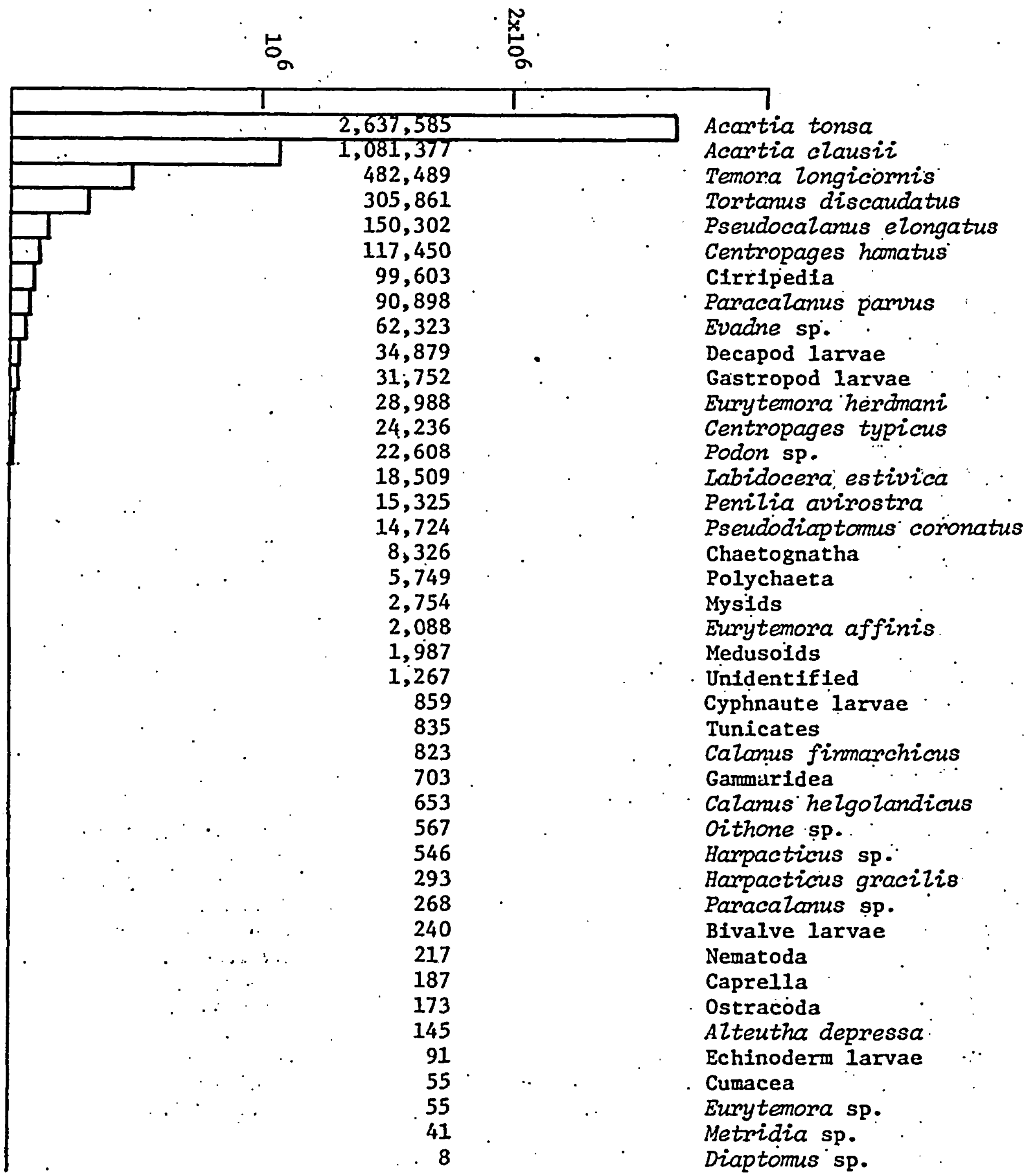


FIGURE 4.8-3. ABSOLUTE TALLEY OF NUMBER OF ZOOPLANKTON COUNTED FROM ALL DAY OBLIQUE TOWS FROM 1973 THROUGH 1975

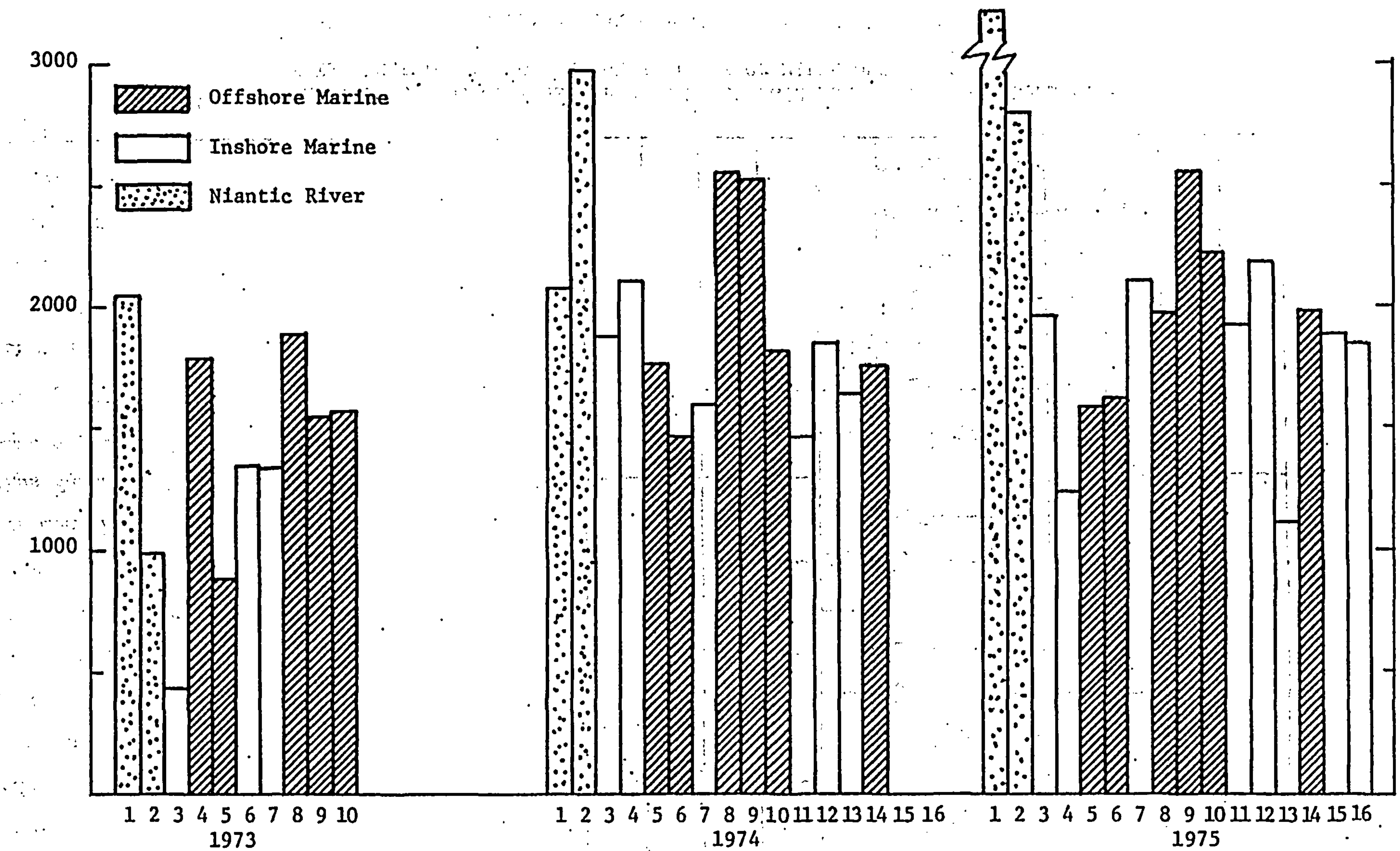


FIGURE 4.8-4. AVERAGE NUMBER OF ZOOPLANKTON PER 10 CUBIC METERS PER YEAR AT ANY GIVEN STATION

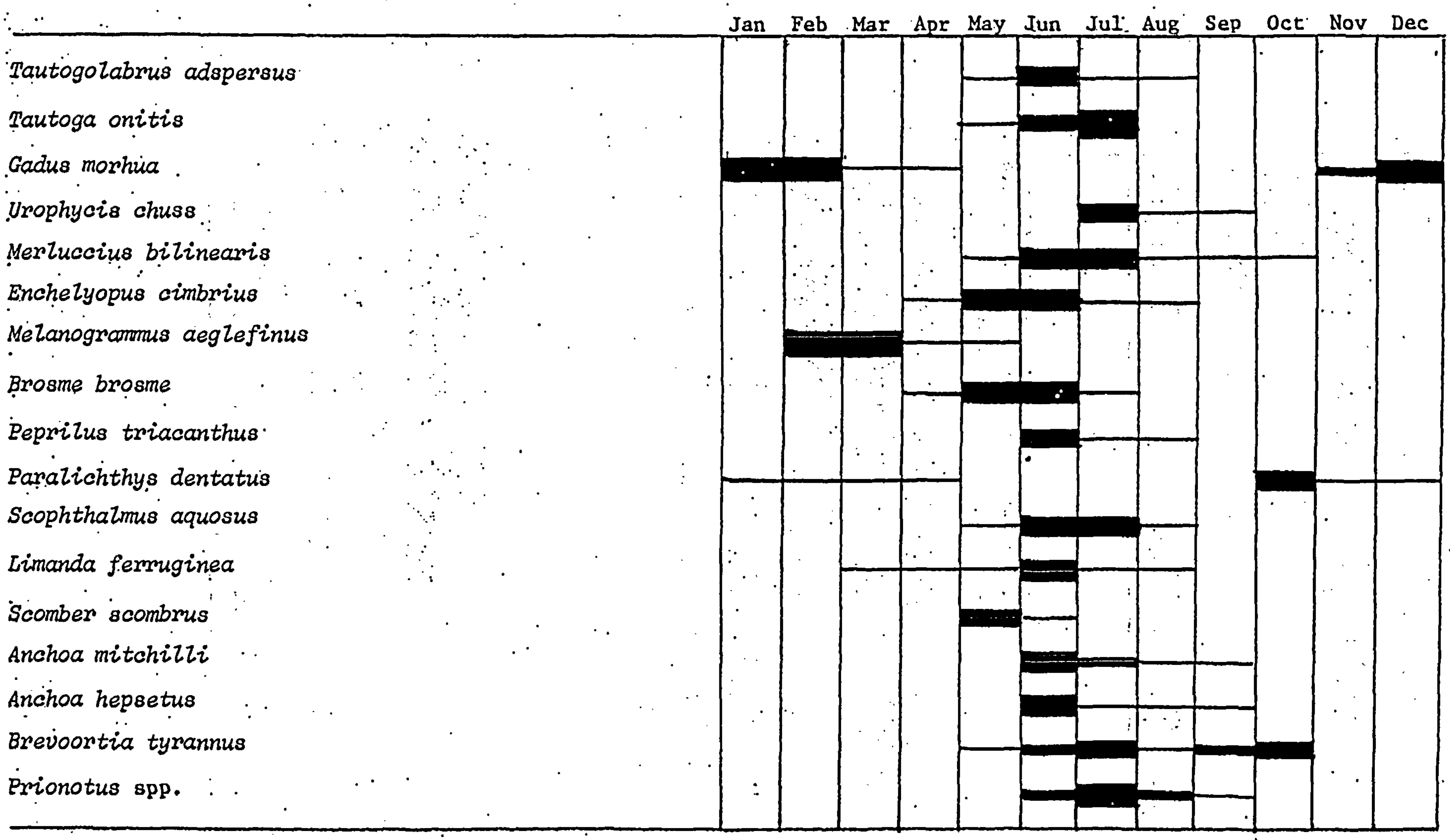


FIGURE 4.8-5. SPAWNING PERIODS OF THOSE SPECIES WHOSE EGGS ARE FOUND MOST ABUNDANTLY IN THE ICHTHYOPLANKTON IN THE VICINITY OF MILLSTONE POINT

Thickened area indicates peak spawning period

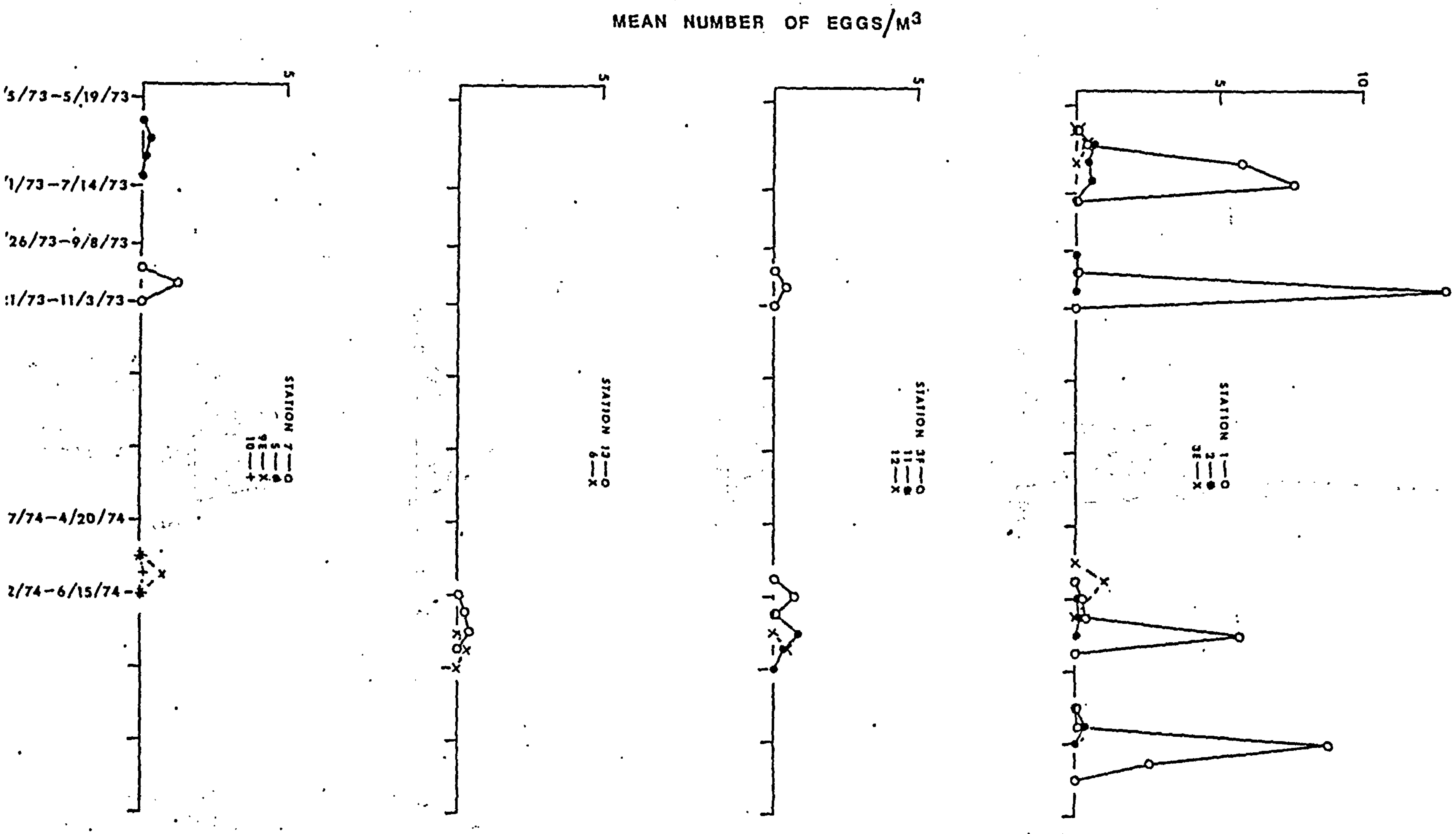


FIGURE 4.8-6. MEAN NUMBERS OF *Brevoortia tyrannus* EGGS /M^3 TAKEN AT EACH STATION FROM MAY, 1973, THROUGH MAY, 1975

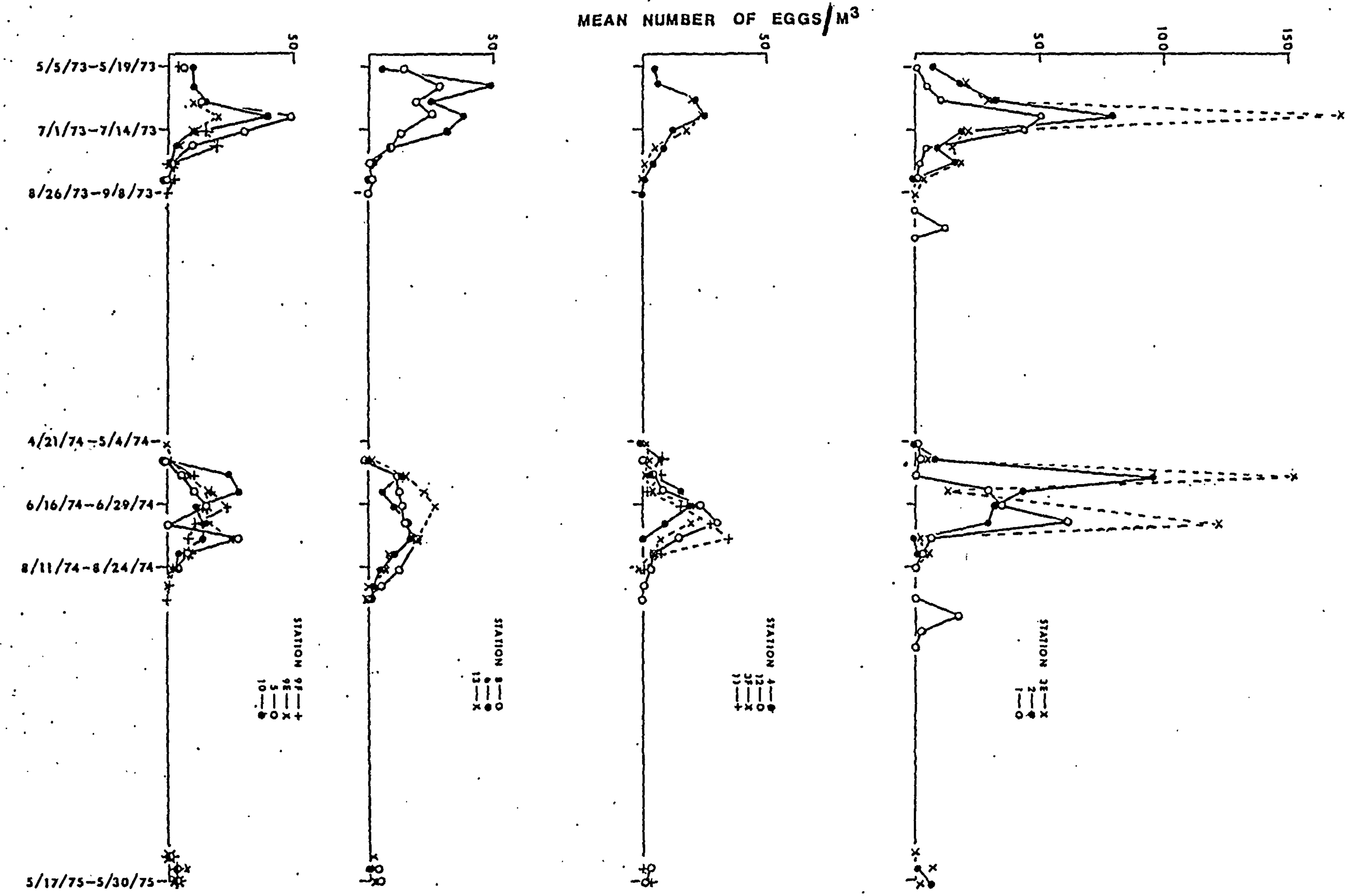


FIGURE 4.8-7. MEAN NUMBERS OF ALL EGGS /M^3 TAKEN AT EACH STATION FROM MAY, 1973 THROUGH MAY, 1975

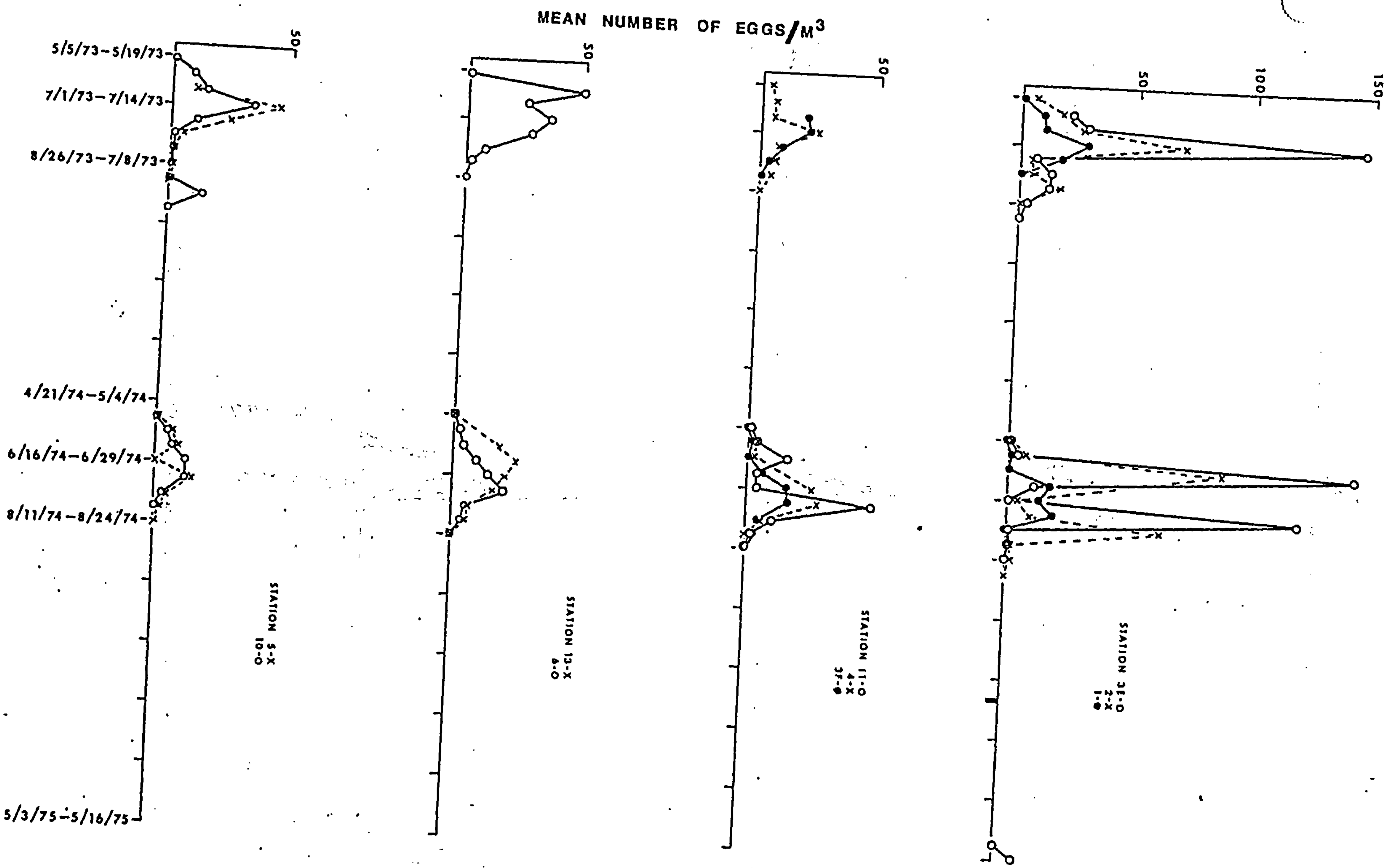


FIGURE 4.8-8. MEAN NUMBERS OF LABRIDAE/*Limanda ferruginea* EGGS /M^3 TAKEN AT EACH STATION FROM MAY, 1973, THROUGH MAY, 1975

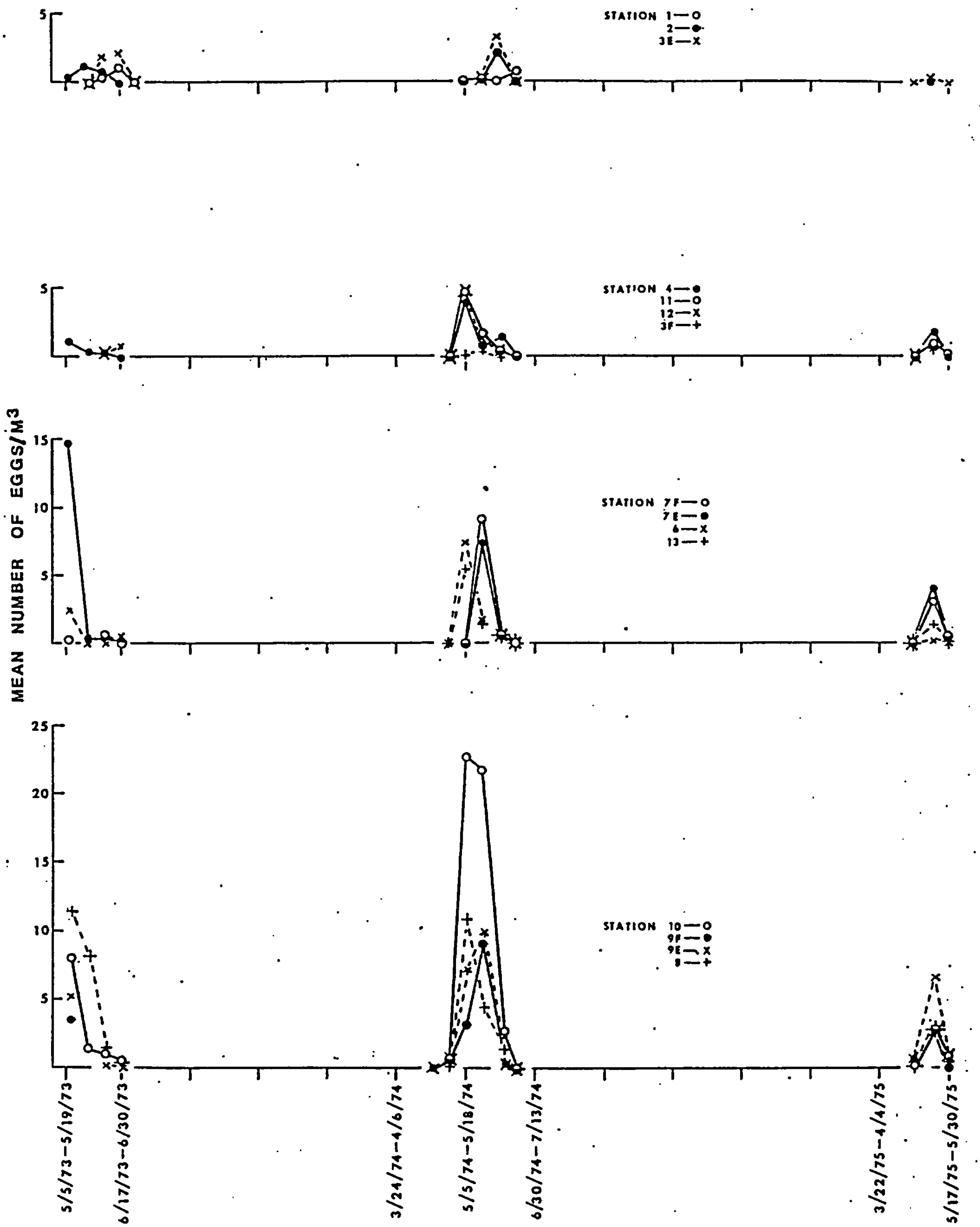


FIGURE 4.8-9. MEAN NUMBERS OF *Scomber scombrus* EGGS /M^3 TAKEN AT EACH STATION FROM MAY, 1973, THROUGH MAY, 1975

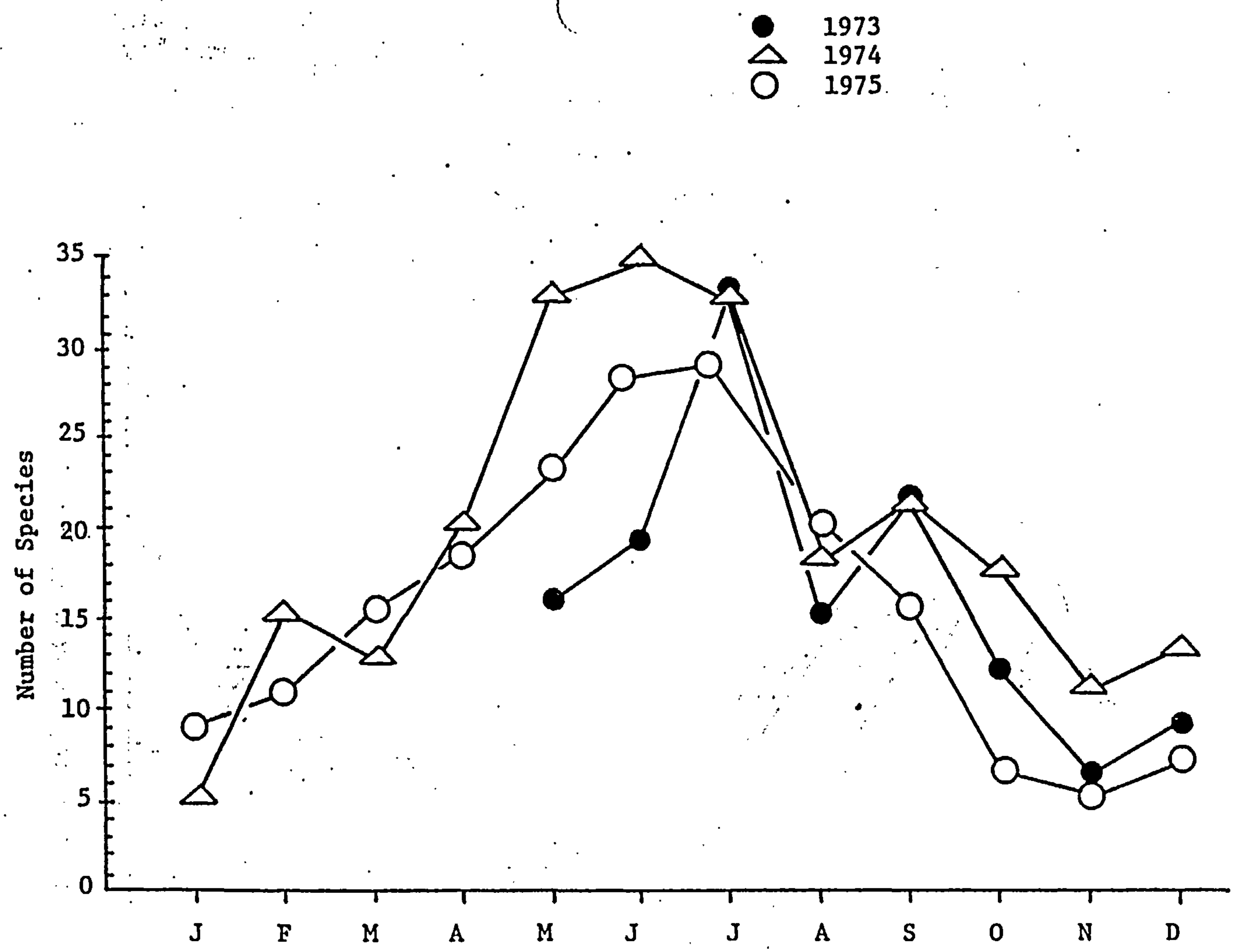


FIGURE 4.8-10. NUMBER OF SPECIES OF FISH LARVAE OCCURRING EACH MONTH FROM DAY OBLIQUE .333mm SAMPLES DURING 1973, 1974, AND 1975 IN THE MILLSTONE POINT AREA

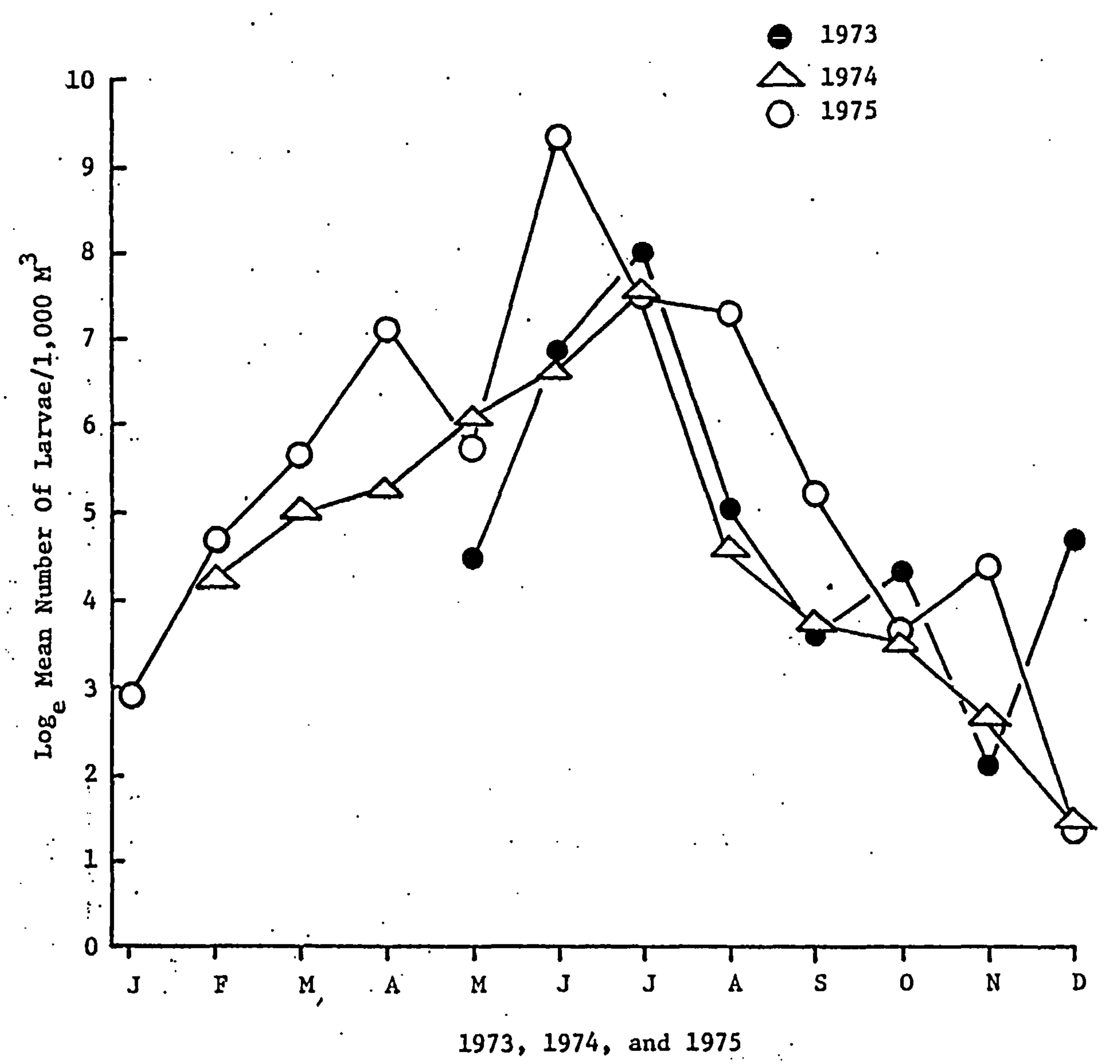


FIGURE 4.8-11. LOG_e NUMBER OF OVERALL MEAN DENSITY OF FISH LARVAE PER 1,000 CUBIC METERS OF WATER FILTERED TAKEN AT ALL STATIONS IN THE MILLSTONE BIGHT IN DAY OBLIQUE .333 mm MESH SAMPLES

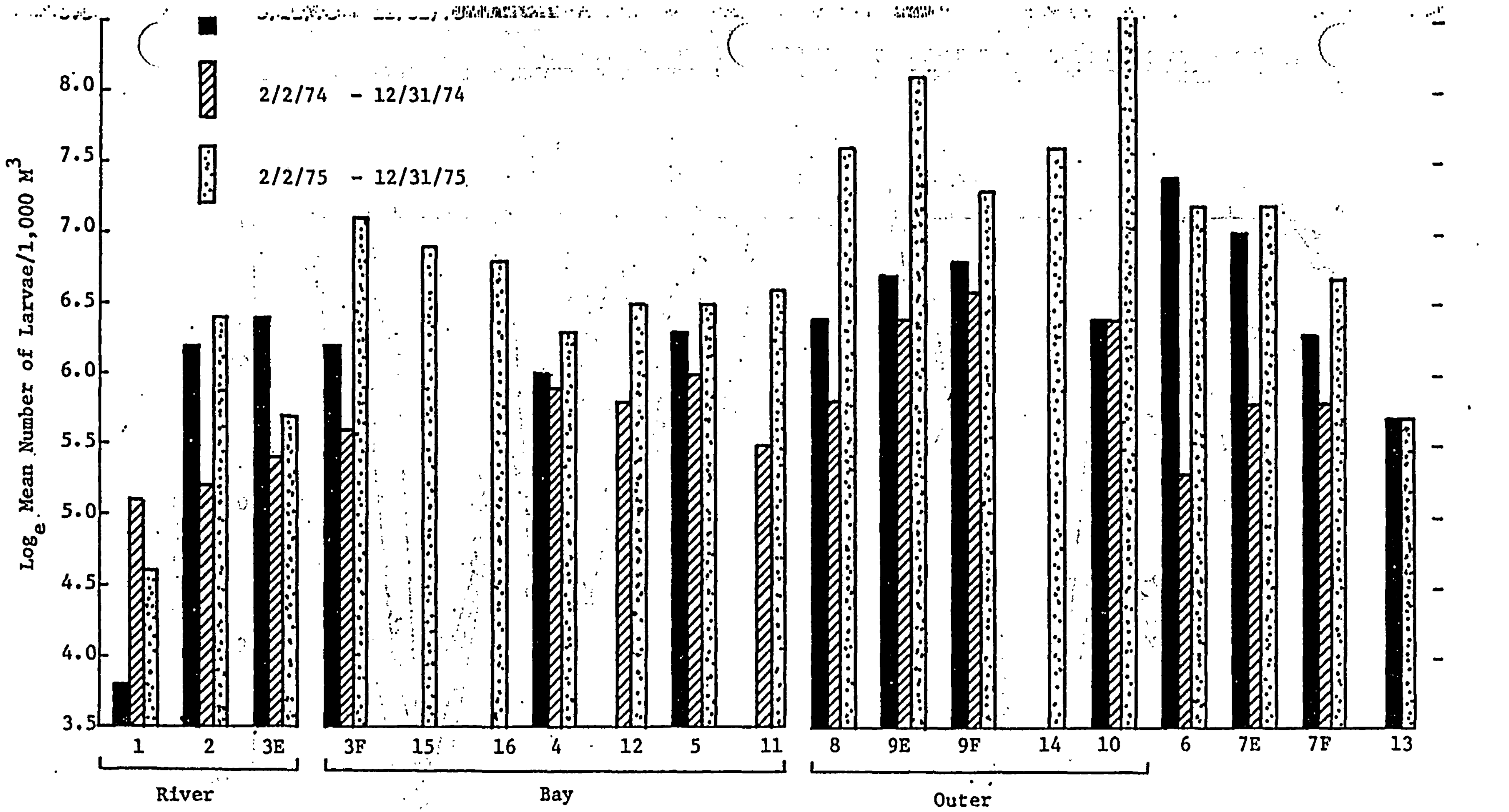


FIGURE 4.8-12. LOG$_e$ OVERALL MEAN NUMBER OF LARVAE PER 1,000 CUBIC METERS OF WATER FILTERED TAKEN IN DAY OBLIQUE .333 MESH SAMPLES TAKEN AT EACH STATION DURING THE PERIODS 5/12/73 to 12/31/73, 2/2/74 to 12/31/74, AND 2/7/75 to 12/31/75

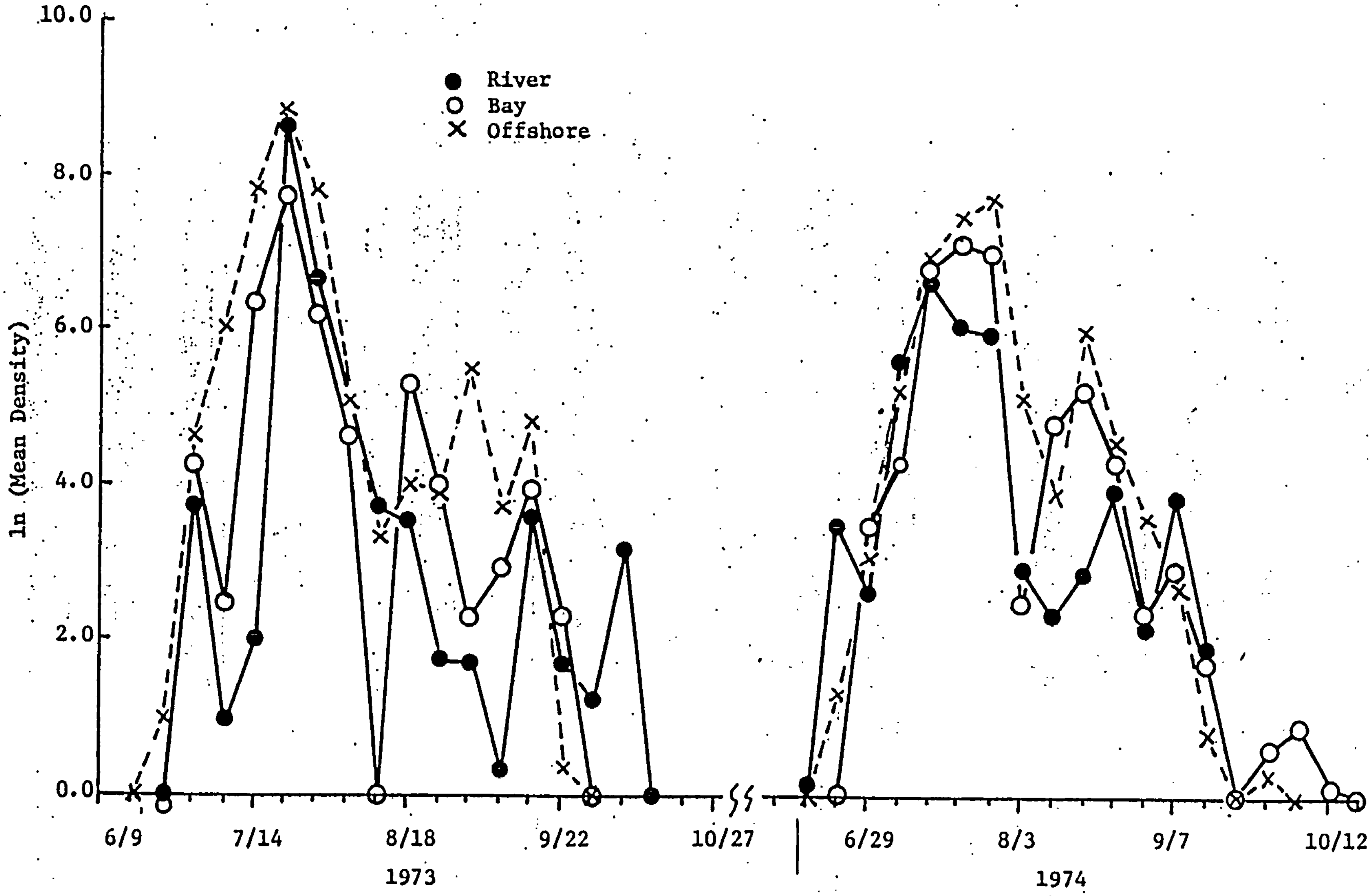


FIGURE 4.8-13. LOG$_e$ OVERALL MEAN DENSITY *Anchoa* spp. LARVAE PER 1000 CUBIC METERS OF WAT FILTERED IN DAYTIME OBLIQ 333 mm MESH SAMPLES FOR EACH WEEK AT RIVER, BA AND OFFSHORE STATION GROUP

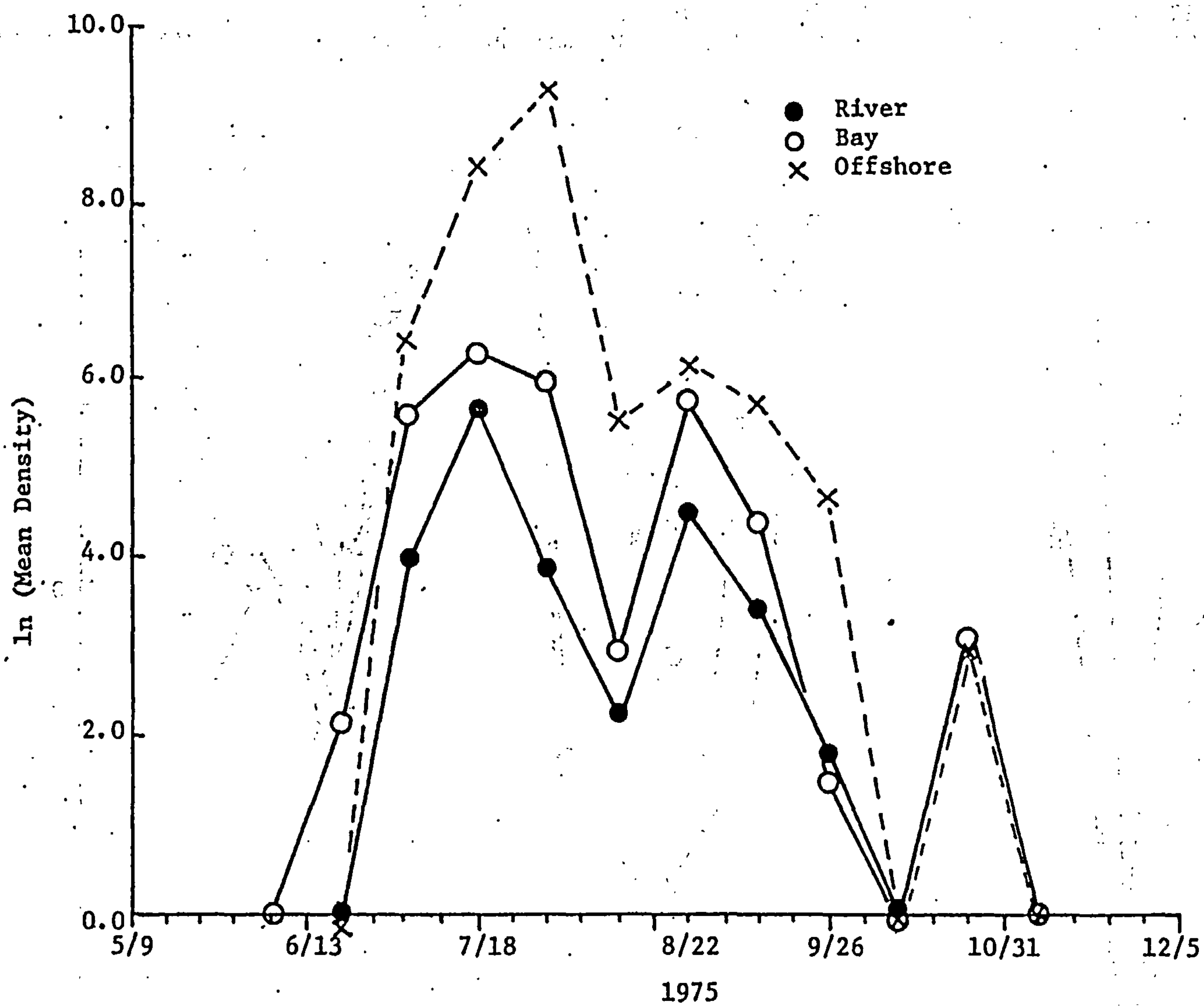


FIGURE 4.8-14. LOG$_e$ OVERALL MEAN DENSITY OF *Anchoa* spp. LARVAE PER 1000 CUBIC METERS OF WATER FILTERED IN DAYTIME OBLIQUE .333 mm MESH SAMPLES FOR EACH WEEK AT RIVER, BAY, AND OFFSHORE STATION GROUPS

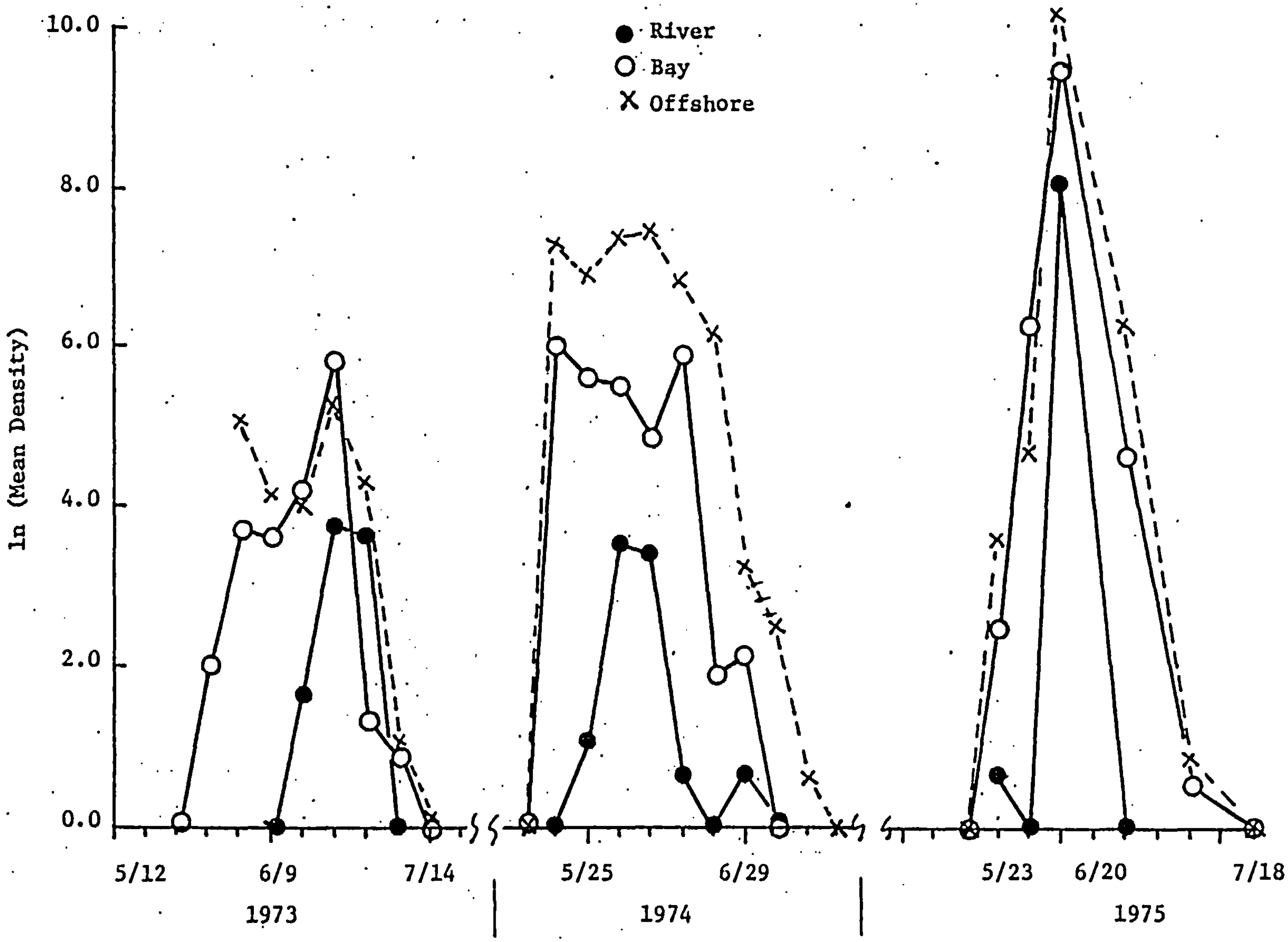


FIGURE 4.8-15. LOG$_e$ OVERALL MEAN DENSITY OF *Scomber scombrus* LARVAE PER 1000 CUBIC METERS OF WATER FILTERED IN DAYTIME OBLIQUE .333 mm MESH SAMPLES FOR EACH WEEK AT RIVER, BAY, AND OFFSHORE STATION GROUPS

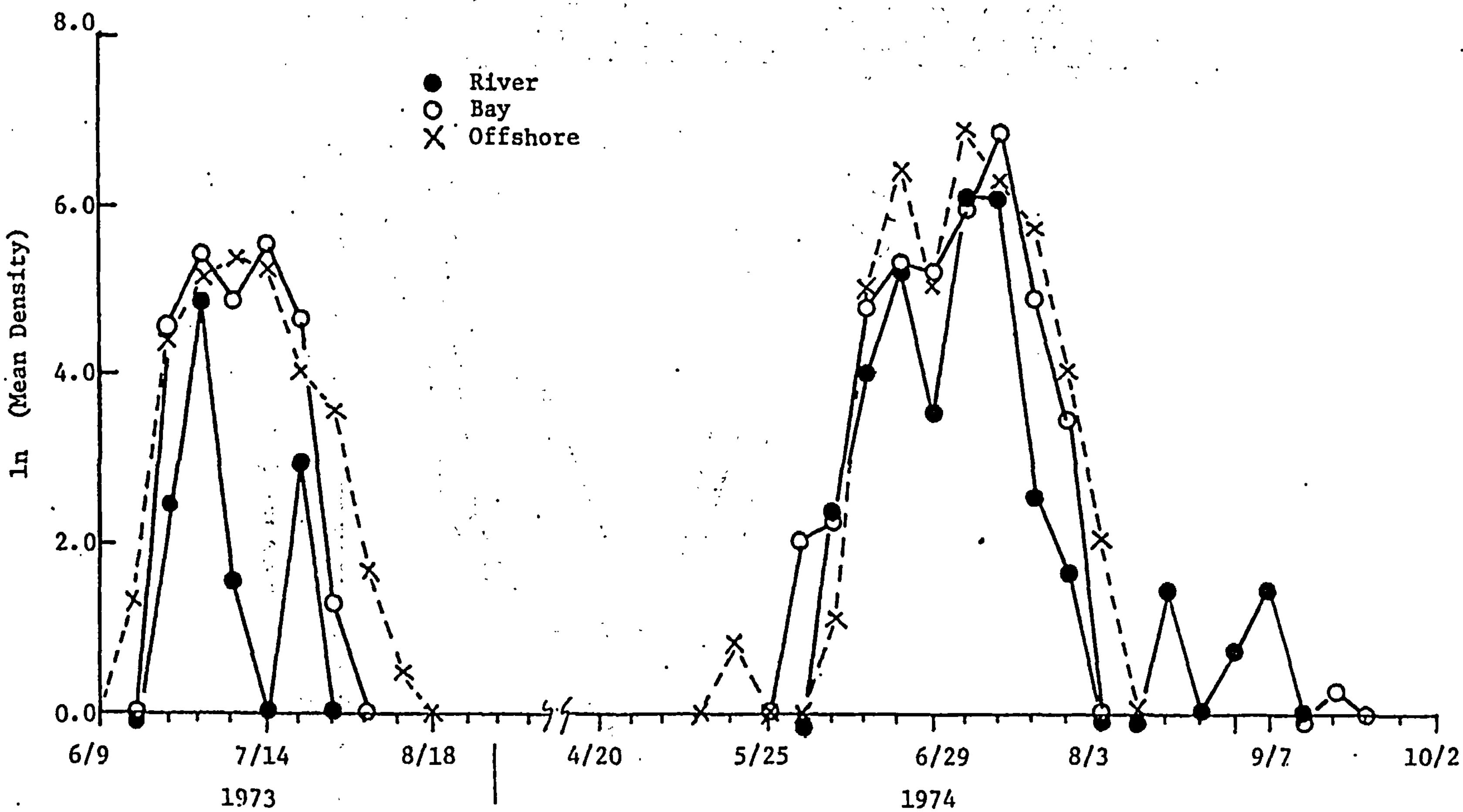


FIGURE 4.8-16. LOG$_e$ OVERALL MEAN DENSITY OF *Tautogolabrus adspersus* LARVAE PER 1000 CUBIC METERS OF WATER FILTERED IN DAYTIME OBLIQUE .333 mm MESH SAMPLES FOR EACH WEEK AT RIVER, BAY, AND OFFSHORE STATION GROUPS

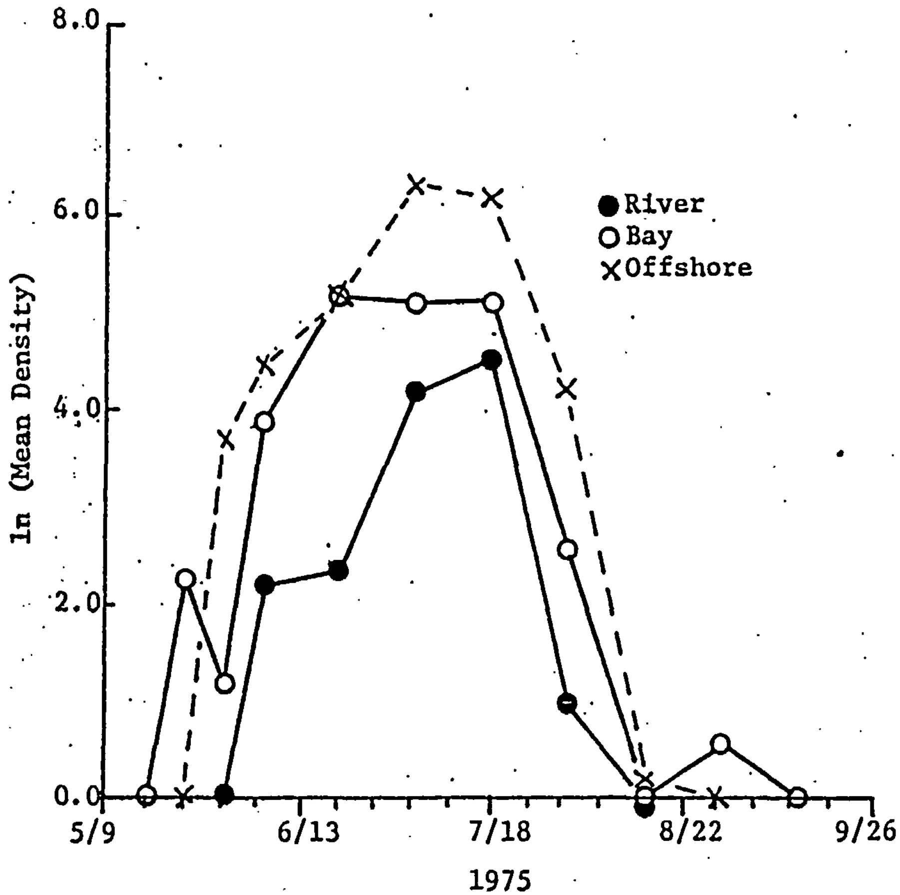


FIGURE 4.8-17. LOG$_e$ OVERALL MEAN DENSITY OF *Tautogolabrus adspersus* LARVAE PER 1000 CUBIC METERS OF WATER FILTERED IN DAYTIME OBLIQUE .333 mm MESH SAMPLES FOR EACH WEEK AT RIVER, BAY, AND OFFSHORE STATION GROUPS

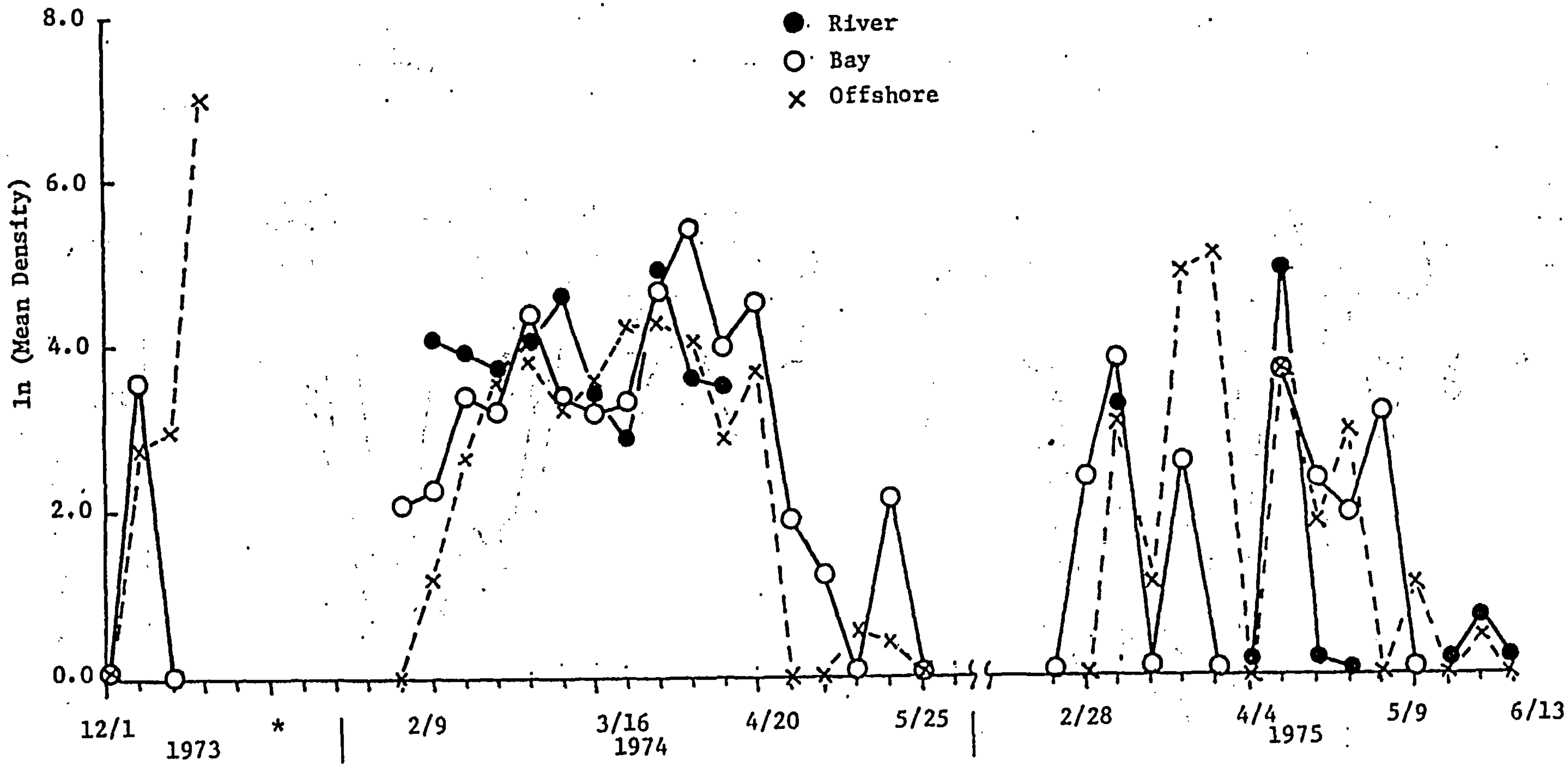


FIGURE 4.8-18. LOG$_e$ OVERALL MEAN DENSITY OF *Ammodytes* spp. LARVAE PER 1000 CUBIC METERS OF WATER FILTERED IN DAYTIME OBLIQUE .333 mm MESH SAMPLES FOR EACH WEEK AT RIVER, BAY, AND OFFSHORE STATION GROUPS

*No samples Weeks 34 through 38.

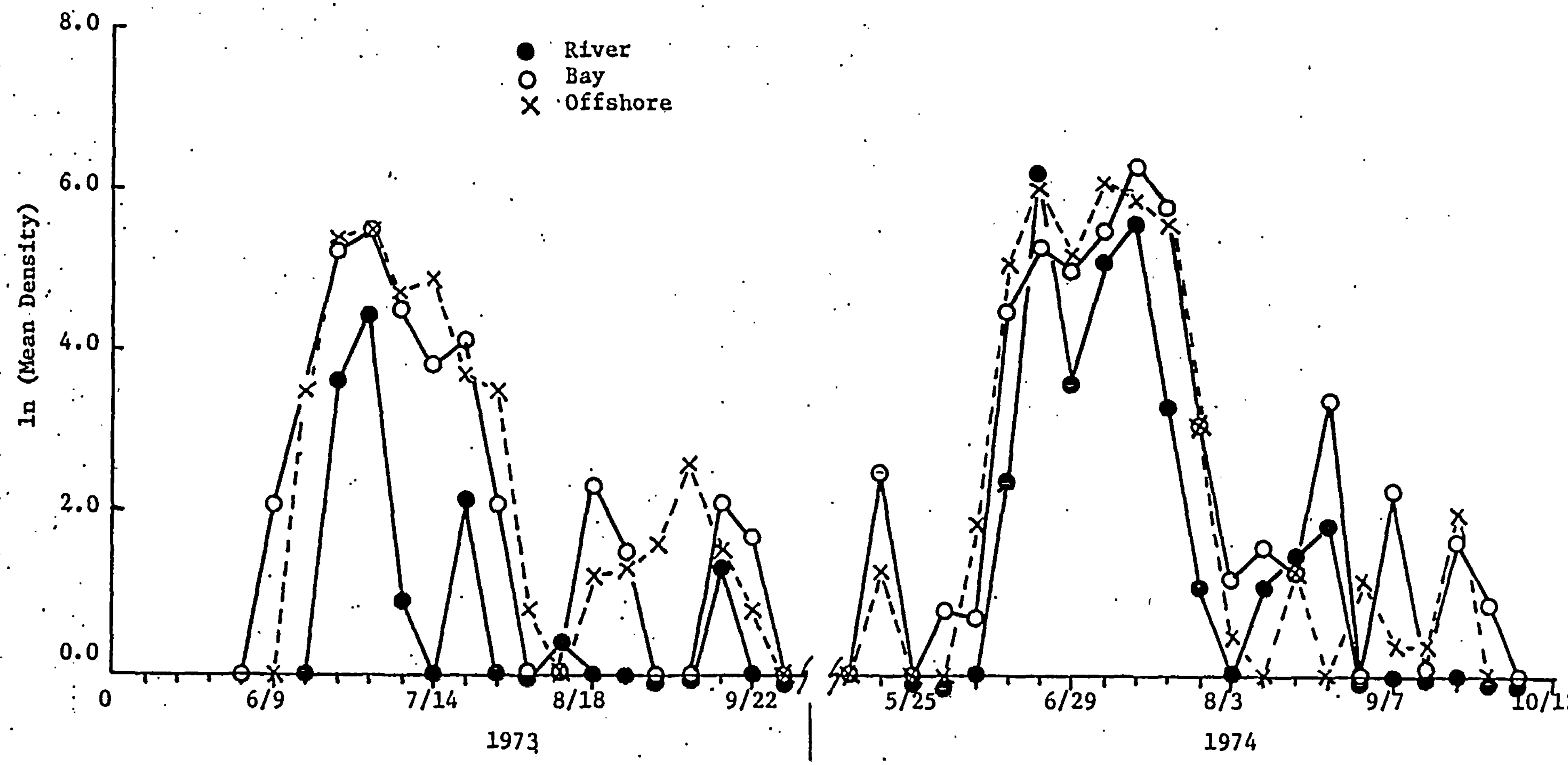


FIGURE 4.8-19. LOG$_e$ OVERALL MEAN DENSITY OF *Tautoga onitis* LARVAE PER 1000 CUBIC METERS OF WATER FILTERED IN DAYTIME OBLIQUE .333 mm MESH SAMPLES FOR EACH WEEK AT RIVER, BAY, AND OFFSHORE STATION GROUPS

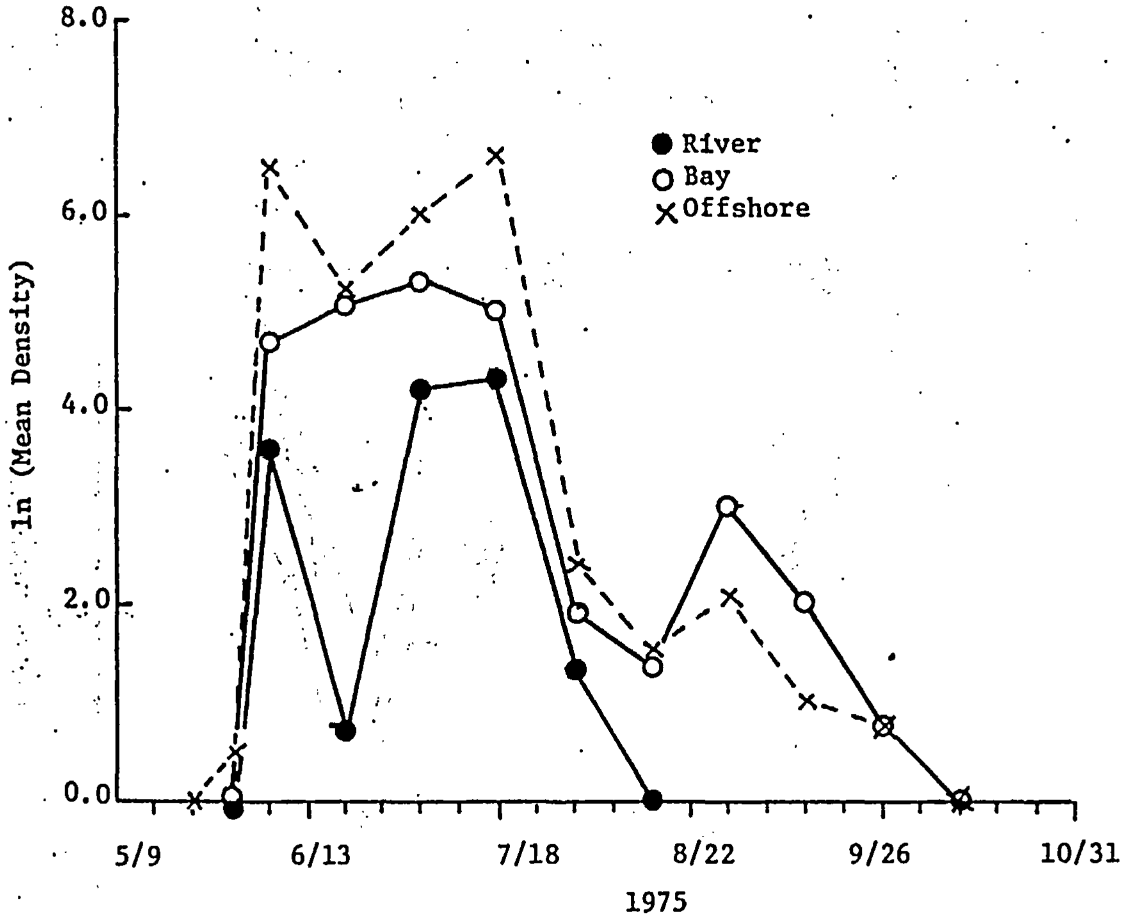


FIGURE 4.8-20. LOG_e OVERALL MEAN DENSITY OF *Tautoga onitis* LARVAE PER 1000 CUBIC METERS OF WATER FILTERED IN DAYTIME OBLIQUE .333 mm MESH SAMPLES FOR EACH WEEK AT RIVER, BAY, AND OFFSHORE STATION GROUPS

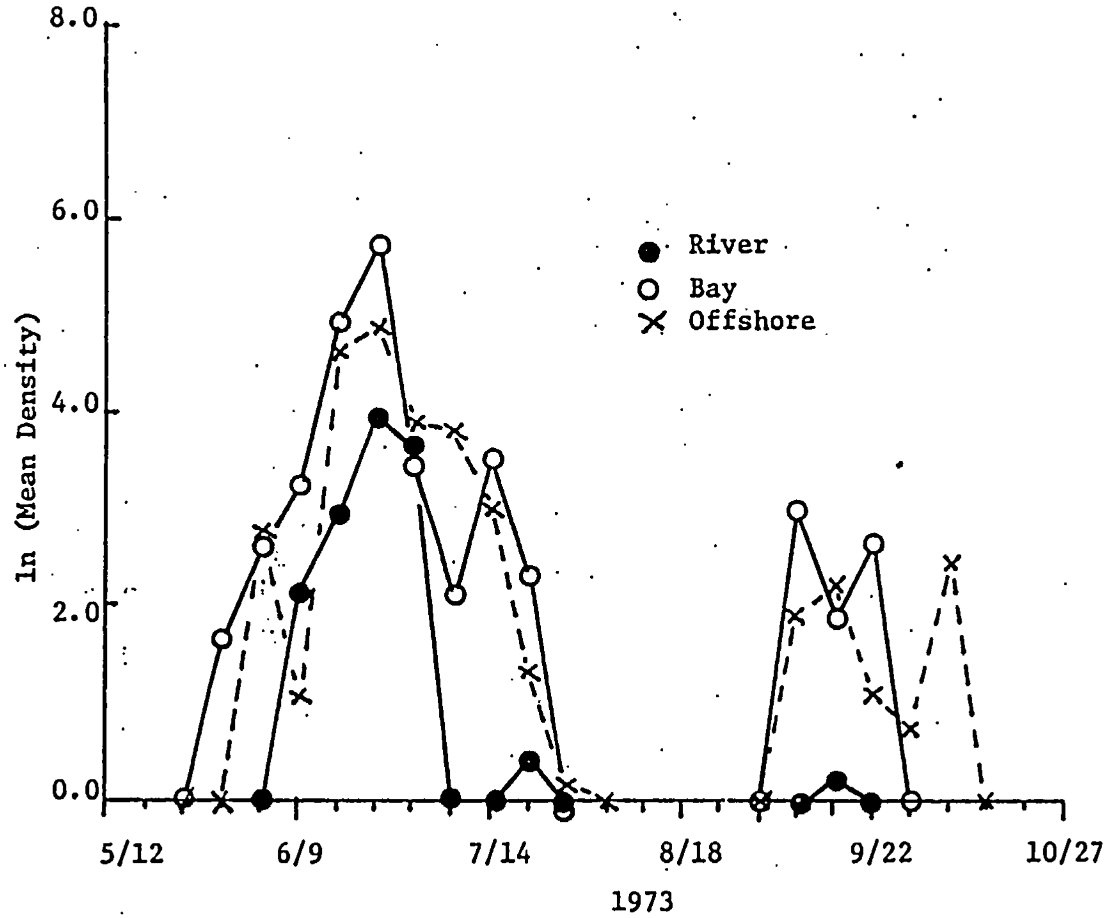


FIGURE 4.8-21. LOG_e OVERALL MEAN DENSITY OF *Scophthalmus aquosus* LARVAE PER 1000 CUBIC METERS OF WATER FILTERED IN DAYTIME OBLIQUE .333 mm MESH SAMPLES FOR EACH WEEK AT RIVER, BAY, AND OFFSHORE STATION GROUPS

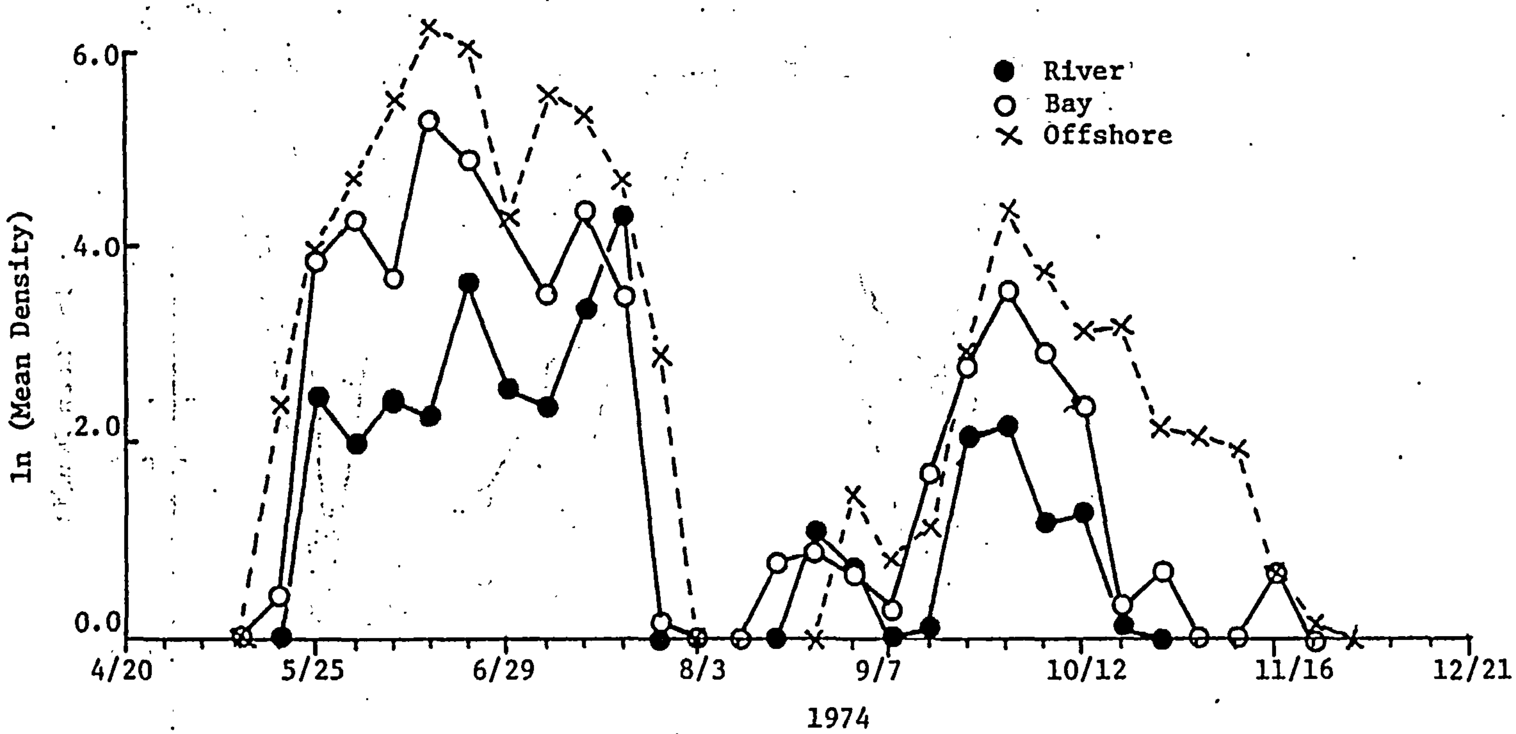


FIGURE 4.8-22. LOG$_e$ OVERALL MEAN DENSITY OF *Scophthalmus aquosus* LARVAE PER 1000 CUBIC METERS OF WATER FILTERED IN DAYTIME OBLIQUE .333 mm MESH SAMPLES FOR EACH WEEK AT RIVER, BAY, AND OFFSHORE STATION GROUPS

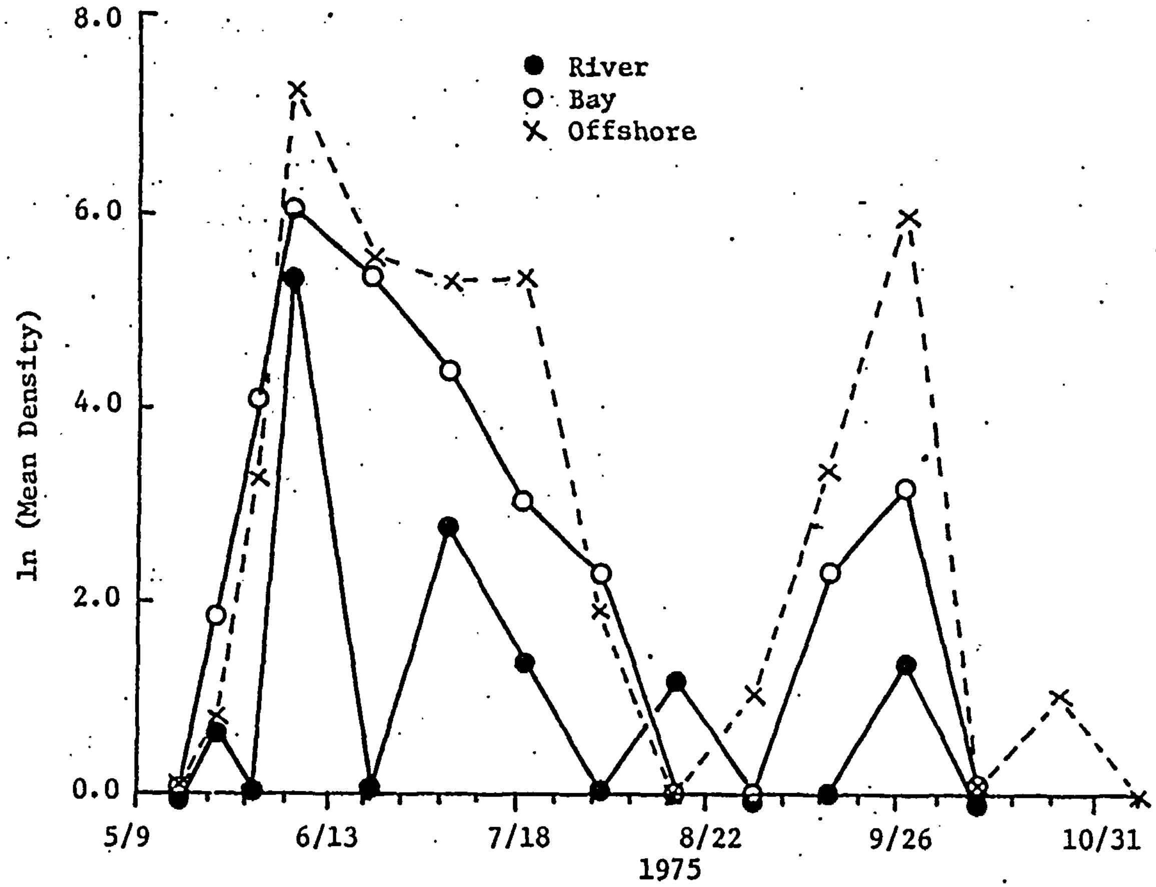


FIGURE 4.8-23. LOG$_e$ OVERALL MEAN DENSITY OF *Scophthalmus aquosus* LARVAE PER 1000 CUBIC METERS OF WATER FILTERED IN DAYTIME OBLIQUE .333 mm MESH SAMPLES FOR EACH WEEK AT RIVER, BAY, AND OFFSHORE STATION GROUPS

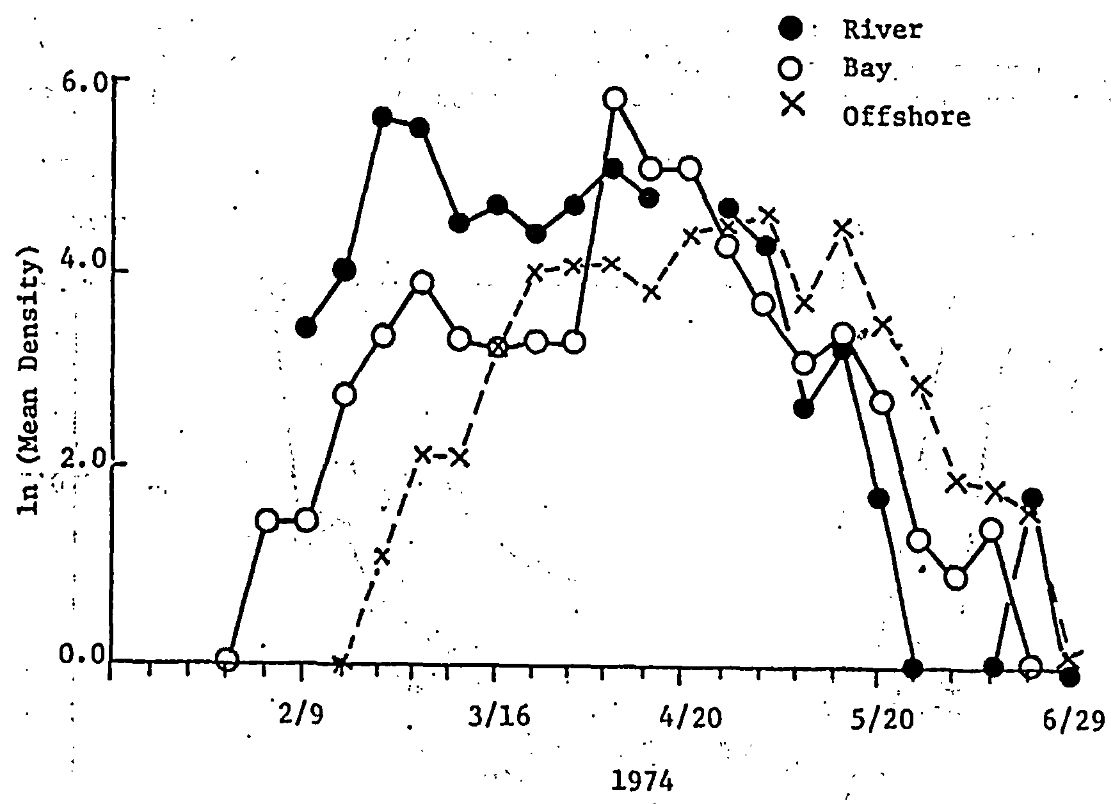


FIGURE 4.8- 24. LOG$_e$ OVERALL MEAN DENSITY OF *Pseudopleuronectes americanus* LARVAE PER 1000 CUBIC METERS OF WATER FILTERED IN DAYTIME OBLIQUE .333 mm MESH SAMPLES FOR EACH WEEK AT RIVER, BAY, AND OFFSHORE STATION GROUPS

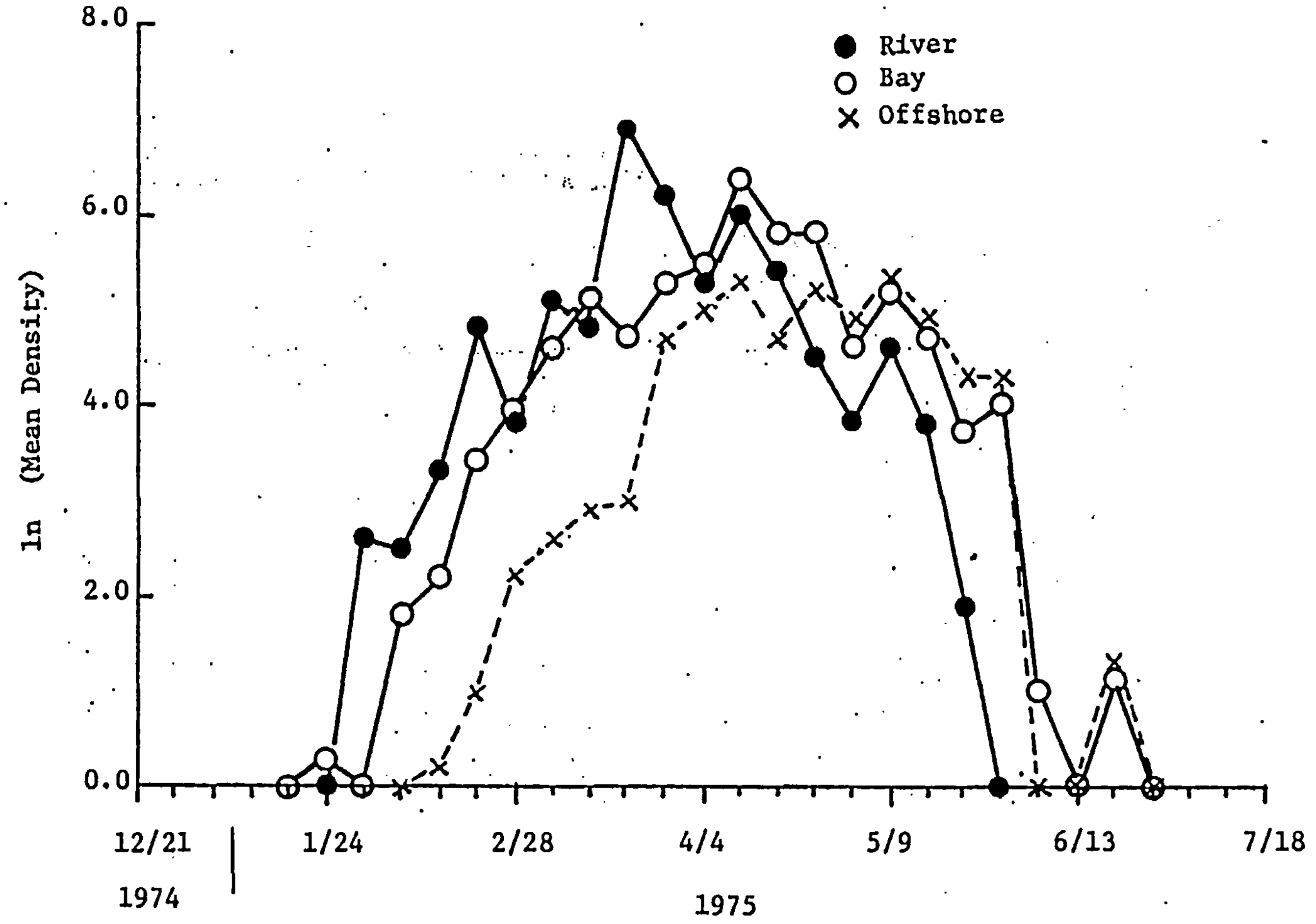


FIGURE 4.8-25. LOG_e OVERALL MEAN DENSITY OF *Pseudopleuronectes americanus* LARVAE PER 1000 CUBIC METERS OF WATER FILTERED IN DAYTIME OBLIQUE .333 mm MESH SAMPLES FOR EACH WEEK AT RIVER, BAY, AND OFFSHORE STATION GROUPS

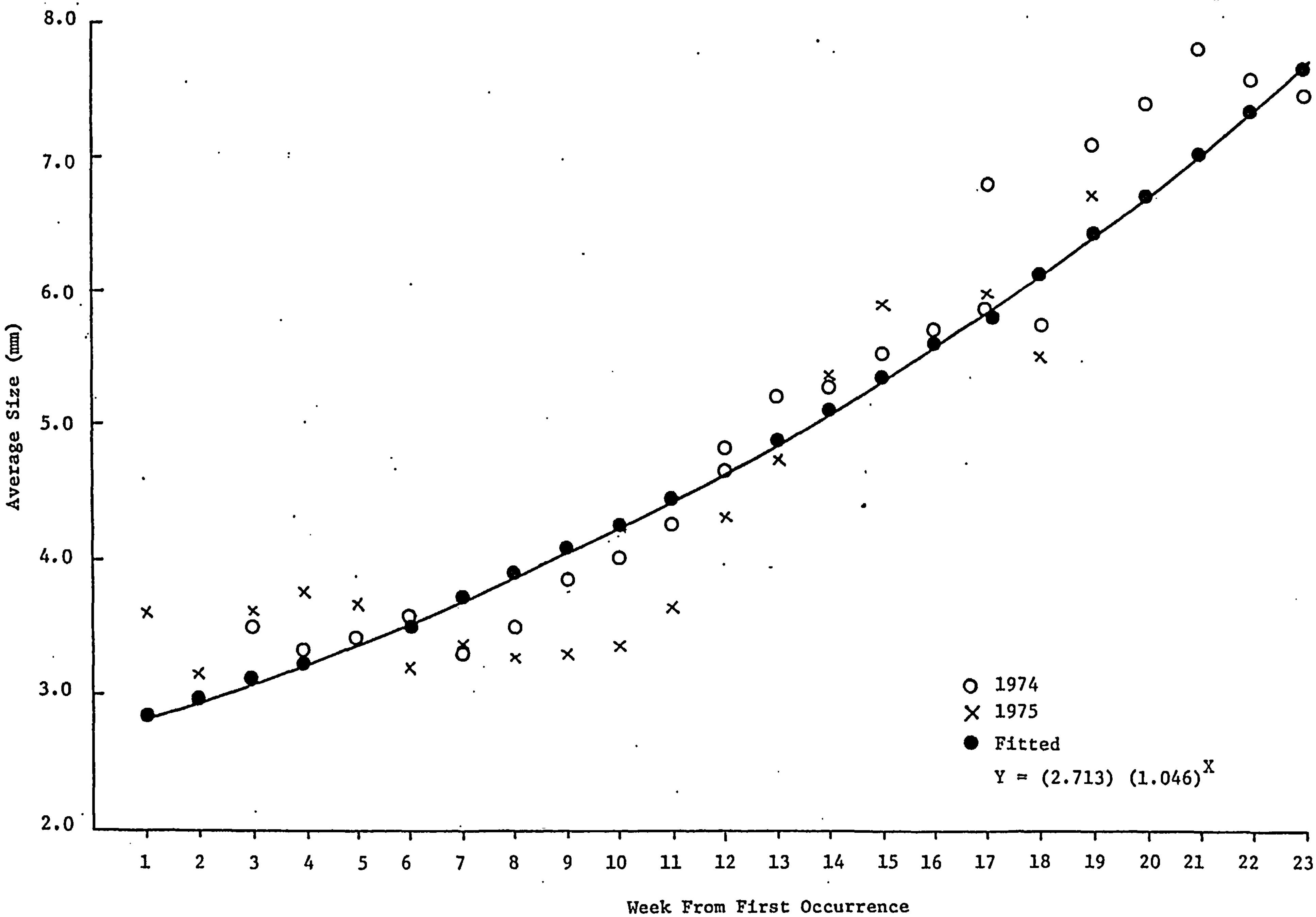


FIGURE 4.8-26. CURVE FITTED TO WEEKLY MEAN WINTER FLOUNDER LARVAE LENGTHS FROM 1974 AND 1975 DAY OBLIQUE .333 mm MESH SAMPLES

TABLE 4.9-1 RANK BY ACTUAL ABUNDANCE OF SHORE-ZONE FISH SPECIES CAPTURED BY SEINE IN THE MILLSTONE POINT AREA FROM MAY, 1969, THROUGH DECEMBER, 1975

Species	Total Number	Percent of Total	Cumulative Percent
Menidia menidia	55,898	64.3	64.3
Fundulus majalis	5,946	6.8	71.1
Fundulus heteroclitus	5,701	6.5	77.6
Menidia spp. (immature)	4,501	5.2	82.8
Brevoortia tyrannus	4,314	5.0	87.8
Ammodytes americanus	3,371	3.9	91.7
Menidia beryllina	2,542	2.9	94.6
Apeltes quadracus	1,437	1.7	96.3
Pungitius pungitius	746	0.9	97.2
Cyprinodon variegatus	571	0.7	97.9
Alosa pseudoharengus	455	0.5	98.4
Mugil cephalus	294	0.3	98.7
Gasterosteus aculeatus	256	0.3	99.0
Anguilla rostrata	186	0.2	99.2
Clupea harengus harengus	155	0.2	99.4
Syngnathus fuscus	103	0.1	99.5
Alosa aestivalis	84	0.1	99.6
Fundulus spp. (immature)	63	<0.1	
Microgadus tomcod	50	<0.1	
Pomatomus saltatrix	37	<0.1	
Pseudopleuronectes americanus	35	<0.1	
Menticirrhus saxatilis	31	<0.1	
Osmerus mordax	22	<0.1	
Strongylura marina	16	<0.1	
Sphoeroides maculatus	14	<0.1	
Anchoa mitchilli	13	<0.1	
Myoxocephalus aenaeus	13	<0.1	
Caranx crysos	11	<0.1	
Morone americana	10	<0.1	
Lucania parva	6	<0.1	
Scomberesox saurus	6	<0.1	
Urophycis chuss	4	<0.1	
Tautoga onitis	3	<0.1	
Tautogolabrus adsperuss	3	<0.1	
Urophycis tenuis	3	<0.1	
Clupeidae (immature)	2	<0.1	
Scophthalmus aquosus	1	<0.1	
Trachinotus falcatus	1	<0.1	

TABLE 4.9-2 RANK BY RELATIVE ABUNDANCE OF SHORE-ZONE FISH SPECIES CAPTURED BY SEINE IN THE MILLSTONE POINT AREA FROM MAY, 1969, THROUGH DECEMBER, 1975

Species	Total Points	Percent of Points	Cumulative Percent
Menidia menidia	502	17.1	17.1
Fundulus majalis	368	12.5	29.6
Fundulus heteroclitus	356	12.1	41.7
Menidia beryllina	324	11.0	52.7
Apeltes quadracus	240	8.2	60.9
Cyprinodon variegatus	131	4.5	65.4
Gasterosteus aculeatus	113	3.8	69.2
Ammodytes americanus	108	3.7	72.9
Syngnathus fuscus	103	3.5	76.4
Anguilla rostrata	85	2.9	79.3
Pungitius pungitius	81	2.8	82.1
Brevoortia tyrannus	73	2.5	84.6
Pseudopleuronectes americanus	61	2.1	86.7
Microgadus tomcod	52	1.8	88.5
Mugil cephalus	48	1.6	90.1
Menidia spp.	46	1.6	91.7
Menticirrhus saxatilis	31	1.0	92.7
Pomatomus saltatrix	23	0.8	93.5
Myoxocephalus aenaeus	22	0.7	94.2
Sphoeroides maculatus	19	0.6	94.8
Tautoga onitis	19	0.6	95.4
Clupea harengus harengus	14	0.5	95.9
Alosa aestivalis	12	0.4	96.3
Osmerus mordax	12	0.4	96.7
Urophycis chuss	12	0.4	97.1
Fundulus spp. (immature)	11	0.4	97.5
Trachinotus falcatus	11	0.4	97.9
Anchoa mitchilli	9	0.3	98.2
Clupeidae (immature)	9	0.3	98.5
Morone americana	9	0.3	98.9
Alosa pseudoharengus	7	0.2	99.1
Urophycis tenuis	7	0.2	99.3
Strongylura marina	5	0.2	99.5
Lucania parva	4	0.1	99.6
Tautogolabrus adspersus	3	0.1	99.7
Scophthalmus aquosus	2	0.1	99.8
Caranx crysos	1	<0.1	
Scomberesox saurus	0	<0.1	100.0

TABLE 4.9-3 ACTUAL ABUNDANCE (TOP 95 PERCENT) AND RELATIVE ABUNDANCE (TOP 80 PERCENT) OF SHORE-ZONE FISH SPECIES CAPTURED BY SEINE AT WHITE POINT EACH YEAR FROM MAY, 1969, THROUGH DECEMBER, 1974

Year	Actual Abundance: Species	Number	Percent	Cumulative Percent	Relative Abundance: Species	Points	Percent	Cumulative Percent
1969[a]	*Brevoortia tyrannus*	752	46	46	*Menidia menidia*	28	18	18
	Menidia menidia	520	32	78	*Fundulus majalis*	19	12	30
	Ammodytes americanus	158	10	88	*Brevoortia tyrannus*	15	9	39
	Fundulus majalis	92	6	94	*Menidia beryllina*	14	9	48
	Menidia beryllina	50	3	97	*Ammodytes americanus*	9	6	54
					Microgadus tomcod	9	6	60
					Apeltes quadracus	8	5	65
					Syngnathus fuscus	7	4	69
					Anchoa mitchilli	7	4	73
					Sphoeroides maculatus	7	4	77
					Urophycis tenuis	7	4	81
1970	*Menidia menidia*	808	68	68	*Menidia menidia*	40	40	40
	Fundulus majalis	234	20	88	*Fundulus majalis*	18	18	58
	Brevoortia tyrannus	96	8	96	*Brevoortia tyrannus*	14	14	72
					Fundulus heteroclitus	8	8	80
1971	*Menidia menidia*	961	52	52	*Menidia menidia*	29	17	17
	Brevoortia tyrannus	754	41	93	*Fundulus majalis*	22	13	30
	Fundulus heteroclitus	47	2	95	*Fundulus heteroclitus*	17	10	40
					Menidia beryllina	16	9	49
					Pseudopleuronectes americanus	15	9	58
					Brevoortia tyrannus	10	6	64
					Microgadus tomcod	10	6	70
					Cyprinodon variegatus	9	5	75
					Ammodytes americanus	8	5	80
1972	*Menidia menidia*	1,066	74	74	*Menidia menidia*	40	30	30
	Fundulus majalis	221	15	89	*Fundulus majalis*	27	20	50
	Brevoortia tyrannus	77	5	94	*Gasterosteus aculeatus*	16	12	62
	Fundulus heteroclitus	67	5	99	*Fundulus heteroclitus*	15	11	73
					Brevoortia tyrannus	8	6	79
					Apeltes quadracus	7	5	84
1973	*Menidia menidia*	305	39	39	*Menidia menidia*	49	29	29
	Ammodytes americanus	198	25	64	*Fundulus majalis*	35	20	49
	Fundulus heteroclitus	151	19	83	*Ammodytes americanus*	15	9	58
	Fundulus majalis	107	14	97	*Pseudopleuronectes americanus*	15	9	67
					Syngnathus fuscus	14	8	75
					Microgadus tomcod	10	6	81
1974[b]	*Menidia menidia*	250	47	47	*Menidia menidia*	68	29	29
	Menidia beryllina	176	33	80	*Menidia beryllina*	45	19	48
	Menidia spp. (immature)	57	11	91	*Fundulus majalis*	19	8	56
	Gasterosteus aculeatus	20	4	95	*Ammodytes americanus*	18	8	64
					Gasterosteus aculeatus	17	7	71
					Fundulus heteroclitus	16	7	78
					Pseudopleuronectes americanus	16	7	85
1975[b]	*Ammodytes americanus*	2,747	81	81	*Fundulus majalis*	37	20	20
	Menidia menidia	173	5	86	*Fundulus heteroclitus*	29	16	36
	Menidia beryllina	161	5	91	*Menidia menidia*	27	15	51
	Fundulus heteroclitus	146	4	95	*Menidia beryllina*	27	15	66
					Ammodytes americanus	21	12	78
					Menidia spp. (immature)	9	5	83

(a) Four sampling periods
(b) Eight sampling periods

TABLE 4.9-4 ACTUAL ABUNDANCE (TOP 95 PERCENT) AND RELATIVE ABUNDANCE (TOP 80 PERCENT) OF SHORE-ZONE FISH SPECIES CAPTURED BY SEINE AT JORDAN COVE EACH YEAR FROM MAY, 1969, THROUGH DECEMBER, 1974

	Actual Abundance				Relative Abundance			
Year	Species	Number	Percent	Cumulative Percent	Species	Points	Percent	Cumulative Percent
	Fundulus majalis	2,394	55	55	*Fundulus majalis*	36	19	19
	Brevoortia tyrannus	796	18	73	*Menidia menidia*	30	16	35
	Menidia menidia	325	8	81	*Gasterosteus aculeatus*	27	14	49
1969[a]	*Apeltes quadracus*	217	5	86	*Menidia beryllina*	19	10	59
	Fundulus heteroclitus	161	4	90	*Brevoortia tyrannus*	18	9	68
	Mugil cephalus	129	3	93	*Fundulus heteroclitus*	12	6	74
	Gasterosteus aculeatus	126	3	96	*Microgadus tomcod*	9	5	79
					Apeltes quadracus	8	4	83
	Menidia menidia	2,578	65	65	*Fundulus heteroclitus*	42	17	17
	Fundulus heteroclitus	415	10	75	*Menidia menidia*	39	16	33
	Brevoortia tyrannus	377	9	84	*Fundulus majalis*	27	11	44
1970	*Fundulus majalis*	203	5	89	*Apeltes quadracus*	26	11	55
	Menidia beryllina	142	4	93	*Menidia beryllina*	20	8	63
	Apeltes quadracus	113	3	96	*Cyprinodon variegatus*	16	7	70
					Anguilla rostrata	15	6	76
					Gasterosteus aculeatus	14	6	82
	Menidia menidia	27,181	96	96	*Fundulus heteroclitus*	43	17	17
					Menidia menidia	35	14	31
					Apeltes quadracus	27	11	42
					Pungitius pungitius	25	10	52
					Fundulus majalis	22	9	61
1971					*Menidia beryllina*	13	5	66
					Cyprinodon variegatus	13	5	71
					Anguilla rostrata	12	5	76
					Syngnathus fuscus	9	4	80
	Menidia menidia	3,009	67	67	*Fundulus heteroclitus*	36	18	18
	Pungitius pungitius	671	15	82	*Apeltes quadracus*	31	15	33
	Fundulus heteroclitus	410	9	91	*Fundulus majalis*	30	15	48
1972	*Apeltes quadracus*	239	5	96	*Menidia menidia*	26	13	61
					Anguilla rostrata	20	10	71
					Menidia beryllina	16	8	79
					Pungitius pungitius	15	7	86
	Menidia menidia	3,347	65	65	*Menidia menidia*	42	19	19
	Fundulus heteroclitus	1,336	26	91	*Fundulus majalis*	32	15	34
	Fundulus majalis	185	4	95	*Apeltes quadracus*	27	12	46
1973					*Fundulus heteroclitus*	26	12	58
					Menidia beryllina	17	8	66
					Pungitius pungitius	15	7	73
					Gasterosteus aculeatus	14	6	79
					Anguilla rostrata	12	5	84
	Menidia menidia	3,362	47	47	*Fundulus heteroclitus*	59	16	16
	Menidia spp. (immature)	2,739	38	85	*Fundulus majalis*	54	15	31
	Fundulus majalis	440	6	91	*Apeltes quadracus*	51	14	44
1974[b]	*Apeltes quadracus*	296	4	95	*Menidia menidia*	44	12	56
					Menidia beryllina	25	7	63
					Anguilla rostrata	21	6	69
					Cyprinodon variegatus	21	6	75
					Pungitius pungitius	20	6	81
	Menidia spp. (immature)	1,261	34	34	*Fundulus majalis*	56	20	20
	Menidia menidia	1,012	27	61	*Fundulus heteroclitus*	41	15	35
	Fundulus majalis	691	19	80	*Menidia menidia*	38	14	49
19[illegible][b]	*Fundulus heteroclitus*	301	8	88	*Apelt*[illegible]*adracus*	34	12	[illegible]
	Apeltes quadracus	227	6	94	*Menia*[illegible]*ryllina*	27	10	[illegible]
	Menidia beryllina	163	4	98	*Cypri*[illegible] *variegatus*	18	6	[illegible]

TABLE 4.9-5 ACTUAL ABUNDANCE (TOP 95 PERCENT) AND RELATIVE ABUNDANCE (TOP 80 PERCENT) OF SHORE-ZONE FISH SPECIES CAPTURED BY SEINE AT BAY POINT EACH YEAR FROM MAY, 1969, THROUGH DECEMBER, 1974

Year	Actual Abundance Species	Number	Percent	Cumulative Percent	Relative Abundance Species	Points	Percent	Cumulative Percent
1969[a]	*Menidia beryllina*	9	35	35	*Menidia menidia*	28	22	22
	Menidia menidia	5	19	54	*Menidia beryllina*	28	22	44
	Clupea harengus harengus	4	11	65	*Clupea harengus harengus*	10	7	51
	Brevoortia tyrannus	2	8	73	*Microgadus tomcod*	10	7	58
	Strongylura marina	2	8	81	*Urophycis tenuis*	10	7	65
	Alosa pseudoharengus	1	4	85	*Alosa pseudoharengus*	9	7	72
	Fundulus majalis	1	4	89	*Fundulus majalis*	9	7	79
	Microgadus tomcod	1	4	93	*Syngnathus fuscus*	9	7	86
	Tautogolabrus adspersus	1	4	97				
1970	*Brevoortia tyrannus*	1,275	97	97	*Menidia menidia*	19	33	33
					Brevoortia tyrannus	10	18	51
					Microgadus tomcod	10	18	69
					Menidia beryllina	9	16	85
1971	*Menidia menidia*	104	74	74	*Menidia menidia*	29	44	44
	Clupea harengus harengus	30	21	95	*Clupea harengus harengus*	10	15	59
					Microgadus tomcod	10	15	74
					Menidia beryllina	9	14	88
1972	*Menidia menidia*	311	55	55	*Menidia menidia*	39	40	40
	Clupea harengus harengus	119	21	76	*Alosa aestivalis*	10	10	50
	Brevoortia tyrannus	79	14	90	*Clupea harengus harengus*	9	9	59
	Alosa aestivalis	43	8	98	*Gasterosteus aculeatus*	9	9	68
					Brevoortia tyrannus	8	8	76
					Syngnathus fuscus	8	8	84
1973	*Menidia menidia*	130	90	90	*Menidia menidia*	29	52	52
	Alosa aestivalis	12	8	98	*Alosa aestivalis*	10	18	70
					Clupea harengus harengus	9	16	86
1974[b]	*Menidia menidia*	129	85	85	*Menidia menidia*	38	24	24
	Syngnathus fuscus	6	4	89	*Syngnathus fuscus*	28	17	41
	Ammodytes americanus	5	3	92	*Urophycis chuss*	19	12	53
	Menidia beryllina	3	2	94	*Ammodytes americanus*	10	6	59
	Urophycis chuss	2	1	95	*Apeltes quadracus*	10	6	65
					Gasterosteus aculeatus	10	6	71
					Menidia beryllina	10	6	77
					Brevoortia tyrannus	9	6	81

(a) Four sampling periods
(b) Eight sampling periods

TABLE 4.9-6 ACTUAL ABUNDANCE (TOP 95 PERCENT) AND RELATIVE ABUNDANCE (TOP 80 PERCENT) OF SHORE-ZONE FISH SPECIES CAPTURED BY SEINE AT GI[illegible]TS NECK FROM MAY, 1969, THROUGH DECEMBER, 1974

Year	Actual Abundance: Species	Number	Percent	Cumulative Percent	Relative Abundance: Species	Points	Percent	Cumulative Percent
1969(a)	*Menidia menidia*	839	96	96	*Menidia menidia*	30	23	23
					Fundulus majalis	18	14	37
					Syngnathus fuscus	18	14	51
					Gasterosteus aculeatus	18	14	65
					Menidia beryllina	9	7	72
					Microgadus tomcod	9	7	79
					Brevoortia tyrannus	7	5	84
1970	*Menidia menidia*	702	88	88	*Menidia menidia*	39	27	27
	Brevoortia tyrannus	74	9	97	*Fundulus majalis*	27	18	45
					Brevoortia tyrannus	17	12	57
					Menidia beryllina	17	12	69
					Gasterosteus aculeatus	10	7	76
					Fundulus heteroclitus	8	5	81
1971	*Menidia menidia*	2,237	76	76	*Menidia menidia*	29	21	21
	Alosa pseudoharengus	443	15	91	*Fundulus heteroclitus*	24	18	39
	Fundulus majalis	188	6	97	*Fundulus majalis*	23	17	56
					Alosa pseudoharengus	9	7	63
					Brevoortia tyrannus	9	7	70
					Myoxocephalus aenaeus	9	7	77
					Menidia beryllina	8	6	83
1972	*Menidia menidia*	1,218	93	93	*Menidia menidia*	38	27	27
	Fundulus heteroclitus	52	4	97	*Fundulus majalis*	19	13	40
					Cyprinodon variegatus	19	13	53
					Fundulus heteroclitus	12	8	61
					Brevoortia tyrannus	9	6	67
					Menidia beryllina	9	6	73
					Syngnathus fuscus	9	6	79
					Apeltes quadracus	8	6	85
1973	*Menidia menidia*	599	88	88	*Menidia menidia*	30	29	29
	Fundulus heteroclitus	54	8	96	*Menidia beryllina*	17	17	46
					Gasterosteus aculeatus	10	10	56
					Fundulus heteroclitus	9	9	65
					Syngnathus fuscus	9	9	74
					Alosa aestivalis	8	8	82
1974(b)	*Menidia menidia*	2,093	88	88	*Menidia menidia*	68	29	29
	Menidia beryllina	161	7	95	*Menidia beryllina*	34	15	44
					Pseudopleuronectes americanus	22	10	54
					Fundulus heteroclitus	19	8	62
					Syngnathus fuscus	15	6	68
					Anguilla rostrata	10	4	72
					Gasterosteus aculeatus	10	4	76
					Pungitius pungitius	9	4	80
1975(b)	*Menidia beryllina*	376	24	24	*Menidia menidia*	45	18	18
	Menidia menidia	362	23	47	*Menidia beryllina*	36	14	32
	Menidia spp. (immature)	318	20	67	*Fundulus heteroclitus*	35	14	46
	Cyprinodon variegatus	271	17	84	*Cyprinodon variegatus*	23	9	54
	Ammodytes americanus	167	10	94	*Ammodytes americanus*	22	9	63
	Fundulus heteroclitus	58	4	98	*Fundulus majalis*	19	7	70
					Mi[illegible]adus tomcod	17	7	77
					A[illegible] quadracus	13	5	83

(a) Four[illegible]ling periods

TABLE 4.9-7 ACTUAL ABUNDANCE (TOP 95 PERCENT) AND RELATIVE ABUNDANCE (TOP 80 PERCENT) OF SHORE-ZONE FISH SPECIES CAPTURED BY SEINE AT SEASIDE AND CRESCENT BEACH FROM 1973 THROUGH 1975

Year	Actual Abundance Species	Number	Percent	Cumulative Percent.	Relative Abundance Species	Points	Percent	Cumulative Percent.
1973(a)	*Menidia menidia*	109	61	61	*Menidia menidia*	20	43	43
	Ammodytes americanus	54	30	91	*Ammodytes americanus*	9	20	63
	Menidia beryllina	16	9	100	*Syngnathus fuscus*	9	20	83
1974(b)	*Menidia menidia*	26	41	41	*Menidia beryllina*	57	31	31
	Menidia beryllina	16	25	66	*Menidia menidia*	47	26	57
	Mugil cephalus	12	19	85	*Fundulus majalis*	10	5	62
	Brevoortia tyrannus	2	3	88	*Sphoeroides maculatus*	10	5	67
	Cyprinodon variegatus	2	3	91	*Trachinotus falcatus*	10	5	72
	Fundulus majalis	1	2	93	*Apeltes quadracus*	9	5	77
	Myoxocephalus aenaeus	1	2	95	*Mugil cephalus*	9	5	82
1975(b)	*Menidia menidia*	206	65	65	*Menidia menidia*	30	26	26
	Menidia beryllina	52	16	81	*Menidia beryllina*	26	22	48
	Gasterosteus aculeatus	24	8	89	*Gasterosteus aculeatus*	10	9	57
	Ammodytes americanus	21	7	96	*Menticirrhus saxatilis*	9	8	65
					Syngnathus fuscus	9	8	73
					Microgadus tomcod	9	8	81
1973(a)	*Menidia menidia*	44	59	59	*Menidia menidia*	20	31	31
	Alosa aestivalis	24	32	91	*Fundulus majalis*	10	16	47
	Anchoa mitchilli	3	4	95	*Pungitius pungitius*	10	16	63
					Alosa aestivalis	9	14	77
					Anchoa mitchilli	8	12	89
1974(b)	*Fundulus heteroclitus*	145	47	47	*Menidia menidia*	54	26	26
	Menidia menidia	85	27	74	*Fundulus heteroclitus*	34	16	42
	Menidia beryllina	42	14	88	*Syngnathus fuscus*	24	11	53
	Ammodytes americanus	10	3	91	*Menidia beryllina*	17	8	61
	Syngnathus fuscus	10	3	94	*Apeltes quadracus*	15	7	68
	Apeltes quadracus	2	1	95	*Menticirrhus saxatilis*	10	5	73
					Mugil cephalus	9	4	77
					Sphoeroides maculatus	9	4	81
1975(b)	*Menidia menidia*	83	59	59	*Menidia menidia*	50	28	28
	Menidia beryllina	32	23	82	*Menidia beryllina*	18	10	38
	Menticirrhus saxatilis	13	9	90	*Tautoga onitis*	17	10	48
	Fundulus heteroclitus	2	1	91	*Apeltes quadracus*	10	6	54
	Tautoga onitis	2	1	92	*Brevoortia tyrannus*	10	6	60
	Apeltes quadracus	1	1	93	*Fundulus heteroclitus*	10	6	66
	Brevoortia tyrannus	1	1	94	*Syngnathus fuscus*	10	6	72
	Cyprinodon variegatus	1	1	95	*Urophycis chuss*	10	6	78
					Cyprinodon variegatus	9	5	83

Five sampling periods
Eight sampling periods

TABLE 4.9-8 ACTUAL ABUNDANCE (TOP 95 PERCENT) AND RELATIVE ABUNDANCE (TOP 80 PERCENT) OF SHORE-ZONE FISH SPECIES CAPTURED BY SEINE AT SANDY POINT DURING 1975

Actual Abundance				Relative Abundance			
Species	Number	Percent	Cumulative Percent	Species	Points	Percent	Cumulative Percent
Menidia menidia	1,978	37	37	*Fundulus majalis*	55	20	20
Fundulus heteroclitus	1,598	30	67	*Menidia beryllina*	47	17	37
Fundulus majalis	789	15	82	*Fundulus heteroclitus*	40	15	52
Menidia beryllina	729	13	95	*Apeltes quadracus*	39	14	66
				Menidia menidia	39	14	80

TABLE 4.9-9 NUMBER OF FISH PER 100-FOOT TOW CAPTURED IN SHORE-ZONE SEINES IN THE MILLSTONE POINT AREA EACH SAMPLING PERIOD FROM 1969 THROUGH 1975

Site	Year	Sampling Month Feb	May	Jun	Jul	Aug	Sep	Oct	Dec
White Point	1969	*	13	*	323	*	194	*	10
	1970	1	0	*	160	*	236	*	1
	1971	0	5	*	521	*	76	*	13
	1972	1	0	*	43	*	400	*	38
	1973	1	1	*	114	*	145	*	1
	1974	1	4	14	32	373	54	59	7
	1975	0	0	4	955	*	73	70	29
Jordan Cove	1969	*	15	*	337	*	1,002	*	87
	1970	1	94	*	868	*	229	*	139
	1971	2	41	*	9,270	*	64	*	30
	1972	1	12	*	951	*	34	*	491
	1973	3	29	*	1,573	*	41	*	83
	1974	3	9	84	941	1,159	61	126	9
	1975	6	4	35	924	*	202	58	6
Bay Point	1969	*	1	*	4	*	2	*	2
	1970	0	1	*	428	*	0	*	5
	1971	0	1	*	13	*	17	*	16
	1972	1	0	*	26	*	127	*	34
	1973	0	0	*	6	*	41	*	1
	1974	2	2	1	3	40	2	*	3
Giants Neck	1969	*	2	*	222	*	60	*	5
	1970	1	2	*	147	*	57	*	61
	1971	0	9	*	621	*	89	*	258
	1972	1	1	*	22	*	410	*	2
	1973	0	0	*	6	*	41	*	1
	1974	1	25	12	10	325	311	1	102
	1975	1	3	7	217	*	103	198	1
Sea-side	1973	0	0	*	3	*	57	*	0
	1974	0	1	4	1	2	1	11	2
	1975	0	0	8	0	*	4	74	18
Cres. Beach	1973	0	1	*	23	*	0	*	1
	1974	0	13	1	2	6	2	68	11
	1975	1	1	1	2	*	28	2	13
Sandy Point	1975	*	159	22	690	*	247	663	9

* No sample taken

TABLE 4.9-10 NUMBER OF FISH CAUGHT PER 100-FOOT TOW AT EACH SHORE-ZONE FISH SAMPLING SITE IN THE MILLSTONE POINT SAMPLING AREA EACH YEAR FROM 1969 THROUGH 1975

Site	Year						
	1969	1970	1971	1972	1973	1974	1975
Seaside[(a)]					12	3	15
White Point	135	79	123	96	52	68	162
Jordan Cove	360	266	1,881	297	346	299	176
Bay Point[(b)]	2	87	9	37	10	49	
Sandy Point[(c)]							298
Crescent Beach[(a)]					5	13	7
Giants Neck	72	53	195	87	45	98	75

(a) Not sampled until 1973
(b) No quantitative sample in 1975
(c) Not sampled until 1975

TABLE 4.9-11 NUMBER OF SPECIES OF SHORE-ZONE FISH COLLECTED AT EACH SEINING SITE IN THE MILLSTONE POINT AREA EACH SAMPLING PERIOD FROM 1969 THROUGH 1975

Site	Year	Sampling Month							
		Feb	May	Jun	Jul	Aug	Sep	Oct	Dec
White Point	1969	*	4	*	10	*	6	*	1
	1970	1	0	*	4	*	6	*	1
	1971	0	6	*	7	*	5	*	3
	1972	2	0	*	5	*	8	*	2
	1973	1	4	*	6	*	7	*	2
	1974	1	3	3	7	6	3	2	4
	1975	0	0	3	4	*	5	6	3
Jordan Cove	1969	*	5	*	11	*	10	*	4
	1970	2	10	*	11	*	8	*	8
	1971	2	12	*	13	*	10	*	6
	1972	1	4	*	9	*	6	*	9
	1973	3	7	*	11	*	6	*	5
	1974	4	8	4	8	7	6	6	4
	1975	1	4	5	8	*	6	8	4
Bay Point	1969	*	2	*	6	*	4	*	2
	1970	0	2	*	2	*	0	*	2
	1971	0	1	*	3	*	2	*	1
	1972	2	0	*	4	*	4	*	1
	1973	0	0	*	3	*	2	*	1
	1974	1	4	2	3	5	1	*	1
Giants Neck	1969	*	4	*	8	*	2	*	1
	1970	1	3	*	5	*	5	*	3
	1971	0	4	*	7	*	4	*	2
	1972	2	1	*	7	*	4	*	3
	1973	0	1	*	3	*	6	*	2
	1974	1	5	5	4	5	2	1	4
	1975	1	3	7	7	*	6	6	1
Sea-side	1973	0	0	*	2	*	3	*	0
	1974	0	2	4	2	2	3	5	2
	1975	0	0	2	0	*	5	4	2
Cres. Beach	1973	0	2	*	4	*	0	*	1
	1974	0	5	1	3	6	2	4	4
	1975	2	1	3	3	*	5	3	2
Sandy Point	1975	*	9	6	7	*	6	6	1

* No sample taken

TABLE 4.9-12 . SPECIES DIVERSITY ($\hat{H}$) INDEXES FOR SHORE-ZONE FISH SAMPLES COLLECTED IN THE MILLSTONE POINT AREA FROM 1969 THROUGH 1975

Site	Year	Sampling Month							
		Feb	May	Jun	Jul	Aug	Sep	Oct	Dec
White Point	1969	*	1.58	*	1.04	*	0.72	*	0
	1970	0	0	*	1.36	*	1.16	*	0
	1971	0	2.20	*	1.21	*	0.68	*	0.66
	1972	0.81	0	*	0.87	*	1.33	*	0.22
	1973	0	2.00	*	1.12	*	1.80	*	0.81
	1974	0	0.99	1.21	1.26	0.17	0.46	0.64	1.02
	1975	–	–	0.82	0.27	(a)	1.91	1.73	0.25
Jordan Cove	1969	*	1.92	*	2.47	*	1.42	*	1.14
	1970	0.92	1.96	*	1.12	*	2.06	*	0.99
	1971	0.60	2.22	*	0.27	*	2.35	*	1.18
	1972	0	1.44	*	0.61	*	2.04	*	1.96
	1973	1.22	1.87	*	1.24	*	1.57	*	0.99
	1974	1.69	2.68	1.13	0.22	0.53	1.36	1.36	1.06
	1975	0	1.68	1.69	1.26	(a)	1.40	1.83	1.61
Bay Point	1969	*	1.00	*	2.25	*	1.37	*	0
	1970	0	0.92	*	0.06	*	0	*	0.72
	1971	0	0	*	1.03	*	0.14	*	0
	1972	0.81	0	*	1.42	*	1.53	*	[illegible]
	1973	0	0	*	1.17	*	0.07	*	[illegible]
	1974	0	1.92	1.00	1.35	0.28	0	*	0
Giants Neck	1969	*	1.92	*	0.24	*	0	*	0
	1970	0	1.58	*	0.78	*	0.32	*	0.23
	1971	0	1.26	*	1.05	*	1.08	*	0.01
	1972	0.81	0	*	1.31	*	0.14	*	1.37
	1973	0	0	*	0.13	*	1.09	*	0.71
	1974	0	1.80	2.22	0.75	0.19	0.50	0	0.72
	1975	0	1.56	1.88	1.38	(a)	1.09	1.85	0
Sea-side	1973	0	0	*	0.54	*	1.29	*	0
	1974	0	1.00	1.68	0.81	0.72	1.58	1.66	0.72
	1975	–	–	0.24	–	(a)	2.07	1.20	0.72
Cres. Beach	1973	0	1.00	*	1.08	*	0	*	0
	1974	0	0.96	0	1.15	2.13	0.59	1.66	1.26
	1975	1.00	0	1.58	1.25	(a)	1.61	1.52	0.30
Sandy Point	1975	*	2.11	2.04	0.64	(a)	1.36	1.31	1.20

* No sample taken
– No fish collected
(a) Sample lost

TABLE 4.9-13 SPECIES RICHNESS (D) INDEXES FOR SHORE-ZONE FISH SAMPLES COLLECTED IN THE MILLSTONE POINT AREA FROM 1969 THROUGH 1975

Site	Year	Feb	May	Jun	Jul	Aug	Sep	Oct	Dec
		Sampling Month							
White Point	1969	*	0.57	*	0.91	*	0.54	*	0
	1970	0	0	*	0.34	*	0.53	*	0
	1971	0	1.28	*	0.56	*	0.51	*	0.37
	1972	0.50	0	*	0.57	*	0.68	*	0.15
	1973	0	1.50	*	0.59	*	0.68	*	0.50
	1974	0	0.54	0.37	0.76	0.49	0.27	0.13	0.69
	1975	0	0	0.56	0.35	(a)	0.51	0.65	0.31
Jordan Cove	1969	*	0.72	*	1.00	*	0.78	*	0.37
	1970	0.63	1.11	*	0.88	*	0.74	*	0.80
	1971	0.43	1.59	*	0.81	*	1.19	*	0.77
	1972	0	0.58	*	0.70	*	0.75	*	0.76
	1973	0.63	0.93	*	0.82	*	0.72	*	0.50
	1974	0.90	1.47	0.37	0.44	0.51	0.66	0.58	0.62
	1975	0	0.87	0.59	0.61	(a)	0.54	0.94	0.71
Bay Point	1969	*	0.10	*	1.11	*	1.29	*	0.36
	1970	0	0.63	*	0.10	*	9	*	0.25
	1971	0	0	*	0.38	*	0.18	*	0
	1972	0.50	0	*	0.48	*	0.35	*	0
	1973	0	0	*	0.47	*	0.14	*	0
	1974	0	1.16	1.00	0.63	0.58	0	*	0
Giants Neck	1969	*	1.16	*	0.75	*	0.13	*	0
	1970	0	0.77	*	0.45	*	0.54	*	0.27
	1971	0	0.62	*	0.55	*	0.37	*	0.10
	1972	0.50	0	*	0.99	*	0.29	*	0.86
	1973	0	0	*	0.24	*	0.61	*	0.20
	1974	0	0.64	0.77	0.61	0.40	0.10	*	0.36
	1975	0	0.67	1.36	0.64	(a)	0.60	0.54	0
Sea-side	1973	0	0	*	0.33	*	0.27	*	0
	1974	0	1.00	0.86	0.50	0.43	1.26	0.78	0.43
	1975	0	0	0.21	0	*	1.08	0.38	0.17
Cres. Beach	1973	0	1.00	*	0.49	*	0	*	0.20
	1974	0	0.75	0	0.71	1.20	0.36	0.39	0.36
	1975	1.00	0	1.26	0.77	(a)	0.62	0.86	0
Sandy Point	1975	*	0.90	0.83	0.54	(a)	0.31	0.55	0.42

* No sample taken
(a) Sample lost

TABLE 4.9-14. SPECIES EVENNESS (J) INDEXES FOR SHORE-ZONE FISH SAMPLES COLLECTED IN THE MILLSTONE POINT AREA FROM 1969 THROUGH 1975

Site	Year	Sampling Month							
		Feb	May	Jun	Jul	Aug	Sep	Oct	Dec
White Point	1969	*	0.79	*	0.37	*	0.28	*	0
	1970	0	0	*	0.68	*	0.45	*	0
	1971	0	0.85	*	0.43	*	0.29	*	0.42
	1972	0.81	0	*	0.37	*	0.44	*	0.22
	1973	0	1.00	*	0.43	*	0.64	*	0.81
	1974	0	0.62	0.76	0.45	.06	0.29	0.64	0.51
	1975	-	-	0.52	0.12	(a)	0.82	0.67	0.16
Jordan Cove	1969	*	0.83	*	0.71	*	0.43	*	0.57
	1970	0.92	0.59	*	0.32	*	0.69	*	0.33
	1971	0.60	0.62	*	0.07	*	0.70	*	0.46
	1972	0	0.72	*	0.19	*	0.79	*	0.62
	1973	0.77	0.66	*	0.36	*	0.60	*	0.43
	1974	0.84	0.89	0.56	0.07	0.19	0.53	0.53	0.53
	1975	0	0.84	0.73	0.42	(a)	0.54	0.61	0.80
Bay Point	1969	*	1.00	*	0.87	*	0.68	*	0
	1970	0	0.92	*	0.06	*	0	*	0.72
	1971	0	0	*	0.65	*	0.14	*	0
	1972	0.81	0	*	0.71	*	0.76	*	
	1973	0	0	*	0.74	*	0.07	*	
	1974	0	0.96	1.00	0.85	0.12	0	*	0
Giants Neck	1969	*	0.96	*	0.08	*	0	*	0
	1970	0	1.00	*	0.33	*	0.14	*	0.14
	1971	0	0.63	*	0.37	*	0.54	*	0.01
	1972	0.81	0	*	0.47	*	0.07	*	0.86
	1973	0	0	*	0.08	*	0.42	*	0.71
	1974	0	0.77	0.95	0.37	0.08	0.50	0	0.36
	1975	0	0.98	0.67	0.49	(a)	0.42	0.71	0
Sea-side	1973	0	0	*	0.54	*	0.81	*	0
	1974	0	1.00	0.84	0.81	0.72	1.00	0.71	0.74
	1975	-	-	0.24	-	(a)	0.89	0.60	0.72
Cres. Beach	1973	0	1.00	*	0.54	*	0	*	0
	1974	0	0.41	0	0.72	0.82	0.59	0.83	0.63
	1975	1.00	0	1.00	0.79	(a)	0.69	0.96	0.30
Sandy Point	1975	*	0.66	0.79	0.23	*	0.68	0.47	0.76

* No sample taken
\- No fish collected
(a) Sample lost

TABLE 4.9-15 NUMBERS OF FISH CAPTURED BY GILL NET EACH YEAR IN THE MILLSTONE POINT AREA FROM DECEMBER, 1971, THROUGH DECEMBER, 1975

Species	1971	1972	1973	1974	1975
Alosa aestivalis				20	50
Alosa mediocris		1		4	
Alosa pseudoharengus	1	2	7	21	40
Alosa sapidissima				1	1
Anchoa hepsetus					34
Anchoa mitchilli					3
Brevoortia tyrannus		4	64	267	237
Caranx crysos				1	
Clupea harengus	1	130	105	1,063	873
Cynoscion regalis		2	4		
Etrumeus teres					2
Gadus morhua					1
Menidia menidia					4
Menticirrhus saxatilis					1
Merluccius bilinearis	1	4	1	8	4
Microgadus tomcod					1
Morone americana			8		2
Morone saxatilis			1	5	
Mugil cephalus			1		
Mustelus canis		12	12	6	18
Myoxocephalus aenaeus		1			
Myoxocephalus octodecemspinosus					1
Osmerus mordax				2	
Peprilus triacanthus		5		35	39
Petromyzon marinus					1
Pollachius virens		1			2
Pomatomus saltatrix		1	4	53	61
Prionotus carolinus		10	85	15	31
Prionotus evolans			2		8
Pseudopleuronectes americanus	26	1	4		6
Raja spp.		1	1		6
Scomber japonicus					7
Scomber scombrus			7	4	2
Scophthalmus aquosus			1		3
Squalus acanthias	8	17	7	24	22
Stenotomus chrysops		84	12	4	11
Tautoga onitis		1	10		4
Tautogolabrus adspersus	1	48	62		15
Urophycis chuss					5
Urophycis tenuis		10			
Total Number of Individuals	38	335	398	1,533	1,495
Total Number of Species	6	19	20	16	32
Number of Samples (Sets)	2	8	20	48	132
Catch Per Sample	19	42	20	32	11

TABLE 4.9-16. RANK BY ACTUAL ABUNDANCE OF FISH CAPTURED BY GILL NETS IN THE MILLSTONE POINT AREA FROM DECEMBER, 1971, THROUGH DECEMBER, 1975

Species	Number Caught	Percent of Total	Cumulative Percent
Clupea harengus	2,172	57	57
Brevoortia tyrannus	572	15	72
Prionotus carolinus	141	4	76
Tautogolabrus adspersus	126	3	79
Pomatomus saltatrix	119	3	82
Stenotomus chrysops	111	3	85
Peprilus triacanthus	79	2	87
Squalus acanthias	78	2	89
Alosa pseudoharengus	71	2	91
Alosa aestivalis	70	2	93
Mustelus canis	48	1	94
Pseudopleuronectes americanus	37	1	95
Anchoa hepsetus	34	1	96
Tautoga onitis	19	<1	96
Merluccius bilinearis	18	<1	97
Scomber scombrus	13	<1	97
Morone americana	10	<1	97
Prionotus evolans	10	<1	97
Urophycis tenuis	10	<1	97
Raja spp.	8	<1	98
Scomber japonicus	7	<1	98
Cynoscion regalis	6	<1	99
Morone saxatilis	6	<1	99
Alosa mediocris	5	<1	99
Urophycis chuss	5	<1	99
Menidia menidia	4	<1	
Scophthalmus aquosus	4	<1	
Anchoa mitchilli	3	<1	
Pollachius virens	3	<1	
Alosa sapidissima	2	<1	
Etrumeus teres	2	<1	
Osmerus mordax	2	<1	
Caranx crysos	1	<1	
Gadus morhua	1	<1	
Menticirrhus saxatilis	1	<1	
Microgadus tomcod	1	<1	
Mugil cephalus	1	<1	
Myoxocephalus aenaeus	1	<1	
Myoxocephalus octodecemspinosus	1	<1	
Petromyzon marinus	1	<1	100
Total	3,799		

TABLE 4.9-17 RANK BY ACTUAL ABUNDANCE OF FISH CAPTURED BY GILL NETS IN THE MILLSTONE POINT AREA FROM JANUARY, 1975, THROUGH DECEMBER, 1975

Species	Abundance	Percent	Cumulative Percent
Clupea harengus	873	58	58
Brevoortia tyrannus	237	16	74
Pomatomus saltatrix	61	4	78
Alosa aestivalis	50	3	82
Alosa pseudoharengus	40	3	84
Peprilus triacanthus	39	3	87
Anchoa hepsetus	34	2	89
Prionotus carolinus	31	2	91
Squalus acanthias	22	1	93
Mustelus canis	18	1	94
Tautogolabrus adspersus	15	1	95
Stenotomus chrysops	11	<1	96
Prionotus evolans	8	<1	96
Scomber japonicus	7	<1	97
Pseudopleuronectes americanus	6	<1	97
Raja spp.	6	<1	98
Urophycis chuss	5	<1	98
Menidia menidia	4	<1	98
Merluccius bilinearis	4	<1	98
Tautoga onitis	4	<1	99
Anchoa mitchilli	3	<1	99
Scophthalmus aquosus	3	<1	99
Etrumeus teres	2	<1	99
Monrone americana	2	<1	99
Pollachius virens	2	<1	99
Scomber scombrus	2	<1	99
Alosa sapidissima	1	<1	99
Gadus morhua	1	<1	99
Menticirrhus saxatilis	1	<1	99
Microgadus tomcod	1	<1	99
Myoxocephalus octodecemspinosus	1	<1	99
Petromyzon marinus	1	<1	100
Total 1975 Catch	1,495		

TABLE 4.9-18 RELATIVE ABUNDANCE OF FISH SPECIES CAPTURED BY GILL NETS IN THE MILLSTONE POINT AREA FROM JANUARY, 1975, THROUGH DECEMBER, 1975

Actual 1975 Abundance	1975 Rank	Previous Year's Rank	Species	Points
2	1	1	*Brevoortia tyrannus*	102
1	2	2	*Clupea harengus*	59
5	3	8	*Alosa pseudoharengus*	53
4	4	13	*Alosa aestivalis*	41
6	5	9	*Peprilus triacanthus*	41
3	6	5	*Pomatomus saltatrix*	40
8	7	7	*Prionotus carolinus*	32
10	8	6	*Mustelus canis*	29
12	9	11	*Stenotomus chrysops*	28
9	10	3	*Squalus acanthias*	24
17	11	–	*Urophycis chuss*	22
7	12	–	*Anchoa hepsetus*	21
13	13	25	*Prionotus evolans*	18
15	14	10	*Pseudopleuronectes americanus*	1[illegible]
19	15	12	*Merluccius bilinearis*	1[illegible]
16	16	20	*Raja* spp.	13
22	17	29	*Scophthalmus aquosus*	12
20	18	18	*Tautoga onitis*	12
14	19	–	*Scomber japonicus*	11
11	20	4	*Tautogolabrus adspersus*	11
21	21	–	*Anchoa mitchilli*	7
18	22	–	*Menidia menidia*	7
24	23	22	*Morone americana*	7
31	24	–	*Myoxocephalus octodecemspinosus*	6
32	25	–	*Petromyzon marinus*	6
25	26	24	*Pollachius virens*	6
26	27	15	*Scomber scombrus*	6
28	28	–	*Gadus morhua*	5
30	29	–	*Microgadus tomcod*	5
23	30	–	*Etrumeus teres*	4
29	31	–	*Menticirrhus saxatilis*	[illegible]
27	32	28	*Alosa sapidissima*	2

– = Not previously caught

TABLE 4.9-19 FISH SPECIES CAUGHT EXCLUSIVELY IN EITHER SURFACE OR BOTTOM GILL NETS SET MONTHLY IN THE AREA OF THE MILLSTONE POINT DURING 1975

Surface	Bottom
Alosa sapidissima	*Gadus morhua*
Anchoa hepsetus	*Merluccius bilinearis*
Anchoa mitchilli	*Morone americana*
Etrumeus teres	*Morone saxatilis*
Menidia menidia	*Myoxocephalus octodecemspinosus*
Microgadus tomcod	*Prionotus evolans*
Petromyzon marinus	*Pseudopleuronectes americanus*
Pollachius virens	*Raja* spp.
Scomber japonicus	*Scophthalmus aquosus*
Scomber scombrus	*Squalus acanthias*
	Stenotomus chrysops
	Tautoga onitis
	Tautogolabrus adspersus
	Urophycis chuss

TABLE 4.9-20 NUMBER OF EACH OF THE TWELVE MOST NUMEROUS FISH SPECIES CAPTURED PER OVERNIGHT SET OF GILL NETS IN THE MILLSTONE POINT AREA DURING 1975

BL = Black Point; TT = Twotree Island Channel; JC = Jordan Cove; EF = Effluent; BP = Bay Point; NB = Niantic Bay; BR = Bartlett Reef;

S = Surface Net; B = Bottom Net; Number in ( ) = Number of Sets.

Species	BL (12)	TT-S (12)	TT-B (11)	JC (12)	EF-S (11)	EF-B (11)	BP-S (12)	BP-B (11)	NB-S (10)	NB-B (10)	BR-S (11)	BR-B (11)
Alosa aestivalis	1.3	0.1		0.9	0.6		0.1	1.5	0.1	0.1	0.2	
Alosa pseudoharengus	0.1	0.6		1.0	1.5	0.4						
Brevoortia tyrannus	1.4	0.5		2.1	4.9	1.1	4.2	0.5	4.3	2.1	0.4	
Clupea harengus	9.7	12.8	8.8	17.8	1.7	2.1	7.8	5.0	4.3	2.8	2.2	0.7
Mustelus canis			0.1	0.2		0.1		0.1	0.1	0.5		0.7
Peprilus triacanthus	1.2	0.7		0.1	0.1	0.1		0.2	0.1	0.2		
Pomatomus saltatrix	0.1			1.8	1.2	0.5	0.2	0.8	0.7	1.0		
Prionotus carolinus			0.4		0.2	0.6		0.9				0.7
Pseudopleuronectes americanus						0.4				0.1		0.1
Squalus acanthias			0.1					0.5		0.6		0.2
Stenotomus chrysops			0.1			0.3		0.4		0.2		0.1
Tautogolabrus adspersus			0.3			0.7		0.2		0.1		0.1
Number of Species (from total)	7	6	10	13	12	13	4	15	9	12	4	13
Catch/Unit Effort (from total)	14.3	14.7	10.2	24.8	11.5	6.6	12.2	10.7	11.8	8.0	2.8	3.9

TABLE 4.9 -21 NUMBER OF EACH FISH SPECIES CAPTURED PER OVERNIGHT SET OF GILL NETS IN THE MILLSTONE POINT AREA DURING 1975

BL = Black Point; TT = Twotree Island Channel; JC = Jordan Cove;
EF = Effluent; BP = Bay Point; NB = Niantic Bay; BR = Bartlett Reef;

S = Surface Net; B = Bottom Net; Number in ( ) = Number of Sets

Species	BL (12)	TT-S (12)	TT-B (11)	JC (12)	EF-S (11)	EF-B (11)	BP-S (12)	BP-B (11)	NB-S (10)	NB-B (10)	BR-S (11)	BR-B (11)
Alosa aestivalis	1.3	0.1		0.9	0.6		0.1	1.5	0.1	0.1	0.2	
Alosa mediocris												
Alosa pseudoharengus	0.1	0.6		1.0	1.5	0.4						
Alosa sapidissima				0.1								
Anchoa hepsetus	0.6			0.1	0.5				2.0			
Anchoa mitchilli					0.3							
Brevoortia tyrannus	1.4	0.5		2.1	4.9	1.1	4.2	0.5	4.3	2.1	0.4	
Caranx crysos												
Clupea harengus	9.7	12.8	8.8	17.8	1.7	2.1	7.8	5.0	4.3	2.8	2.2	0.7
Cynoscion regalis												
Etrumeus teres				0.2								
Gadus morhua												0.1
Menidia menidia				0.1	0.3							
Menticirrhus saxatilis												
Merluccius bilinearis								0.2		0.2		
Microgadus tomcod				0.1								
Morone americana						0.2						
Morone saxatilis			0.1									
Mugil cephalus												
Mustelus canis			0.1	0.2		0.1		0.1	0.1	0.5		0.7
Myoxocephalus aenaeus												
Myoxocephalus octodecemspinosus												0.1
Osmerus mordax												
Peprilus triacanthus	1.2	0.7		0.1	0.1	0.1		0.2	0.1	0.2		
Petromyzon marinus									0.1			
Pollachius virens					0.2							

TABLE 4.9-21 (continued)

Species	BL (12)	TT-S (12)	TT-B (11)	JC (12)	EF-S (11)	EF-B (11)	BP-S (12)	BP-B (11)	NB-S (10)	NB-B (10)	BR-S (11)	BR-B (11)
Pomatomus saltatrix	0.1			1.8	1.2	0.5	0.2	0.8	0.7	1.0		
Prionotus carolinus			0.4		0.2	0.6		0.9				0.7
Prionotus evolans			0.1			0.1		0.3				0.3
Pseudopleuronectes americanus						0.4				0.1		0.1
Raja spp.								0.1				0.5
Scomber japonicus				0.4	0.1				0.1			
Scomber scombrus		0.1									0.1	
Scophthalmus aquosus												0.3
Squalus acanthias			0.1					0.5		0.6		0.2
Stenotomus chrysops			0.1			0.3		0.4		0.2		0.1
Tautoga onitis			0.1			0.2		0.1				
Tautogolabrus adspersus			0.3			0.7		0.2		0.1		0.1
Urophycis chuss			0.2					0.1		0.1		0.1
Urophycis tenuis												
Number of Species	7	6	10	13	12	13	4	15	9	12	4	13
Catch/Unit Effort (from total)	14.3	14.7	10.2	24.8	11.5	6.6	12.2	10.7	11.8	8.0	2.8	3.9

TABLE 4.9.-22 TOP ELEVEN SPECIES, RANKED BY PERCENT COMPOSITION, FOR THE BAY POINT GILL NET AND THE INTAKE SCREENS AT UNIT NO. 1 AT THE MILLSTONE POINT NUCLEAR POWER STATION, JANUARY, 1975, THROUGH DECEMBER, 1975

Bay Point Gill Net	Percent	Intake Screens	Percent
**Clupea harengus*	56	*Pseudopleuronectes americanus*	22
Brevoortia tyrannus	21	*Gasterosteus aculeatus*	12
Alosa aestivalis	7	**Merluccius bilinearis*	12
Pomatomus saltatrix	4	*Myoxocephalus aenaeus*	8
Prionotus carolinus	4	Atherinidae	6
Squalus acanthias	2	*Tautoga onitis*	6
Stenotomus chrysops	2	*Morone americana*	6
Prionotus evolans	1	**Tautogolabrus adspersus*	5
**Merluccius bilinearis*	<1	*Anchoa* spp.	4
Peprilus triacanthus	<1	**Clupea harengus*	2
**Tautogolabrus adspersus*	<1	*Scophthalmus aquosus*	2
Percent catch accounted for	99		85
Clupeidae	84	Clupeidae	5

* = Common to both lists

TABLE 4.9-23 FISH SPECIES TAKEN IN TRAWLS IN THE MILLSTONE POINT AREA FROM APRIL, 1973, THROUGH DECEMBER, 1975, RANKED BY ACTUAL ABUNDANCE

Numbers under "Stations" indicate relative ranking at that station; X denotes presence

Species	Actual Abundance Total Numbers	Percent of Total	Relative Abundance Total Points	Abundances by Numbers of Fish Per 15-Min. Tow	Stations 1	2	4	5	6	7	8	9	10	11	Number of Stations Per Species
Pseudopleuronectes americanus	13,176	43	326	19.06	1	1	1	2	1	1	1	1	1	1	10
Stenotomus chrysops	5,493	18	139	6.19	X	4	2	1	2	4	2	4	4	2	10
Scophthalmus aquosus	2,906	9	262	3.59	X	X	3	3	4	3	4	2	2	5	10
Raja spp.	2,231	7	218	2.72		X	4	4	5	5	3	3	3	4	9
Tautogolabrus adspersus	1,656	5	152	2.41	X	3	X	X	3	2	5	X	5	3	10
Merluccius bilinearis	720	2	45			X	X	5	X	X	X	5	X	X	10
Prionotus spp.	595	2	99		X	5	X	X	X	X	X	X	X	X	10
Menidia menidia	566	2	75		5	X	X	X	X	X	X	X	X	X	10
Apeltes quadracus	437	1	62		2	X			X		X				4
Urophycis chuss	416	1	59		X	X	X	X	X	X	X	X	X	X	10
Tautoga onitis	356	1	83		X	2	X	X	X	X	X	X	X	X	10
Eugraulidae	334	1	25		4		5	X			X				4
Gasterosteus aculeatus	208	1	35		3				X		X				3
Myoxocephalus aenaeus	186	1	42		X	X	X	X	X	X	X	X	X	X	10
Paralichthys dentatus	174	1	41		X	X	X	X	X	X	X	X	X	X	10
Etropus microstomus	123	<1	23				X	X	X	X	X	X	X	X	8
Morone americana	117	<1	30		X	X	X		X	X					5
Syngnthus fuscus	103	<1	24		X	X	X	X	X		X	X		X	8
Myoxocephalus octodecemspinosus	91	<1	19				X	X	X	X	X	X	X	X	8
Hemitripterus americanus	72	<1	20				X	X	X	X	X	X	X	X	8
Urophycis spp.	50	<1	9				X	X	X	X	X	X	X	X	8
Gadidae	50	<1	20		X		X	X	X	X	X	X	X	X	9
Peprilus triacanthus	50	<1	12				X	X			X	X	X		5
Anguilla rostrata	48	<1	18		X	X			X	X	X				5
Centropristis striata	39	<1	10		X	X		X	X	X	X		X	X	8
Gadus morhua	37	<1	12				X	X	X	X	X		X	X	7
Pholis gunnellus	34	<1	6				X	X	X	X	X			X	6
Opsanus tau	30	<1	7		X	X								X	3
Osmerus mordax	30	<1	7		X	X	X		X	X		X	X	X	8
Microgadus tomcod	25	<1	16		X				X	X	X	X	X	X	7
Urophycis tenuis	24	<1	19		X				X	X		X	X	X	6
Alosa pseudoharengus	23	<1	6		X		X		X		X	X	X	X	7

TABLE 4.9-23. (continued)

Species	Actual Abundance Total Numbers	Percent of Total	Relative Abundance Total Points	Abundances by Numbers of Fish Per 15-Min. Tow	Stations 1	2	4	5	6	7	8	9	10	11	Number of Stations Per Species
Paralichthus oblongus	18	<1	2				X	X				X	X	X	5
Urophycis regius	15	<1	1		X		X	X	X		X		X	X	7
Gobiidae	15	<1			X	X									2
Fundulus spp.	13	<1	1		X										1
Cynoscion regalis	12	<1	2		X		X	X							3
Monocanthus hispidus	11	<1	4				X		X		X	X	X	X	6
Pollachius virens	10	<1	4						X						1
Sphoeroides maculatus	9	<1	3			X			X		X			X	4
Clupeidae	9	<1	3		X									X	2
Hippocampus spp.	7	<1	2			X	X		X		X			X	5
Alosa aestivalis	7	<1	3		X							X	X		3
Alosa sapidissima	6	<1	6									X			1
Brevoortia tyrannus	6	<1	4		X		X						X		3
Myoxocephalus spp.	5	<1	6						X		X		X		3
Lophius americanus	5	<1	6				X			X		X			3
Ammodytes americanus	5	<1	1		X										1
Liparis atlanticus	5	<1							X		X		X	X	4
Liparis liparis	5	<1			X		X				X	X	X		5
Mustelus canis	5	<1					X			X			X		3
Macrozoarces americanus	5	<1							X	X	X		X		4
Menticirrhus saxatilis	4	<1	2			X							X	X	3
Trinectes maculatus	3	<1					X			X			X		3
Pomatomus saltatrix	3	<1				X		X			X				3
Dactylopterus volitans	3	<1				X					X			X	3
Pristigerys alta	3	<1								X	X				2
Cyclopterus spp.	2	<1	9						X	X					2
Gasterosteidae	2	<1			X										1
Clupea harengus	2	<1									X	X			2
Ehteostoma spp.	2	<1			X										1
Myoxocephalus scorpius	2	<1	2						X				X		2
Squalus acanthias	1	<1								X	X				2
Liparis spp.	1	<1										X			1
Vomer setapinnis	1	<1					X								1
Carcharias taurus	1	<1									X				1
Limanda ferruginea	1	<1								X					1
Total	30,605		1,982	42.78											
				Total Number of Species Per Station	34	25	36	27	39	33	42	31	37	35	
				Average Catch Per 15-Min. Tow Per Station	65.0	56.4	44.3	77.0	32.5	17.8	28.1	48.0	41.0	48.7	

TABLE 4.9-24 . FISH SPECIES TAKEN IN TRAWLS IN THE MILLSTONE POINT AREA FROM APRIL THROUGH DECEMBER, 1973, RANKED BY ACTUAL ABUNDANCE

Numbers under "stations" indicate relative ranking at that station; X denotes presence

Species	Actual Abundance Total Numbers	Percent of Total	Relative Abundance Total Points	Abundances by Number of Fish Per 15-Min. Tow	Stations 1	4	6	7	8	9	10	Numbers of Stations Per Species
Pseudopleuronectes americanus	3,232	61	90	20.25	1	1	1	1	1	1	1	7
Scophthalmus aquosus	575	11	71	3.09	X	2	4.5	4	4	2	2	7
Tautogolabrus adspersus	359	7	50	2.61	4	X	2.5	2	2	X	3	7
Stenotomus chrysops	273	5	39	1.34		3	4.5	3	X	4	X	6
Prionotus spp.	242	5	42	1.71	3	4	X	X	5	5	5	7
Raja spp.	230	4	61	1.28		5	X	X	3	3	4	6
Menidia menidia	125	2	22	.53	2	X	2.5		X	X	X	6
Tautoga onitis	62	1	29	.39	X	X	X	5	X	X	X	7
Engraulidae	45	1	11	.25	X				X			2
Paralichthys dentatus	24	<1	13	.16	X	X	X	X		X	X	6
Morone americana	17	<1	7		5							1
Anguilla rostrata	15	<1	15		X			X				2
Myoxocephalus octodecemspinosus	14	<1	8						X	X	X	3
Gadidae	14	<1	8			X			X			2
Microgadus tomcod	12	<1	8		X	X	X					3
Urophycis chuss	10	<1	10		X	X	X				X	4
Hemitripterus americanus	9	<1	11			X	X		X		X	4
Alosa pseudoharengus	8	<1	6		X	X	X					3
Peprilus triacanthus	7	<1	8			X				X	X	3
Urophycis tenuis	6	<1	6							X	X	2
Alosa sapidissima	5	<1	6							X		1
Merluccius bilinearis	5	<1	5			X	X			X		3
Myoxocephalus spp.	5	<1	6				X		X		X	3
Brevoortia tyrannus	5	<1	4							X	X	2
Clupeidae	4	<1	3						X			1
Myoxocephalus aenaeus	3	<1	4			X						1
Paralichthys oblongus	3	<1	2			X					X	2
Sphoeroides maculatus	3	<1	3						X			1
Etropus microstomus	2	<1	1			X						1
Opsanus tau	2	<1	3		X							1
Osmerus mordax	2	<1	1		X		X					2
Gasterosteidae	2	<1			X							1
Syngnathus fuscus	1	<1					X					1
Gadus morhua	1	<1				X						1
Urophycis regius	1	<1	1								X	1
Monocanthus hispidus	1	<1	3							X		1
Alosa aestivalis	1	<1	1							X		1
Lophius americanus	1	<1				X						1
Squalus acanthias	1	<1						X				1
Limanda ferruginea	1	<1						X				1
Total	5,326		558	32.57								
Total Number of Species Per Station					16	21	17	11	15	17	18	
Average Catch Per 15-Min. Tow Per Stat[illegible]					28.3	39.5	27.4	13.8	22.1	34.2	59.63	

TABLE 4.9 -25 FISH SPECIES TAKEN IN TRAWLS IN THE MILLSTONE POINT AREA FROM JANUARY THROUGH DECEMBER, 1974, RANKED BY ACTUAL ABUNDANCE

Numbers under "Stations" indicate relative ranking at that station; X denotes presence

Species	Actual Abundance Total Numbers	Percent of Total	Relative Abundance Total Points	Abundances by Number of Fish Per 15-Min. Tow	Stations 1	4	6	7	8	9	10	11	Number of Stations Per Species
Pseudopleuronectes americanus	4,215	50	118	18.82	1	1	1	1	1	1	1	1	8
Raja spp.	875	10	71	3.46		2	4	4	2	2	3	3	7
Scophthalmus aquosus	869	10	97	3.19	X	3	3	3	4	3	2	2	8
Tautogolabrus adspersus	418	5	57	2.63	5	4.5	2	2	X	X	5	5	8
Stenotomus chrysops	398	5	49	1.76	X	4.5	X	5	3	X	4	X	8
Menidia menidia	326	4	40	1.73	X	X	5	X	X	5	X	4	8
Urophycis chuss	248	3	17	.76	X	X		X	X	4	X	X	7
Prionotus spp.	171	2	33	.67	X	X	X	X	5	X	X	X	8
Apeltes quadracus	158	2	32	1.01	2								1
Tautoga onitis	101	1	26	.60	X	X	X	X	X	X	X	X	8
Merluccius bilinearis	99	1	21	.30		X	X	X	X	X	X	X	7
Gasterosteus aculeatus	77	1	9	.41	3								1
Engraulidae	69	1	7	.49	4								1
Myoxocephalus aenaeus	55	1	16	.16		X	X	X	X	X		X	6
Syngnathus fuscus	49	1	16		X		X					X	3
Myoxocephalus octodecemspinosus	41	<1	29			X	X	X	X	X	X		6
Paralichthys dentatus	35	<1	15		X	X	X	X	X	X	X	X	7
Urophycis spp.	32	<1	7			X	X	X	X	X	X	X	7
Morone americana	30	<1	15		X		X						2
Etropis microstomus	29	<1	9			X	X			X	X	X	4
Hemitripterus americanus	23	<1	10				X	X	X	X	X	X	6
Osmerus mordax	17	<1	6		X	X	X				X	X	5
Urophycis tenuis	17	<1	13		X		X	X			X	X	5
Gadidae	11	<1	9		X	X	X	X			X		5
Gadus morhua	11	<1	7				X	X	X		X		4
Anguilla rostrata	10	<1	1		X								1
Fundulus spp.	10	<1	1		X								1
Urophycis regius	10	<1	0		X	X	X					X	4
Peprilus triacanthus	8	<1	2			X			X		X		5
Alosa pseudoharengus	8	<1	0						X	X		X	5
Opsanus tau	7	<1	2		X								1
Microgadus tomcod	7	<1	8		X		X	X	X	X	X		6
Pholis gunnellus	6	<1	5			X	X	X				X	4

TABLE 4.9-25 (continued)

Species	Actual Abundance Total Numbers	Percent of Total	Relative Abundance Total Points	Abundances by Number of Fish Per 15-Min. Tow	1	4	6	7	8	9	10	11	Number of Stations Per Species
Gobiidae	6	<1	0		X								1
Pollachius virens	5	<1	3				X						1
Hippocampus sp.	5	<1	2			X			X			X	3
Alosa aestivalis	5	<1	2		X					X			2
Ammodytes americanus	5	<1	1		X					X			2
Monacanthus hispidus	4	<1	1			X			X		X		3
Cynoscion regalis	3	<1	2		X								1
Lophius americanus	3	<1	6			X				X			2
Paralichthys oblongus	2	<1	0							X			1
Clupeidae	2	<1	0		X								1
Liparis atlanticus	2	<1	0				X		X				2
Liparis liparis	2	<1	0			X					X		2
Menticirrhus saxatilis	2	<1	0								X		1
Mustelus canis	2	<1	2			X					X		2
Cyclopterus sp.	2	<1	9				X	X					2
Myoxocephalus scorpius	2	<1	2				X				X		2
Alosa sapidissima	1	<1	0							X			1
Centropristes striatus	1	<1	4				X						1
Brevoortia tyrannus	1	<1	0			X							1
Trinectes maculatus	1	<1	0		X								1
Etheostoma sp.	1	<1	0		X								1
Liparis sp.	1	<1	3					X					1
Sphoeroides maculatus	1	<1	0				X						1
Total	8,499		785	38.85									
				Total No. of Species	29	26	30	22	22	23	26	22	
				No./15-Min. Tow	66.4	25.8	32.7	19.7	27.8	53.4	41.7	40.9	

TABLE 4.9-26 FISH SPECIES TAKEN IN TRAWLS IN THE MILLSTONE POINT AREA FROM JANUARY, 1975, THROUGH DECEMBER, 1975, RANKED BY ACTUAL ABUNDANCE

Numbers under "Stations" indicate relative ranking at that station; X denotes presence

Species	Actual Abundance Total Numbers	Percent of Total	Relative Abundance Total Points	Abundances by Number of Fish Per 15-Min. Tow	Stations 1	2	4	5	6	7	8	9	10	11	Number of Stations Per Species
Pseudopleuronectes americanus	5,729	34	118	18.22	1	1	2	2	1	2	1	1	2	1	10
Stenotomus chrysops	4,822	29	51	11.12	X	4	1	1	2	4	2	5	4	2	10
Scophthalmus aquosus	1,462	9	94	3.95	X	X	4	3	3	X	4	3	1	5	10
Raja spp.	1,126	7	86	3.10		X	5	4	4	3	3	2	3	4	9
Tautogolabrus adspersus	879	5	45	2.55	X	3	X	X	5	1	X	X	X	3	10
Merluccius bilinearis	616	4	19	2.01		X	X	5	X	X	5	4	5	X	9
Apeltes quadracus	279	2	30	2.28	2	X			X		X				4
Engraulidae	219	1	7	.99	4		3	X			X				4
Tautoga onitis	193	1	28	.58	X	2	X	X	X	5	X	X	X	X	10
Prionotus spp.	184	1	24	.46	X	5	X	X	X	X	X	X	X	X	10
Urophycis chuss	158	1	32	.48	X	X	X	X	X	X	X	X	X	X	10
Gasterosteus aculeatus	131	1	26	1.20	3				X		X				3
Myoxocephalus aenaeus	128	1	22	.36	X	X	X	X	X	X	X	X	X	X	10
Menidia menidia	115	1	13	.32	X	X	X	X	X	X	X	X	X	X	10
Paralichthys dentatus	115	1	13	.29	X	X	X	X	X	X	X	X	X	X	10
Etropus microstomas	92	1	13				X	X	X	X	X	X	X	X	8
Morone americana	70	<1	8		5	X				X					3
Syngnathus fuscus	53	<1	0		X	X	X	X	X		X	X		X	8
Hemitripterus americanus	40	<1	5					X	X	X	X	X	X	X	7
Centropristes striatus	38	<1	6		X	X		X	X	X	X		X	X	8
Myoxocephalus octodecemspinosus	36	<1	8				X	X		X	X	X	X	X	7
Peprilus triacanthus	35	<1	2				X	X			X	X	X		5
Pholis gunnellus	28	<1	1					X	X		X			X	4
Gadidae	25	<1	3					X	X	X	X	X		X	6
Gadus morhua	25	<1	5				X	X	X		X		X	X	6
Anguilla rostrata	23	<1	2		X	X			X	X	X				5
Opsanus tau	21	<1	2		X	X								X	3
Urophycis spp.	18	<1	2					X		X	X	X	X		5
Paralichthys oblongus	13	<1	0				X	X				X	X	X	5
Osmerus mordax	11	<1	0		X	X	X		X	X		X			6
Cynoscion regalis	9	<1	1		X		X	X							3
Gobiidae	9	<1	0		X	X									2

TABLE 4.9-26 (continued)

Species	Actual Abundance Total Numbers	Percent of Total	Relative Abundance Total Points	Abundances by Number of Fish Per 15-Min. Tow	1	2	4	5	6	7	8	9	10	11	Number of Stations Per Species
Microgadus tomcod	8	<1	0		X				X					X	3
Alosa pseudoharengus	7	<1	0						X		X	X	X	X	5
Monacanthus hispidus	6	<1	0						X			X		X	3
Pollachius virens	5	<1	0				X								1
Sphoeroides maculatus	5	<1	0			X					X			X	3
Macrozoarces americanus	5	<1	0						X	X	X		X		4
Urophycis regius	4	<1	0					X			X			X	3
Fundulus spp.	3	<1	0		X										1
Clupeidae	3	<1	0											X	1
Liparis atlanticus	3	<1	0										X	X	2
Liparis liparis	3	<1	0		X						X	X			3
Mustelus canis	3	<1	0					X							1
Pomotomus saltatrix	3	<1	0			X		X			X				3
Dactylopterus volitans	3	<1	0			X					X			X	3
Pseudopriacanthus altus	3	<1	0								X	X			2
Hippocampus spp.	2	<1	0			X			X						2
Menticirrhus saxatilis	2	<1	0			X								X	2
Trinectes maculatus	2	<1	0				X		X						2
Clupea harengus	2	<1	0								X	X			2
Urophycis tenuis	1	<1	0							X					1
Alosa aestivalis	1	<1	0										X		1
Lophius americanus	1	<1	0							X					1
Carcharias taurus	1	<1	0								X				1
Etheostoma spp.	1	<1	0		X										1
Vomer setapinnis	1	<1	0				X								1
Total	16,779		674	51.05											
				Total No. of Species	25	25	24	28	29	24	36	26	24	31	
				No./15-Min. Tow	88.2	56.4	66.2	77.0	35.7	21.8	35.4	52.9	30.0	51.3	

TABLE 4.9-27   RESULTS OF TUKEY TEST FOR STATION DIFFERENCES

Year	Stations That are Not Significantly Different
1974 and 1975	1, 9, 4, 6, 8, 10, 7
1975	1, 4, 5, 9, 11, 6, 10, 8, 7

TABLE 4.9-28 TOW AREAS DETERMINED FOR THE MILLSTONE POINT AREA

Total area		42 million sq. yds. (13.58 sq. miles
Boat tow speed (average)		1.5 knots
Tow area (15 minutes)		7,600 sq. yds.
Total number of tow areas for the Millstone Point Area		5,531
	River stations	398
	Inner stations	1,504
	No. 1 Outer stations	752
	No. 2 Outer stations	2,877

TABLE 4.9-29. AVERAGE MONTHLY INSTANTANEOUS POPULATION ESTIMATES FOR WINTER FLOUNDER IN THE MILLSTONE POINT AREA

Year	Month	Population	Year	Month	Population
1973	4	52,308	1975	1	78,411
	5	225,500		2	45,727
	6	209,295		3	82,668
	7	247,934		4	151,743
	8	52,421		5	139,975
	9	47,794		6	92,723
	10	14,816		7	63,771
	11	46,700		8	52,804
	12	165,652		9	65,299
1974	1	13,318		10	57,240
	2	20,240		11	107,894
	3	103,410		12	56,680
	4	116,663			
	5	169,702			
	6	155,134			
	7	74,497			
	8	134,848			
	9	62,262			
	10	86,338			
	11	173,432			
	12	109,451			

TABLE 4.9-30 AVERAGE INSTANTANEOUS POPULATIONS DURING APRIL, 1973, THROUGH DECEMBER, 1975, IN THE MILLSTONE POINT AREA

	River	Inner	No. 1 Outer	No. 2 Outer	Total
Winter flounder	12,501	26,741	5,813	53,081	98,136
Scup	378	28,268	699	8,074	37,419
Windowpane flounder	641	4,824	842	16,006	22,313
Skates	28	4,245	436	13,042	17,[illegible]
Cunner	969	3,610	4,520	4,229	13,328
All species	24,153	76,129	13,363	112,356	226,001

TABLE 4.9-31 RANK BY ABUNDANCE OF FISH SPECIES CAPTURED IN SURFACE TRAWLS AT STATIONS IN THE MILLSTONE POINT AREA FROM FEBRUARY THROUGH DECEMBER, 1975

Species	5	8	10	11	Total	Percent of Total	Rank
Peprilus triacanthus	32	937	144	4	1,117	76.8	1
Menidia menidia	10		10	265	285	19.6	2
Gasterosteus aculeatus	16		2	10	28	1.9	3
Myoxocephalus aenaeus				9	9	<1	4
Osmerus mordax				4	4	<1	5
Urophycis chuss				4	4	<1	6
Apeltes quadracus				2	2	<1	7
Stenotomus chrysops	1	1			2	<1	8
Ammodytes americanus				1	1	<1	9
Pomatomus saltatrix				1	1	<1	10
Tautogolabrus adspersus				1	1	<1	11
Species/Station	4	2	3	10			
					1,454	Total Catch	

TABLE 4.9-32 1976 WINTER FLOUNDER POPULATION STUDY FIN CLIPPING SCHEDULE

Week of	Week Number	Clip
Jan 5 thru Feb 23		Weekly Monitoring
March 1	1	UPLV
8	2	UPUV
15	3	LPUV
22	4	LPLVUV
29	5	UPUVLV
April 5	6	UPUVLP
12	7	LPLVUP
19	8	UVLV
26	9	UPLP
May 3	10	UPAD
10 thru 24		Weekly Monitorin
June 14		Monitoring Week

UP = Upper Pectoral
LP = Lower Pectoral
UV = Upper Ventral
LV = Lower Ventral
AD = Anterior Dorsal

TABLE 4.9-33 ESTIMATES OF TOTAL POPULATION, PROBABILITY OF SURVIVAL, RECRUITMENT AND STANDARD ERRORS FOR THE NIANTIC RIVER WINTER FLOUNDER POPULATION IN 1974 (Jolly Method)

Sample Date	Total No. $(\hat{N})$	S. E. $\hat{N}$	Survival $(\widehat{\text{Phi}})$	S. E. $(\widehat{\text{Phi}})$	Recruits $\hat{B}$	S. E. $\hat{B}$
Feb 27	-	-	0.45	0.22	-	-
Feb 28	4,834	2,928	1.34	0.79	9,271	8,793
March 1	15,678	10,906	0.45	0.27	21,648	17,247
March 4-5	28,637	18,834	0.95	0.52	56,829	66,831
March 6-7	83,749	71,989	4.60	4.03	-134,063	325,944
March 8	250,432	279,137	0.29	0.34	31,998	83,450
March 13-19	105,326	98,658	1.25	1.16	-62,107	107,225
March 26-28	69,627	57,658	0.08	0.11	121.65	2,618
April 1-3	5,876	6,663	-	-	-	-
April 11-July 24	-	-	-	-	-	-

TABLE 4.9-34 CATCH DATA FOR DETERMINATION OF POPULATION ESTIMATE OF NIANTIC RIVER WINTER FLOUNDER, 1975

		Size			Recaptures							
Date (week of)	Captured	Group Total #1	Group Total #2	Group Total #3	Lower Pectoral	Upper Pectoral	Lower Ventral	Upper Ventral	Lower Pectoral Lower Ventral	Total Clipped	Total Recapture	Total Examined
1-March 31	2,761	1,026	1,551	184						1,735		1,735
2-April 7	2,355	1,044	1,154	89	68					1,243	68	1,311
3-April 14	3,355	1,043	2,045	215	31	21				2,260	52	2,312
4-April 21	2,641	273	2,103	192	11	10	52			2,295	73	2,368
5-April 28	3,684	442	2,687	413	18	13	58	53		3,100	142	3,242
7-May 12	4,007	794	2,739	262	20	7	43	39	103		212	3,213
Grand Totals	18,803	4,622	12,279	1,355	148	51	153	92	103	10,633	547	14,181

TABLE 4.9.-35 NIANTIC RIVER WINTER FLOUNDER POPULATION ESTIMATES (TRIPLE-CATCH TRELLIS METHOD), 1975

Date (week of)	N (Population)	$\hat{S}$ (Survival)	$\hat{R}$ (Recruitment)	R (Calculated)	R Actual	Number Added To Population
1-March 31	8,800 (calculated)	1.0095	-	-	-	8,800
2-April 7	33,304 ± 9,816	.3431	3.7491	31,412	33,405	24,504
3-April 14	44,832 ± 17,631	1.0907	1.9471	46,312	61,282	33,405
4-April 21	110,181 ± 15,321	.5065	1.2070	11,553	14,645	65,349
5-April 28	70,452 ± 3,910	.5671	1.3068	12,257	-	14,645
6-May 5	63,962 (calculated)					
7-May 12	52,210 (calculated)					12,257
Total Populations Weeks 1-5						146,703
Total Populations Weeks 1-7						158,960

TABLE 4.9-36 . NIANTIC RIVER WINTER FLOUNDER POPULATION ESTIMATES (JOLLY'S METHOD) BASED ON OBSERVED DATA, 1975

Date (week of)	Total Number (N)	Probability of Survival (PHI)	Number Joining (calculated) (B)	Number Joining (actual)	S. E. $(\hat{N})$	S. E. $(\hat{PHI})$	S. E. $(\hat{B})$
1-March 31		1.2245		40,958.54		0.2078	
2-April 7	40,958.54	0.3699	40,236.80	40,236.80	8,434.90	0.0624	9,274.79
3-April 14	55,389.19	1.1882	69,309.88	79,734.13	10,284.43	0.1592	20,544.84
4-April 21	135,122.56	0.5530	6,845.13	6,845.13	22,995.82	0.0850	11,337.34
5-April 28	81,571.75				12,459.41		
7-May 12							
Total Population				167,775.00			
For Weeks 1-5				S.E.≈18,307.00			

TABLE 4.9-37 NIANTIC RIVER WINTER FLOUNDER POPULATION ESTIMATES (JOLLY'S METHOD) BASED ON DATA CORRECTED FOR MULTIPLE RECAPTURES, 1975

Date (week of)	Total Number (N)	Probability of Survival (PHI)	Number Joining (calculated) (B)	Number Joining (actual)	S. E. ($\hat{N}$)	S. E. ($\hat{PHI}$)	S. E. ($\hat{B}$)
1-March 31		1.0833		36,236.88		0.1808	
2-April 7	36,236.88	0.4066	41,716.61	41,716.61	7,366.85	0.0671	9,505.04
3-April 14	56,450.74	1.1460	66,522.44	74,764.25	10,508.36	0.1538	19,966.42
4-April 21	131,217.31	0.5435	7,355.56	7,355.56	22,320.81	0.0831	10,881.33
5-April 28	78,669.88				11,994.60		
7-May 12							
Total Population				160,073.00			
For Weeks 1-5				S.E.≈19,389.00			

TABLE 4.9- 38 CATCH DATA FOR DETERMINATION OF POPULATION ESTIMATE OF NIANTIC RIVER WINTER FLOUNDER, 1976

Week No.	Week of	Size Groups #1	#2	#3	#4	Total Caught	Total Clip.	Total Rem.	Total Exam.	1975 Recapture 1 LP	2 UP	3 LV	4 UV	5 LPLV	Total 1975	1976 Recapture 1 UPLV	2 UPUV	3 LPUV	4 LPLVUV	5 UPUVLV	6 UPUCLP	7 LPLVUP	8 UVLV	9 UPLP	10 UPAD	Total Recaptures
1	3/1	311	189	537	285	1330	1011	8	1019	3	0	8	4	2	17											-
2	8	690	490	801	353	2353	1644	19	1663	1	1	12	2	1	17	34										34
3	15	282	248	622	183	1340	1053	5	1058	5	1	13	12	11	42	18	67									85
4	22	638	342	499	163	1649	1004	7	1011	3	0	7	6	8	24	15	44	32								91
5	29	424	312	466	75	1292	853	15	868	1	1	3	2	2	9	6	18	13	17							54
6	4/5	451	324	543	83	1501	950	100	1050	2	1	4	0	2	9	8	12	7	25	29						81
7	12	345	296	646	76	1371	1018	8	1026	0	0	4	4	3	11	6	11	5	10	22	32					86
8	19	232	352	1161	83	1833	1596	5	1601	0	0	3	4	3	10	5	10	7	7	9	17	32				87
9	26	270	132	566	68	1041	766	5	771	0	0	2	3	3	8	3	4	1	2	10	8	11	30			69
10	5/3	339	184	591	23	1165	798	28	826	1	0	1	3	3	8	4	3	5	2	11	7	15	22	18	5	87
Total		3982	2869	6432	1392	14875	10693	200	10893	16	4	57	40	38	155	99	169	70	63	81	64	58	52	18	5	674
May 10 thru May 24		198	97	359	17	671	-	-	473	0	0	1	2	3	6	1	2	4	3	3	2	4	10	7	9	45

TABLE 4.9-39 NIANTIC RIVER WINTER FLOUNDER POPULATION ESTIMATES (JOLLY'S METHOD), 1976

Date (week of)	Total Number (N)	Probability of Survival (PHI)	Number Joining (calculated) (B)	Number Joining (actual)	S. E. ($\hat{N}$)	S. E. ($\hat{PHI}$)	S. E. ($\hat{B}$)
March 1	≈24,000.00	.6613		32,698.90		.0874	
March 8	32,698.90	.9866	-4,260.84	0.00	6,882.47	.1351	6,763.04
March 15	27,979.98	.6669	5,170.68	5,170.68	4,658.02	.1115	3,189.25
March 22	23,826.67	.5117	12,962.03	12,962.03	4,051.78	.0820	3,872.04
March 29	25,151.67	.9556	5,259.73	5,259.73	4,544.24	.1544	4,548.76
April 5	29,279.34	.7336	5,967.83	5,967.83	5,082.25	.1306	3,776.63
April 12	27,374.42	.8653	27,699.27	27,699.27	4,887.59	.1627	7,299.55
April 19	51,380.78	.7446	-2,469.01	0.00	9,598.15	.1868	6,063.63
April 26	35,785.98	.6618	822.71	822.71	9,160.30	.2870	3,784.16
May 3	24,502.29				9,876.60		
Total Population For Weeks 1-10				91,394.03			
				S.E. ≈ 14,620.57			

TABLE 4.9-40 AVERAGE SIZE AND PERCENT SIZE COMPOSITION OF WINTER FLOUNDER IN THE NIANTIC RIVER DURING THE 1975 AND 1976 POPULATION STUDY PERIOD

Year	Length Groups					
	0-150 mm	150-300 mm	150-200 mm	200-300 mm	Greater than 300 mm	All Sizes
1975	106.2 mm	239.6 mm	-	-	321.1 mm	213.0 mm
1976	100.2 mm	223.0 mm	178.0 mm	243.1 mm	331.9 mm	204.1 mm
1975	25.3 %	67.3 %	-	-	7.4 %	
1976	27.1 %	63.4 %	19.6 %	43.8 %	9.5 %	

TABLE 4.9 -41 . 1976 NIANTIC RIVER WINTER FLOUNDER SEX RATIO

Week of	Size Group 2		Size Group 3		Size Group 4		Over 250 mm
	% Male	% Female	% Male	% Female	% Male	% Female	% Female
Feb 2 thru March 15 (1976)	32	68	34	66	33	67	66
March 22 thru May 24 (1976)	31	69	36	64	48	52	62
Feb 2 thru May 24 (1976)	32	68	38	62	35	65	63

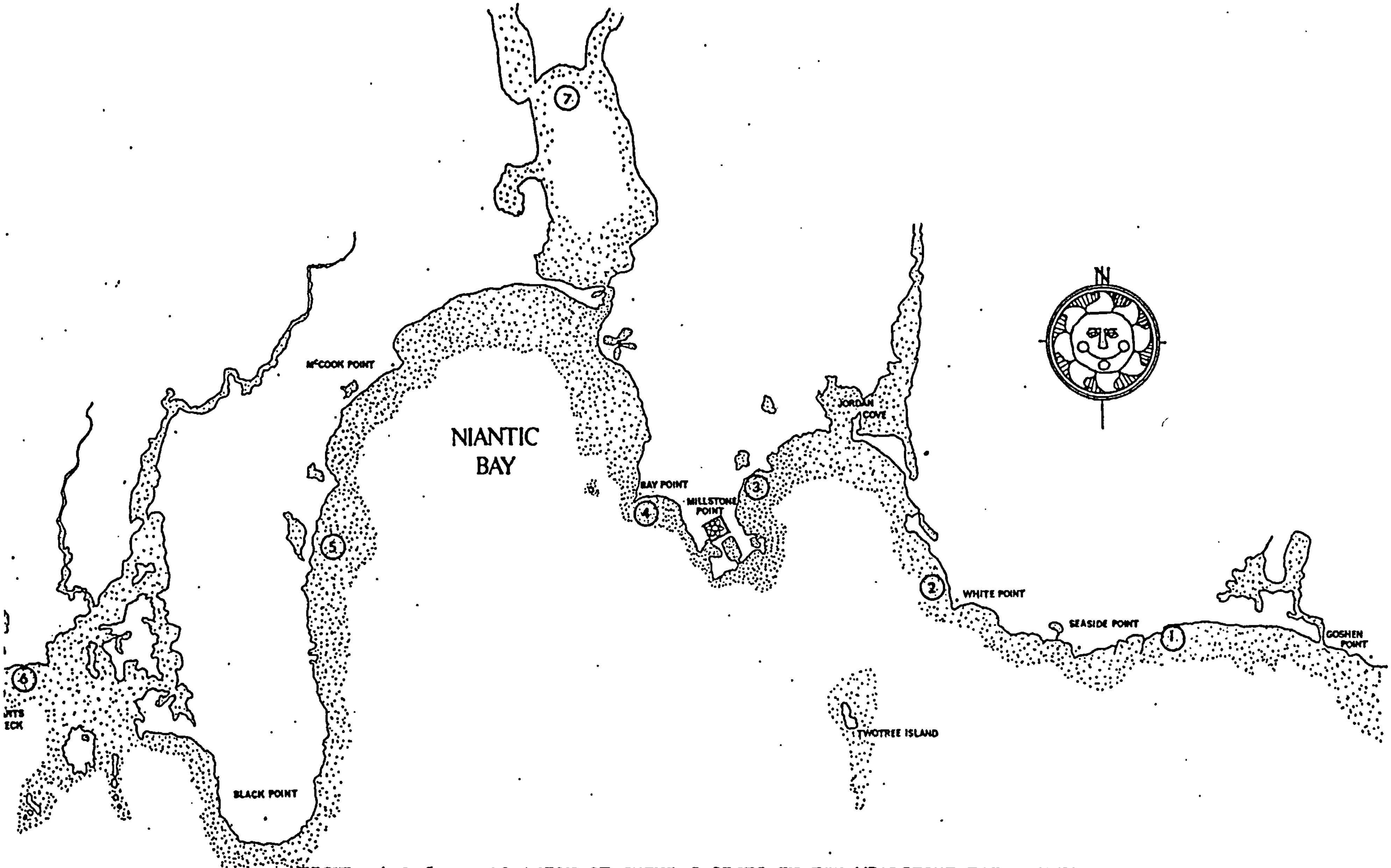


FIGURE 4.9-1 LOCATION OF SEINING SITES IN THE MILLSTONE POINT AREA

1. Seaside, 2. White Point, 3. Jordan Cove, 4. Bay Point
5. Crescent Beach, 6. Giants Neck, 7. Sandy Point

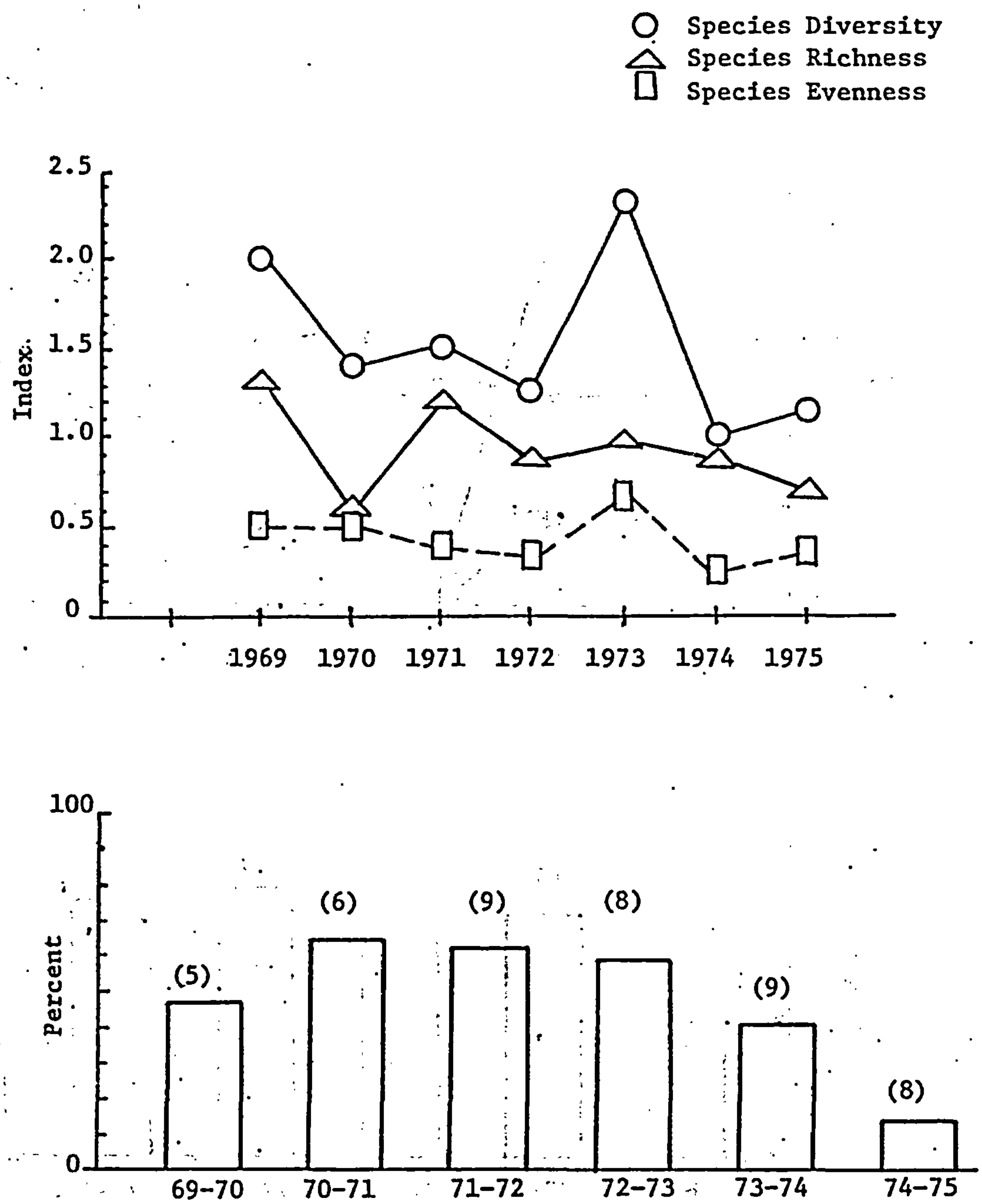


FIGURE 4.9-2. GRAPHS SHOWING (TOP) ANNUAL SPECIES DIVERSITY ($\hat{H}$), SPECIES RICHNESS (D), AND SPECIES EVENNESS (J) INDEXES AND (BOTTOM) PERCENT OF ANNUAL COMMUNITY SIMILARITY AT WHITE POINT FROM 1969 THROUGH 1975. NUMBER OVER BAR INDICATES NUMBER OF OVERLAPPING SPECIES.

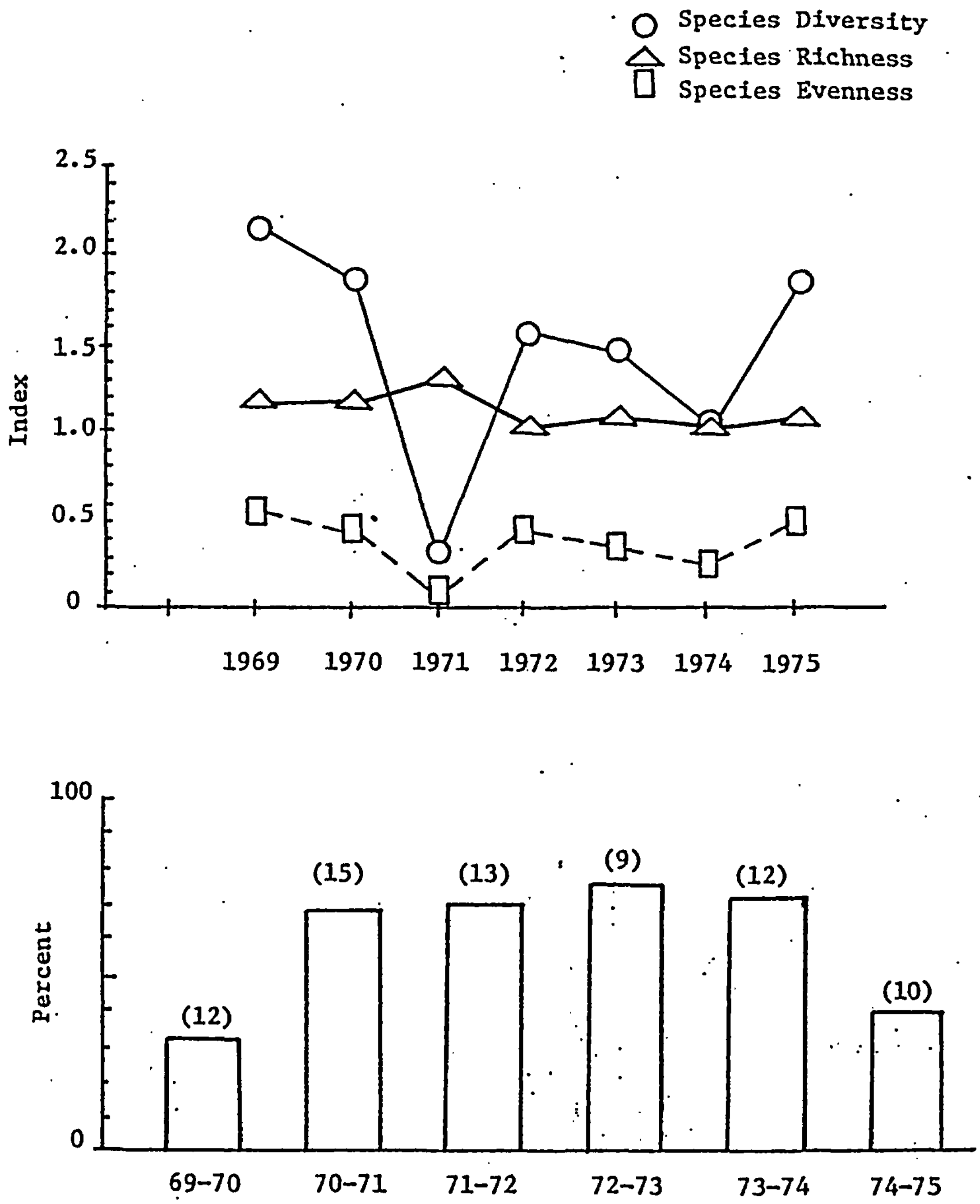
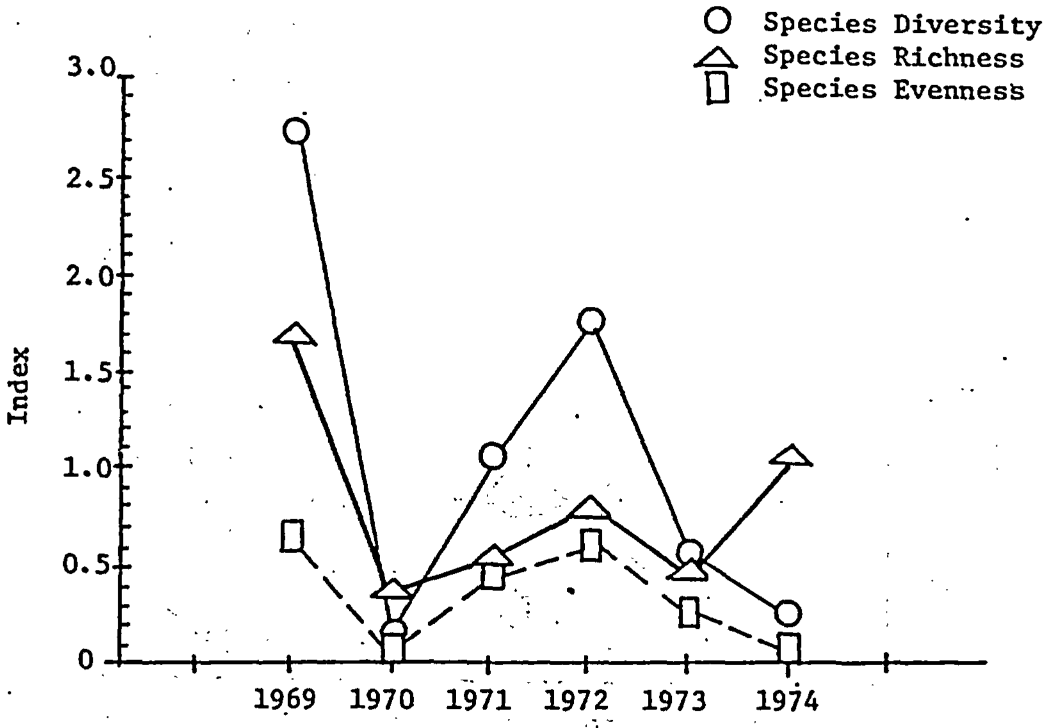


FIGURE 4.9-3. GRAPHS SHOWING (TOP) ANNUAL SPECIES DIVERSITY ($\hat{H}$), SPECIES RICHNESS (D), AND SPECIES EVENNESS (J) INDEXES AND (BOTTOM) PERCENT OF ANNUAL COMMUNITY SIMILARITY AT JORDAN COVE FROM 1969 THROUGH 1975. NUMBER OVER BAR INDICATES NUMBER OF OVERLAPPING SPECIES.



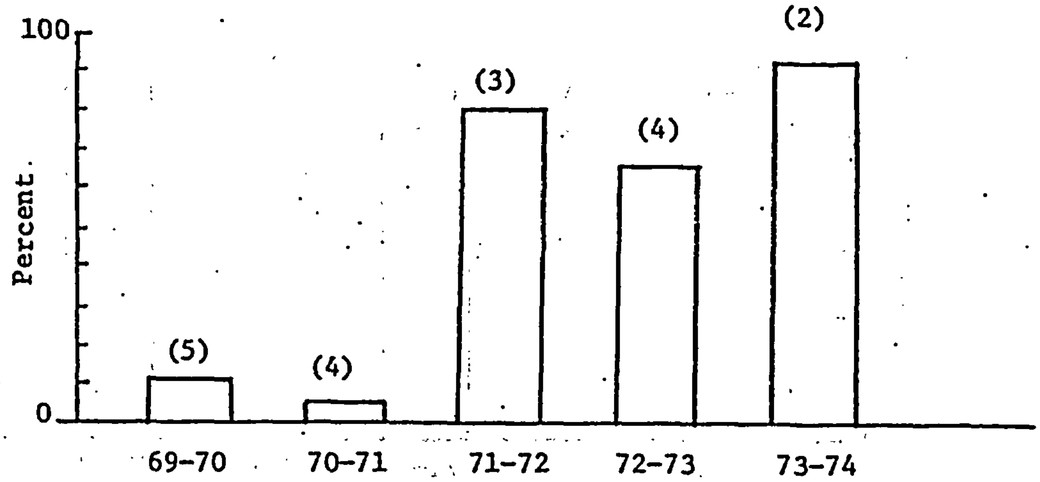


FIGURE 4.9-4. GRAPHS SHOWING (TOP) ANNUAL SPECIES DIVERSITY ($\hat{H}$), SPECIES RICHNESS (D) AND SPECIES EVENNESS (J) INDEXES AND (BOTTOM) PERCENT OF ANNUAL COMMUNITY SIMILARITY AT BAY POINT FROM 1969 THROUGH 1975. NUMBER OVER BAR INDICATES NUMBER OF OVERLAPPING SPECIES.

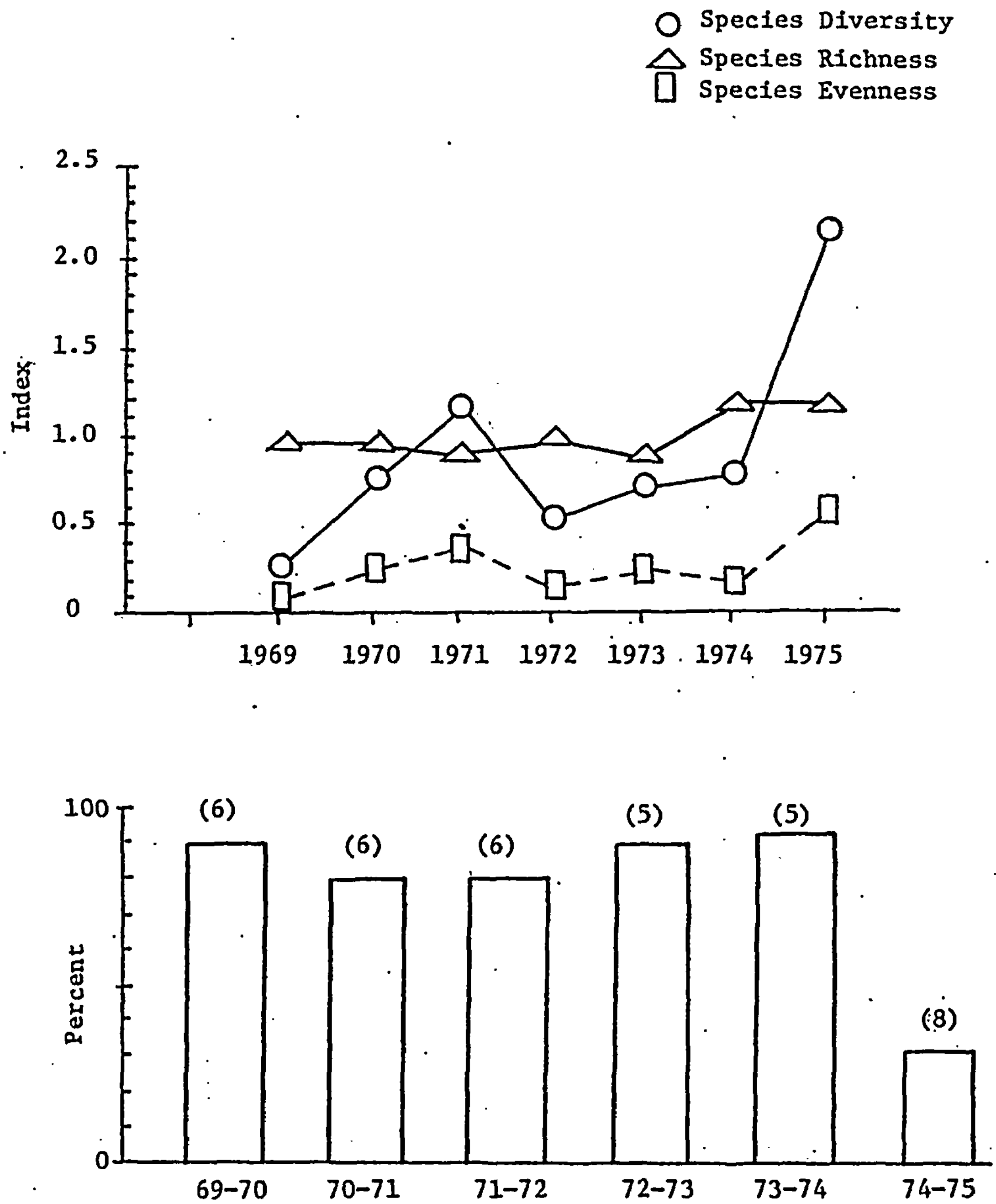


FIGURE 4.9-5 . GRAPHS SHOWING (TOP) ANNUAL SPECIES DIVERSITY ($\hat{H}$), SPECIES RICHNESS (D) AND SPECIES EVENNESS (J) INDEXES AND (BOTTOM) PERCENT OF ANNUAL COMMUNITY SIMILARITY AT GIANTS NECK FROM 1969 THROUGH 1975. NUMBER OVER BAR INDICATES NUMBER OF OVERLAPPING SPECIES.

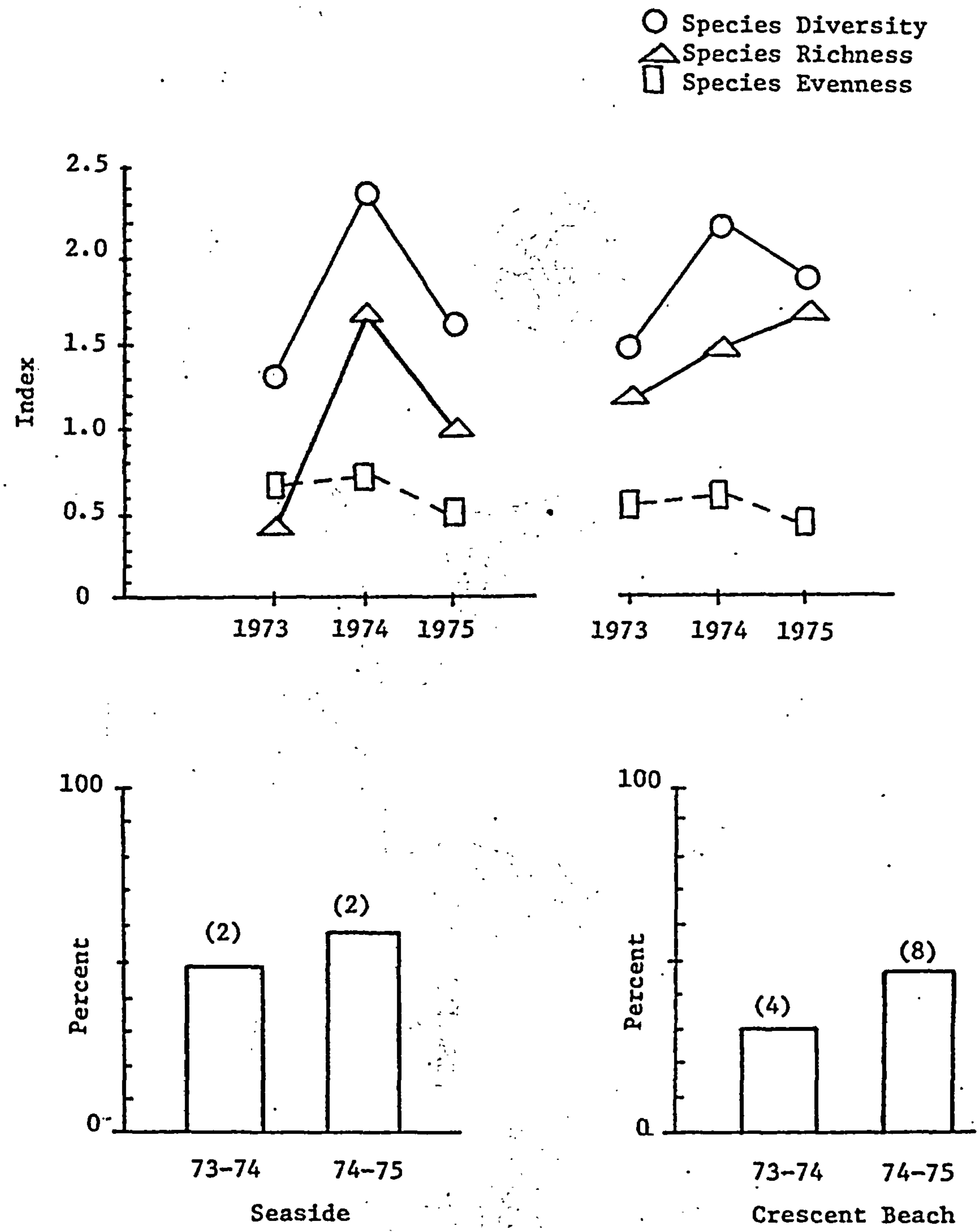


FIGURE 4.9-6. (TOP) ANNUAL SPECIES DIVERSITY ($\hat{H}$), SPECIES RICHNESS (D), AND SPECIES EVENNESS (J) INDEXES AT SEASIDE AND CRESCENT BEACH. (BOTTOM) PERCENT OF COMMUNITY SIMILARITY AT SEASIDE AND CRESCENT BEACH FROM 1973 THROUGH 1975. NUMBER OVER BAR INDICATES NUMBER OF OVERLAPPING SPECIES.

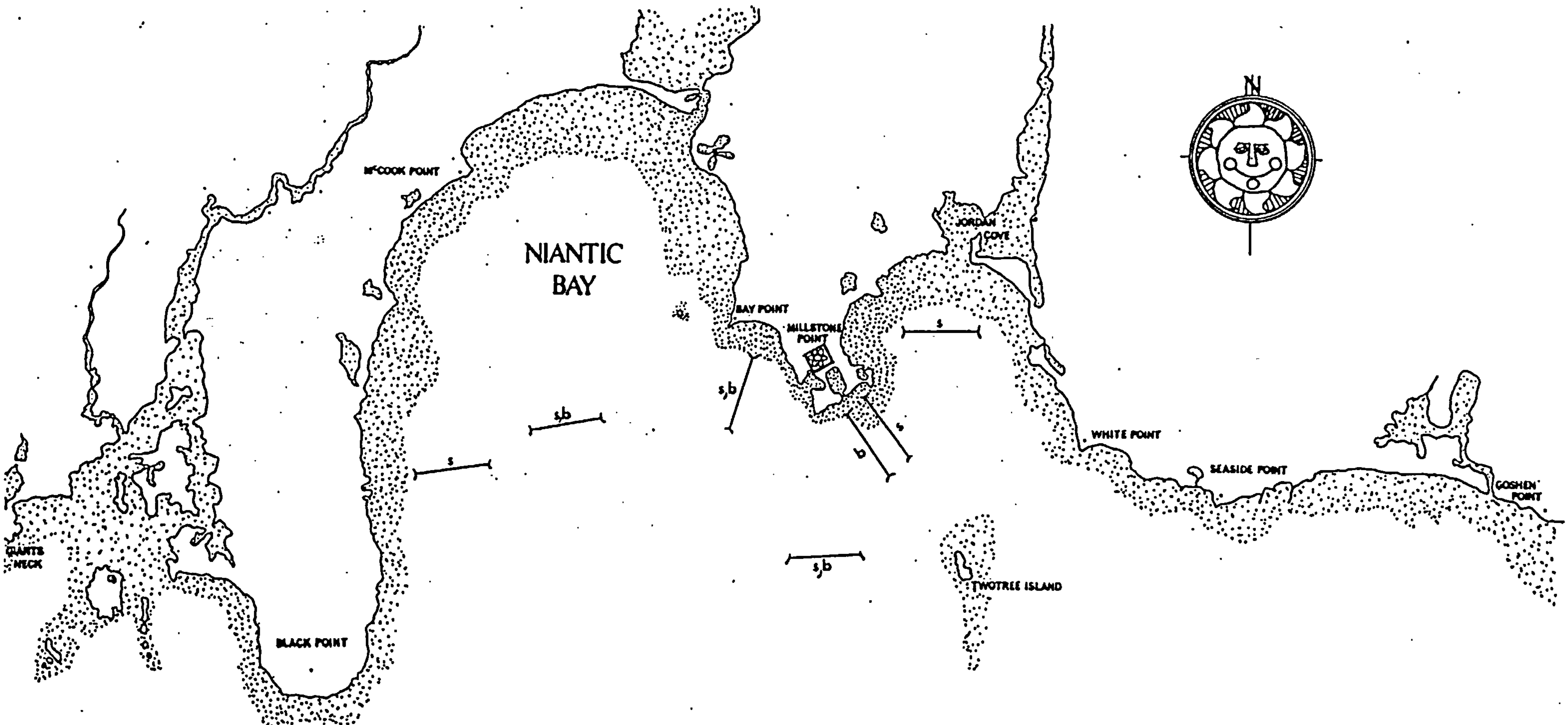


FIGURE 4.9-7 LOCATION O^ GILL NETTING STATIONS

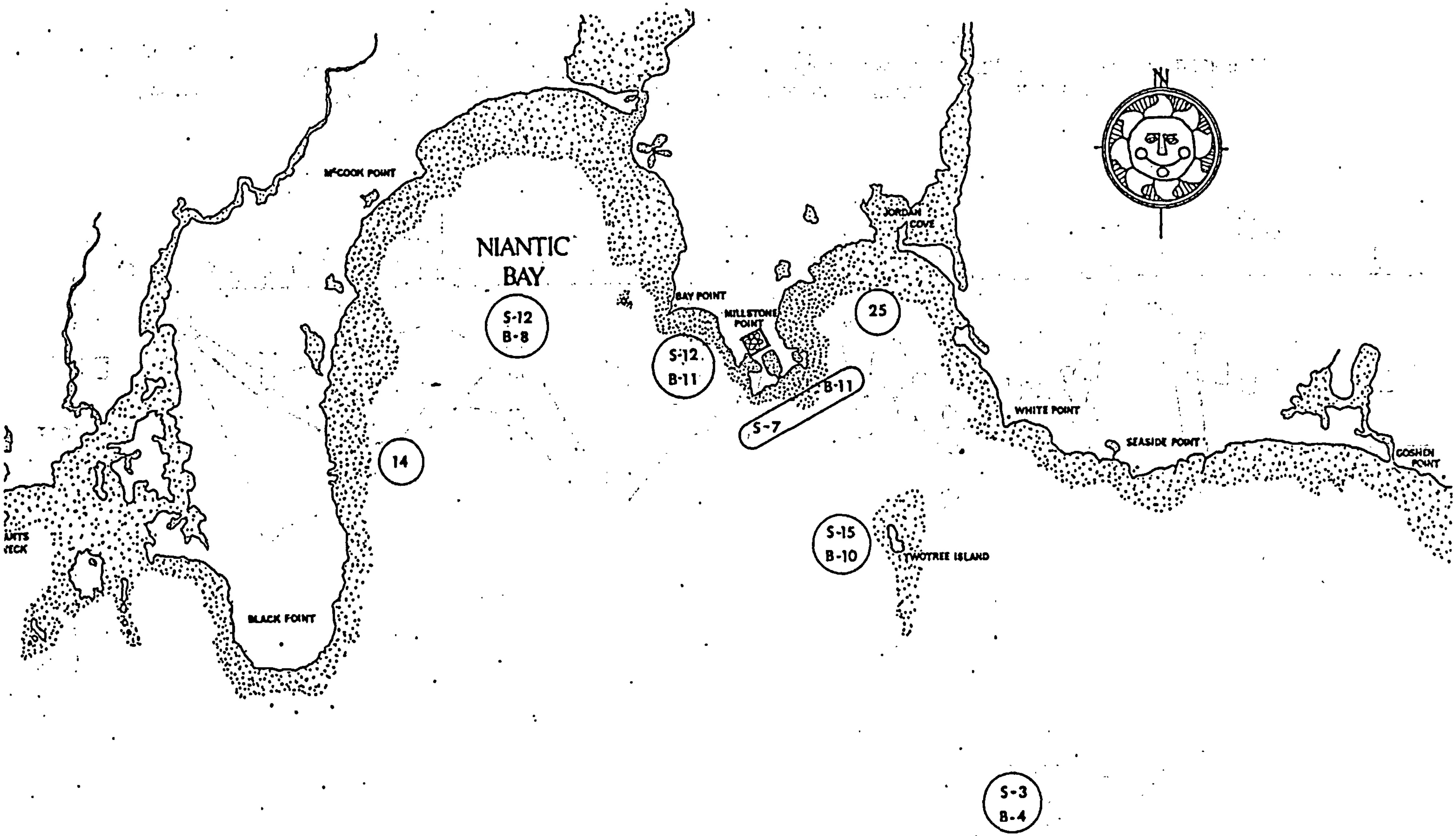


FIGURE 4.9-8 . NUMBER OF FISH TAKEN IN GILL NETS PER OVERNIGHT SET IN THE MILLSTONE POINT AREA DURING 1975.
S = Surface net; B = Bottom net

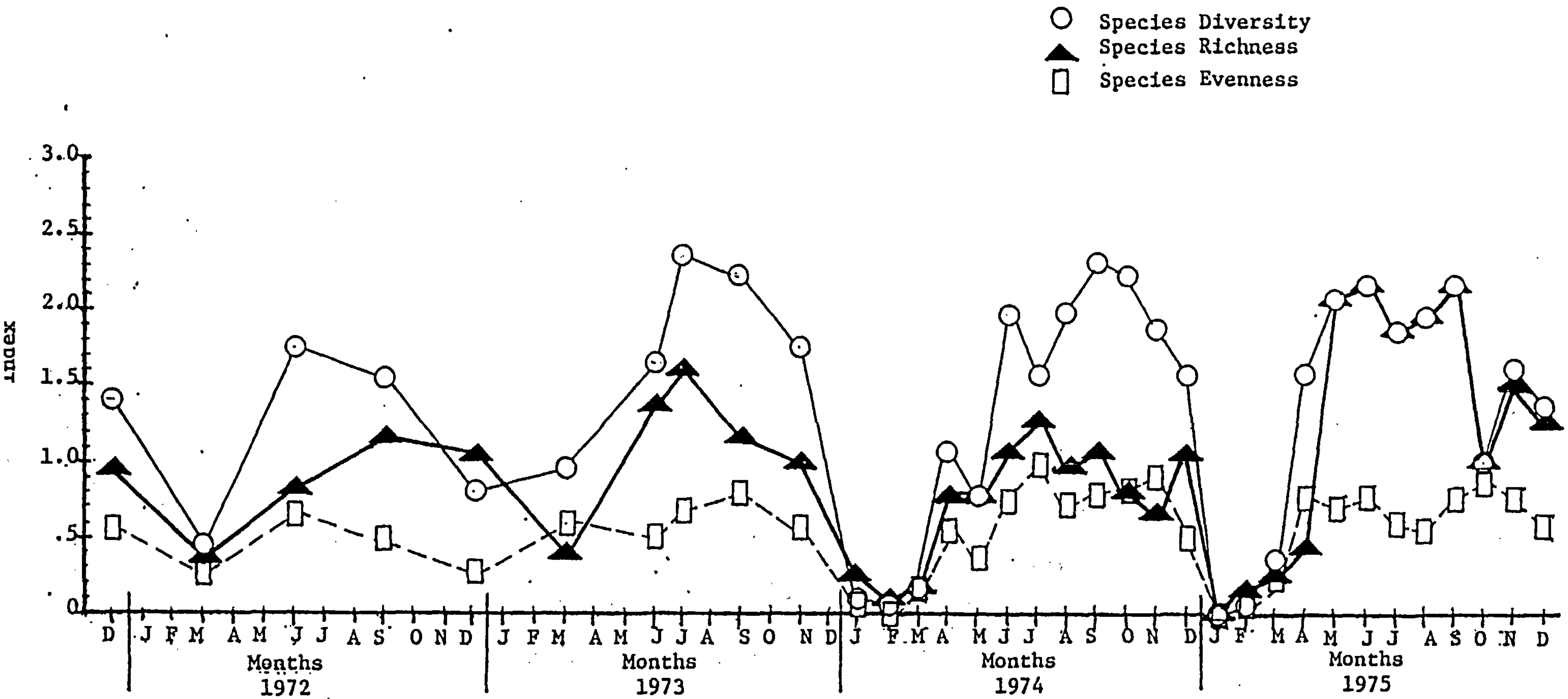


FIGURE 4.9 -9 SPECIES DIVERSITY, SPECIES RICHNESS, AND SPECIES EVENNESS OF FISH TAKEN IN GILL NETS AT EACH SAMPLING PERIOD IN THE MILLSTONE POINT AREA FROM DECEMBER, 1971, THROUGH DECEMBER, 1975.

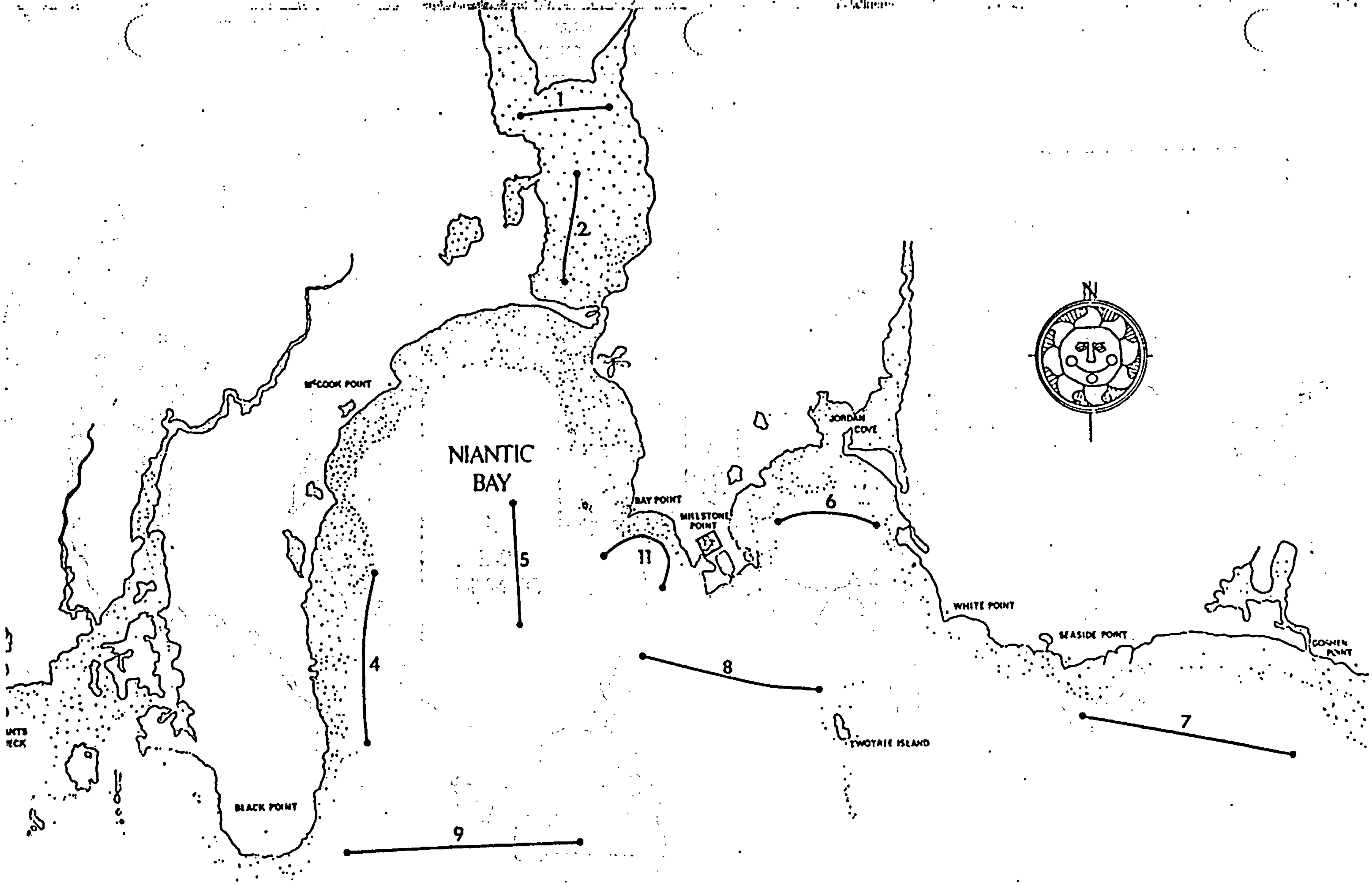
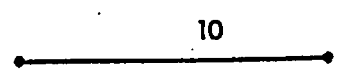


FIGURE 4.9-10 LOCATION OF OTTER TRAWL STATIONS



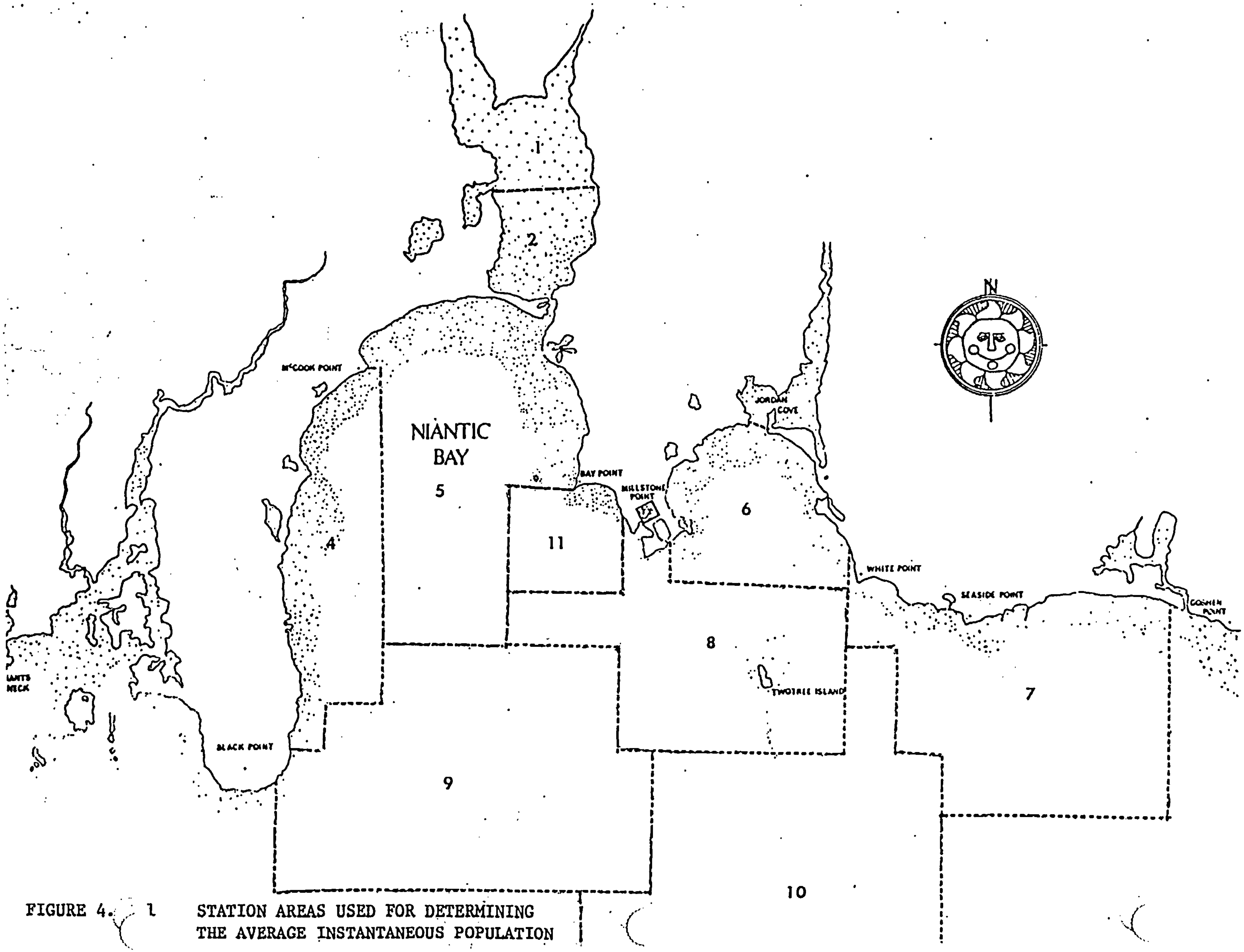
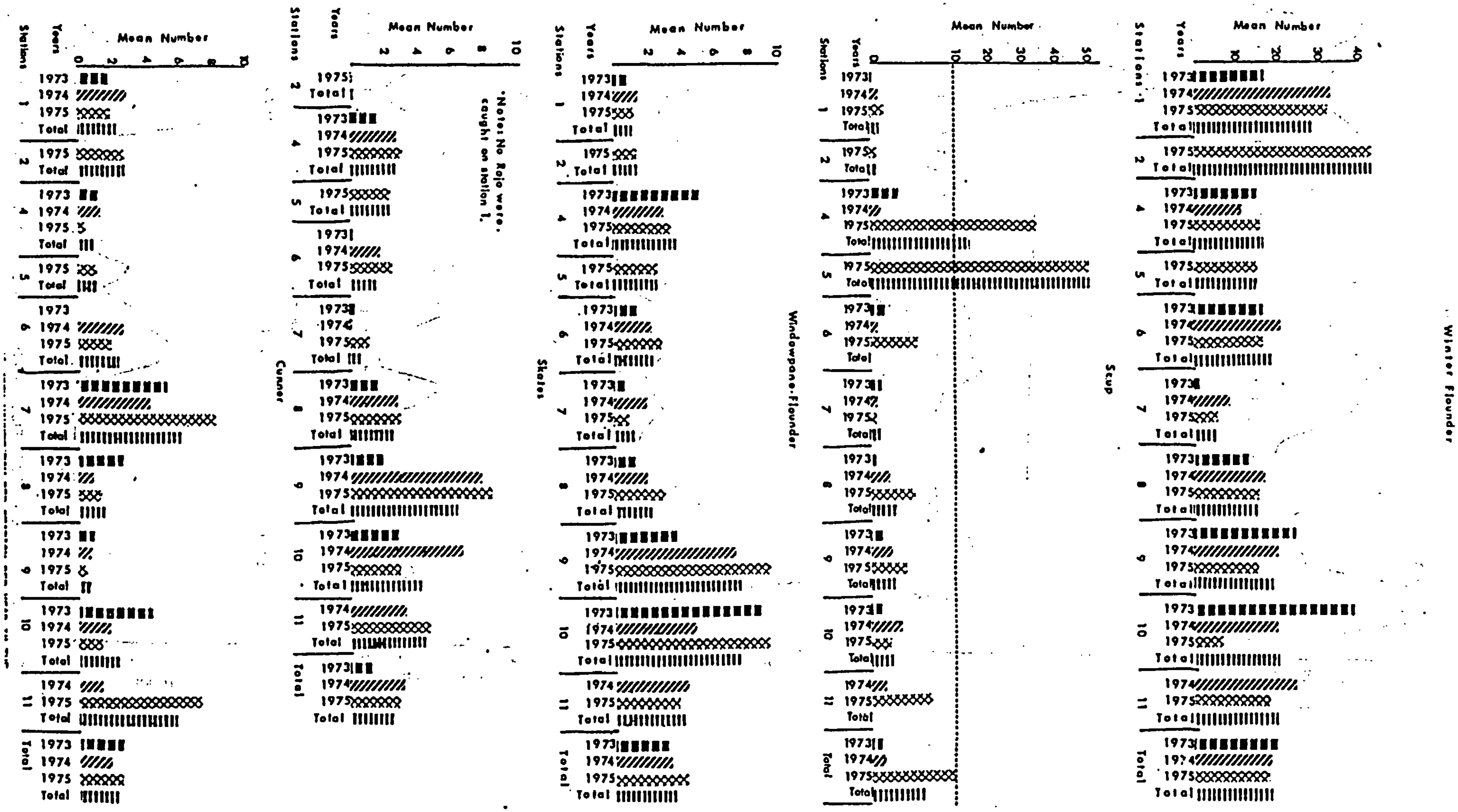


FIGURE 4. 1 STATION AREAS USED FOR DETERMINING THE AVERAGE INSTANTANEOUS POPULATION


Mean Number
Stations
Years
Cunner
*Note: No Raja were caught on station 1.
Skates
Windowpane Flounder
Scup
Winter Flounder

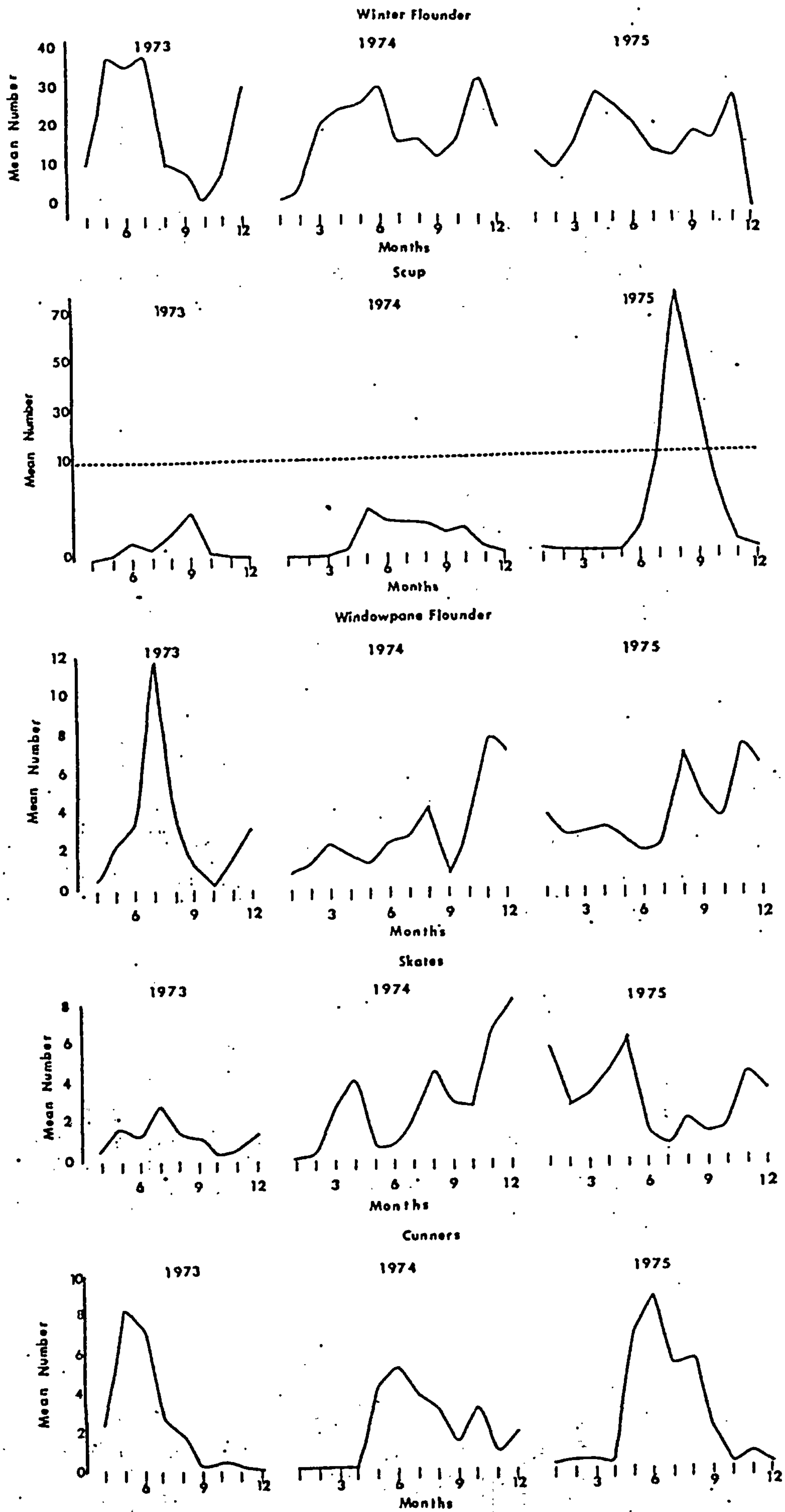
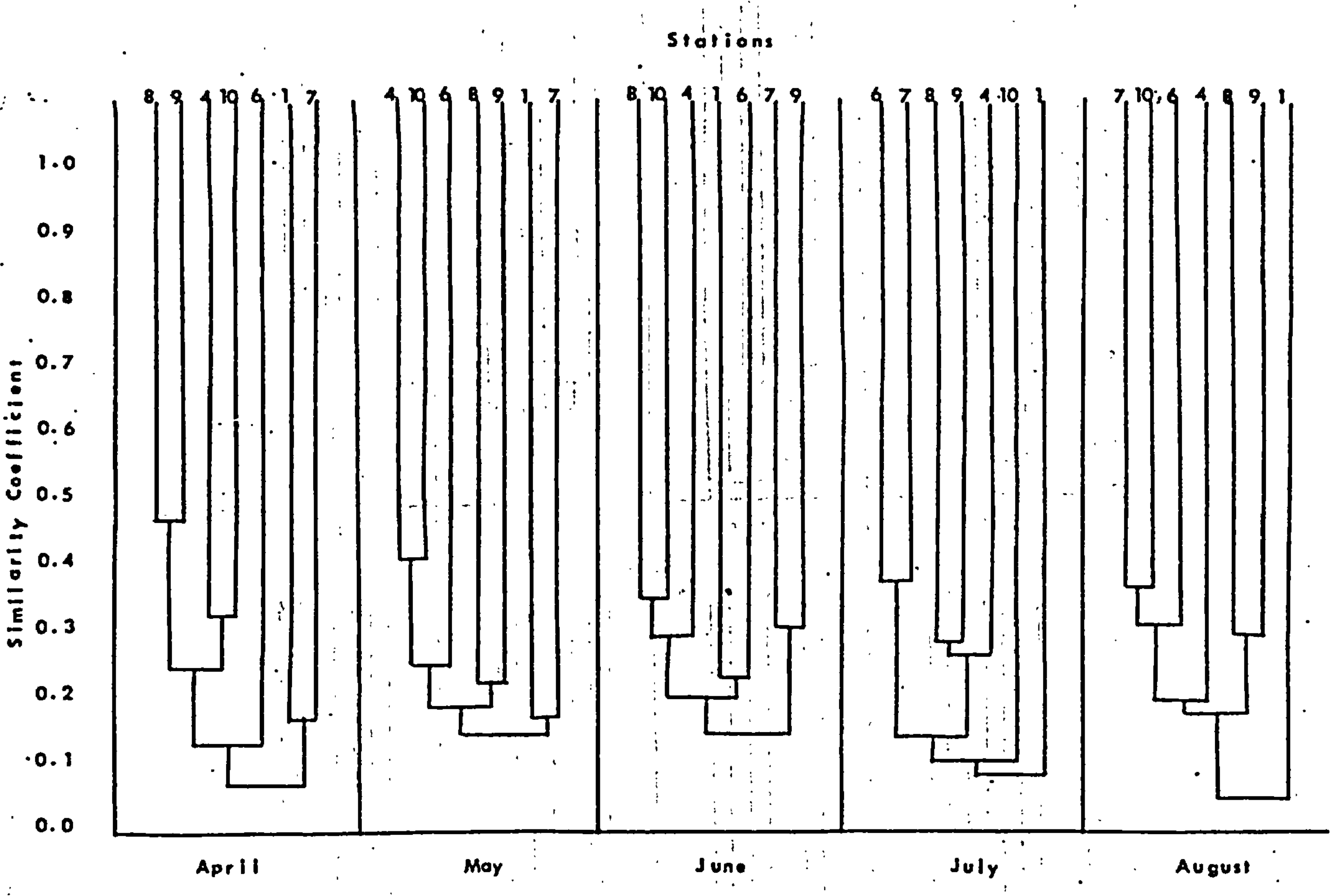
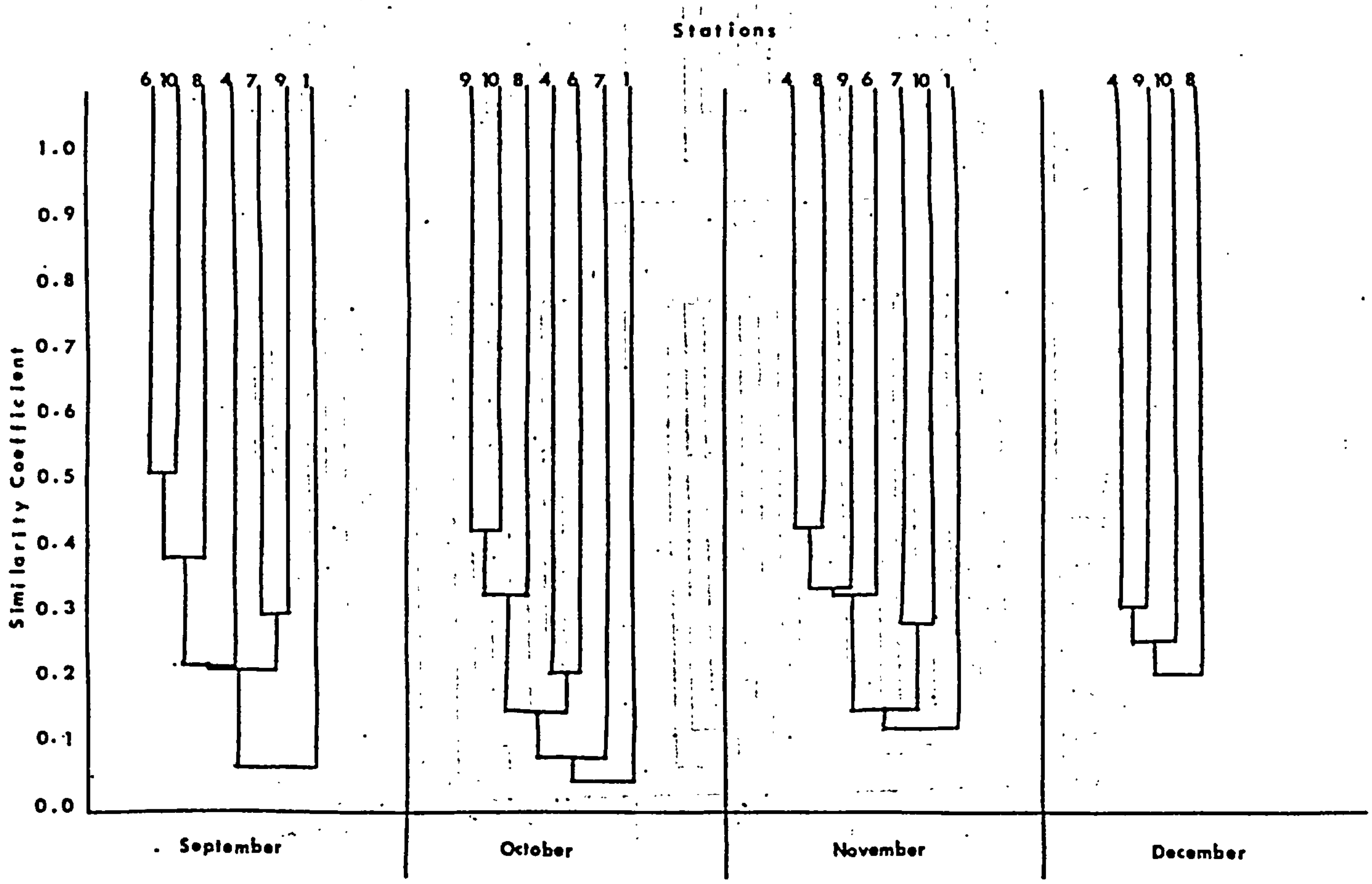


FIGURE 4.9-13 MEAN NUMBER OF FISH PER FIFTEEN MINUTE TOW AT ALL STATIONS IN THE MILL-


Stations
8 9 4 10 6 1 7
4 10 6 8 9 1 7
8 10 4 1 6 7 9
6 7 8 9 4 10 1
7 10 6 4 8 9 1
Similarity Coefficient
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
April
May
June
July
August


Stations
6 10 8 4 7 9 1
9 10 8 4 6 7 1
4 8 9 6 7 10 1
4 9 10 8
Similarity Coefficient
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
September
October
November
December

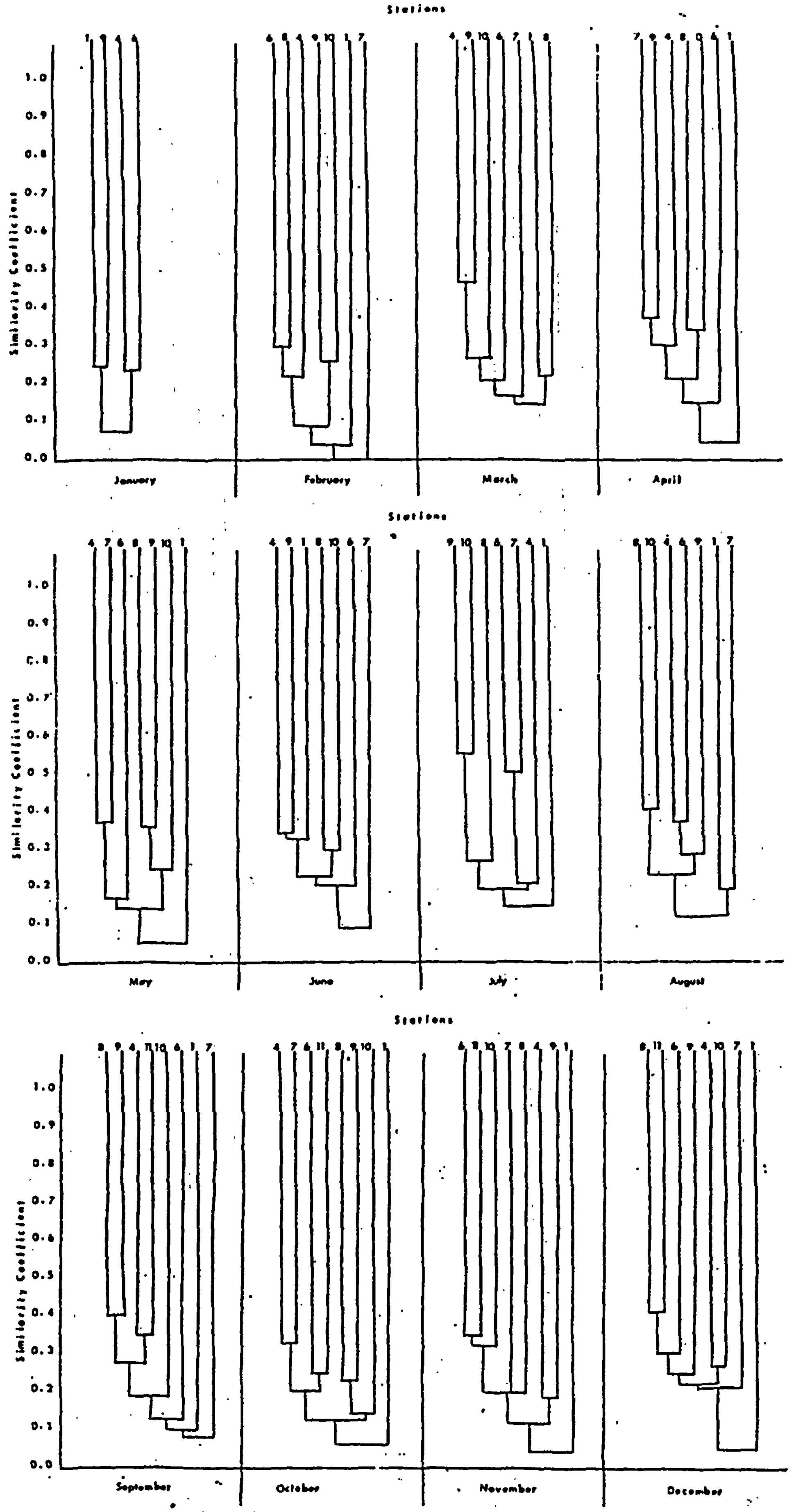


FIGURE 4.9-15 CLUSTER ANLAYSIS OF ALL STATIONS IN THE MILLSTONE POINT AREA DURING JANUARY, 1974, THROUGH DECEMBER, 1974

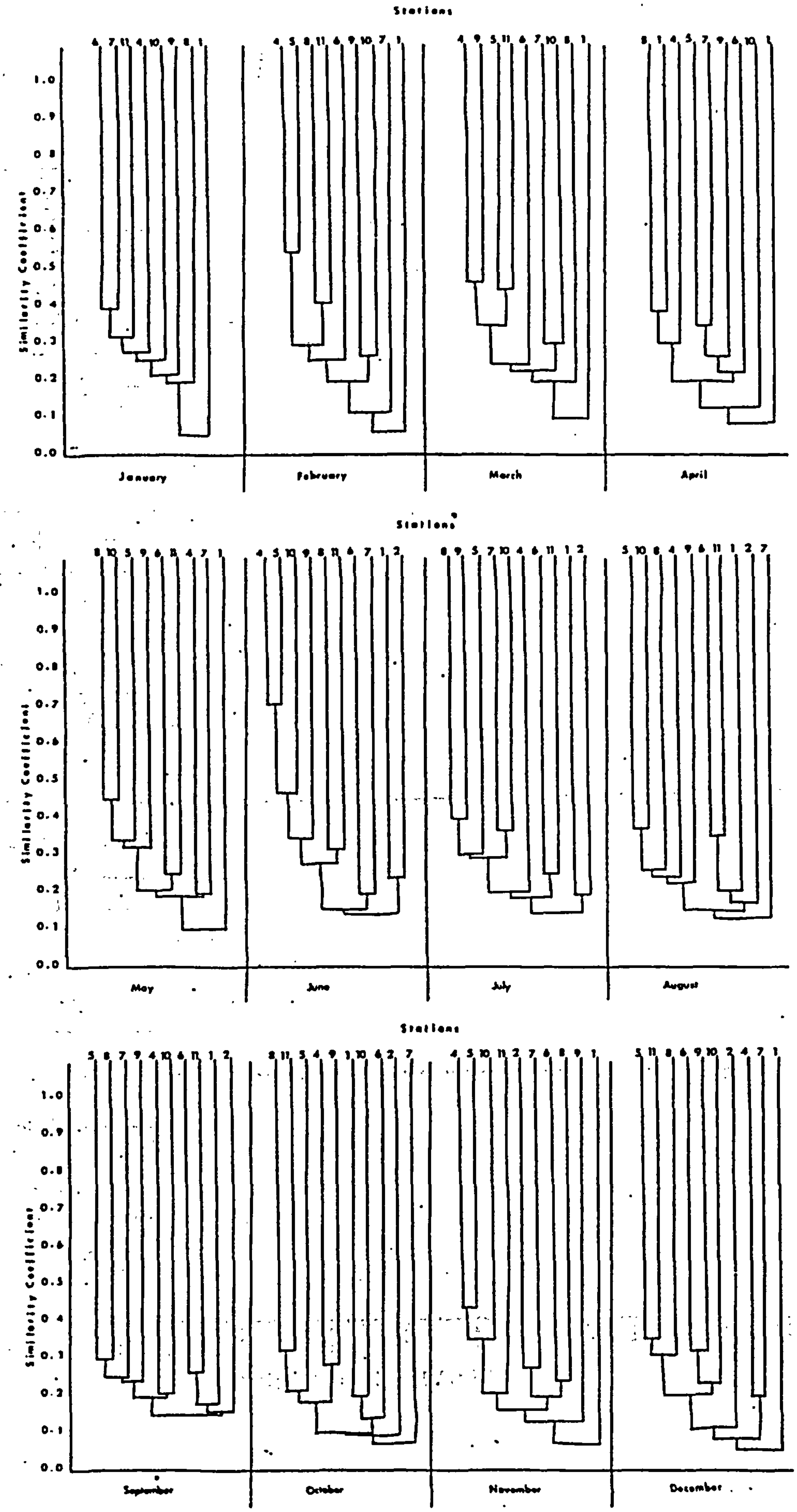


FIGURE 4.9-16 CLUSTER ANALYSIS OF ALL STATIONS IN THE MILLSTONE POINT AREA DURING

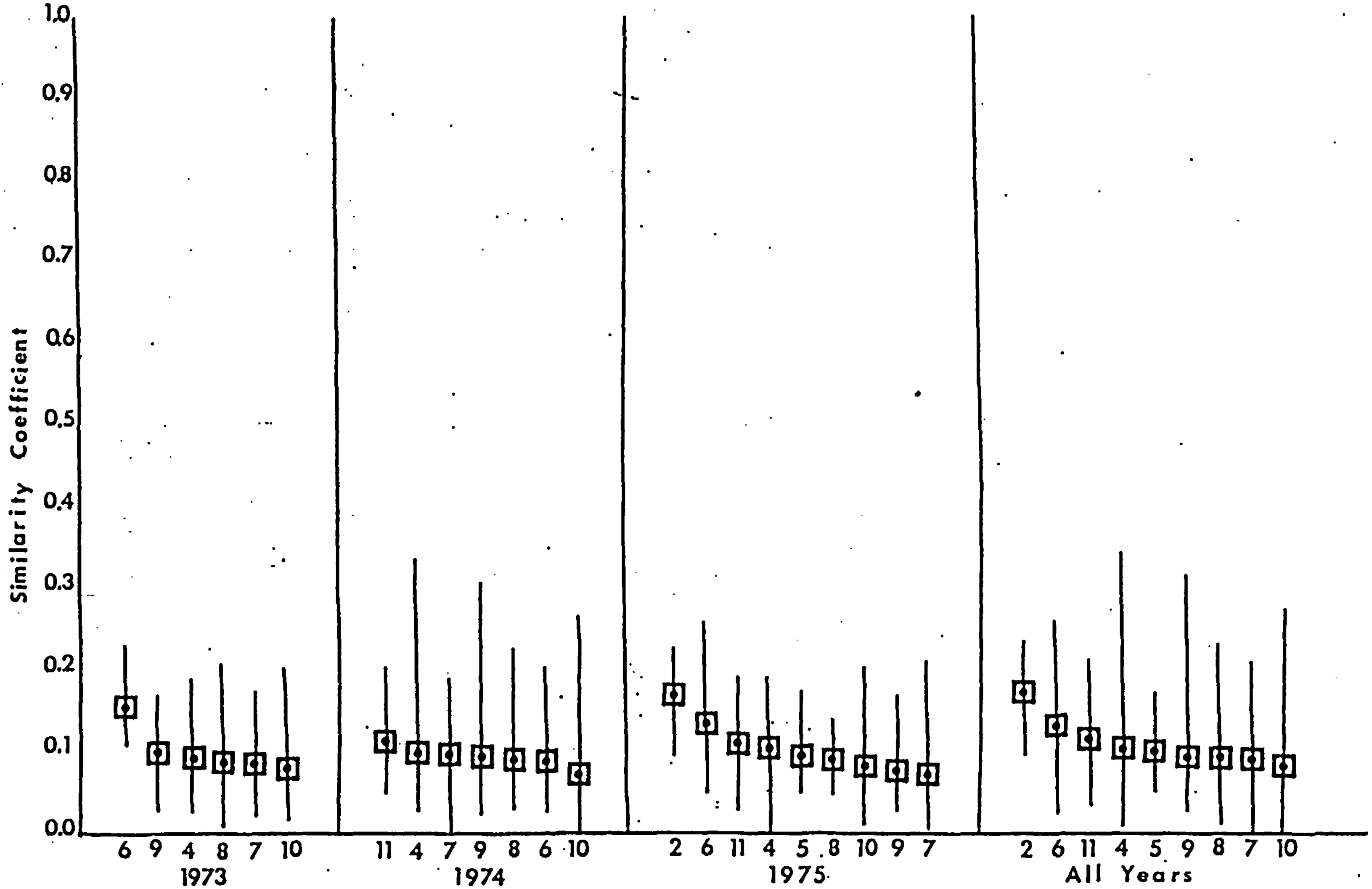


FIGURE 4.9-17 AVERAGE AND RANGE OF ~~ARLY SIMILARITY COEFFICIENTS FOR STATION 1 DURING APR. 1973, THROUGH DECEMBER, 1975

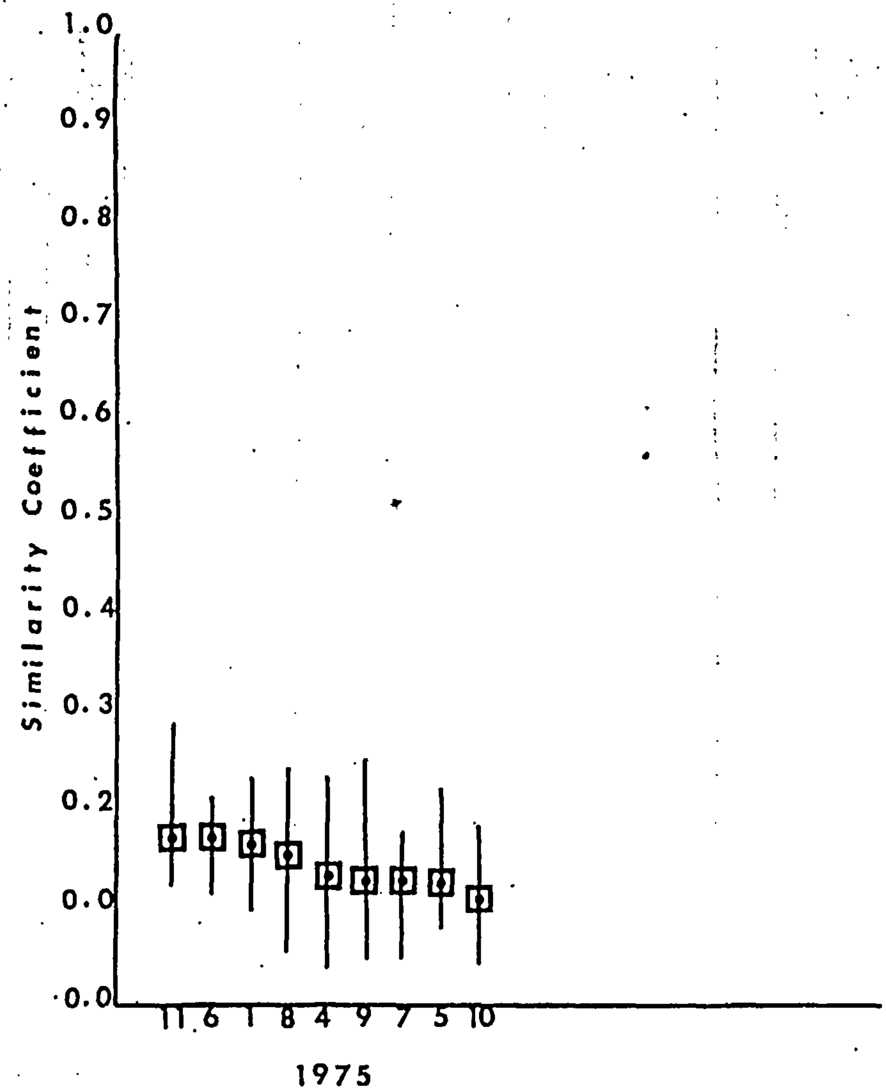


FIGURE 4.9-18 AVERAGE AND RANGE OF YEARLY SIMILARITY COEFFICIENTS FOR STATION 2 DURING APRIL, 1973, THROUGH DECEMBER, 1975

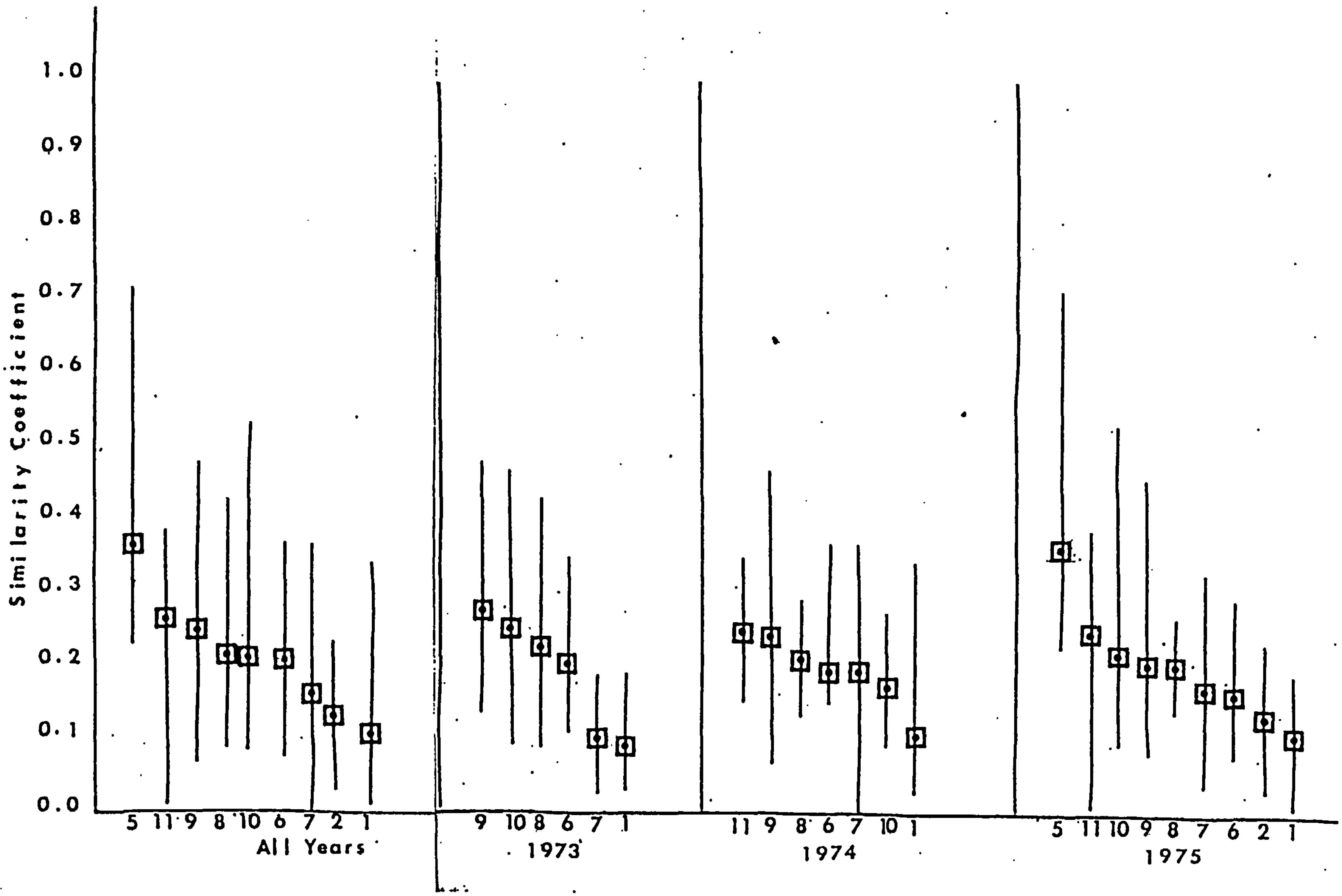


FIGURE 4.9-19 AVERAGE AND RANGE O[illegible] [illegible]EARLY SIMILARITY COEFFICIENTS FOR STATION 4 DURING AP[illegible] 1973, THROUGH DECEMBER, 1975

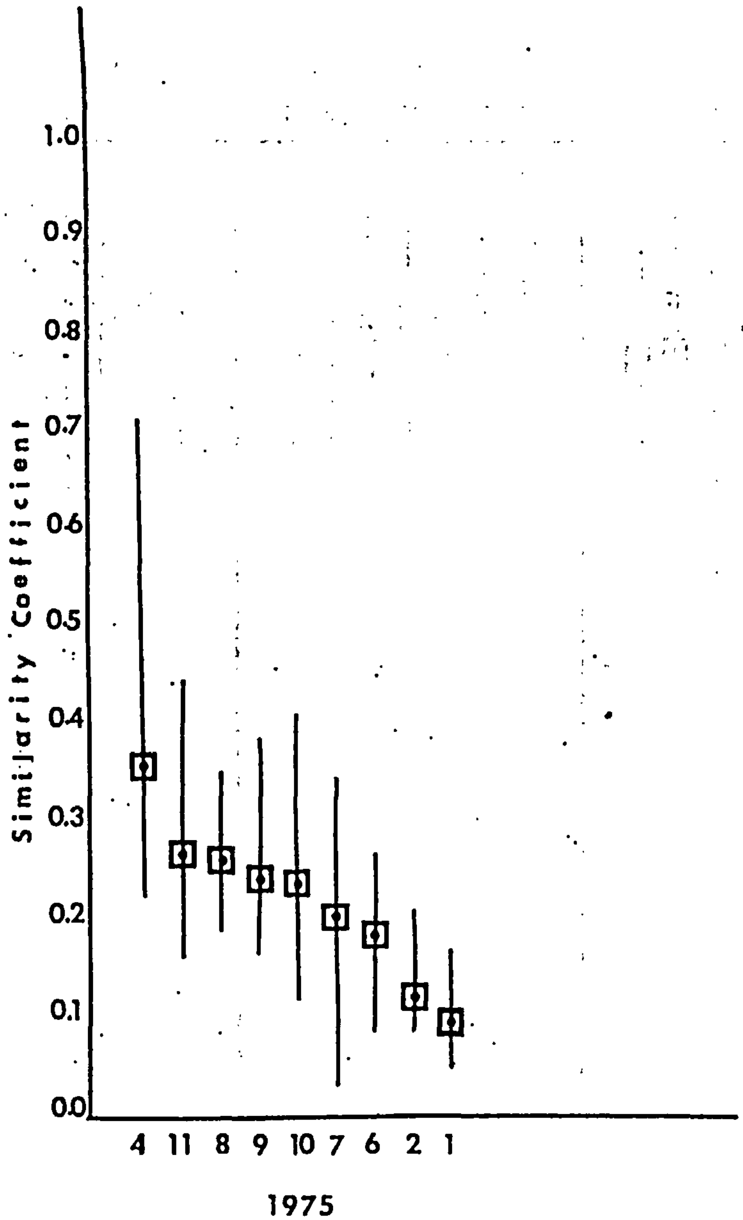


FIGURE 4.9-20 AVERAGE AND RANGE OF YEARLY SIMILARITY COEFFICIENTS FOR STATION 5 DURING APRIL, 1973, THROUGH DECEMBER, 1975

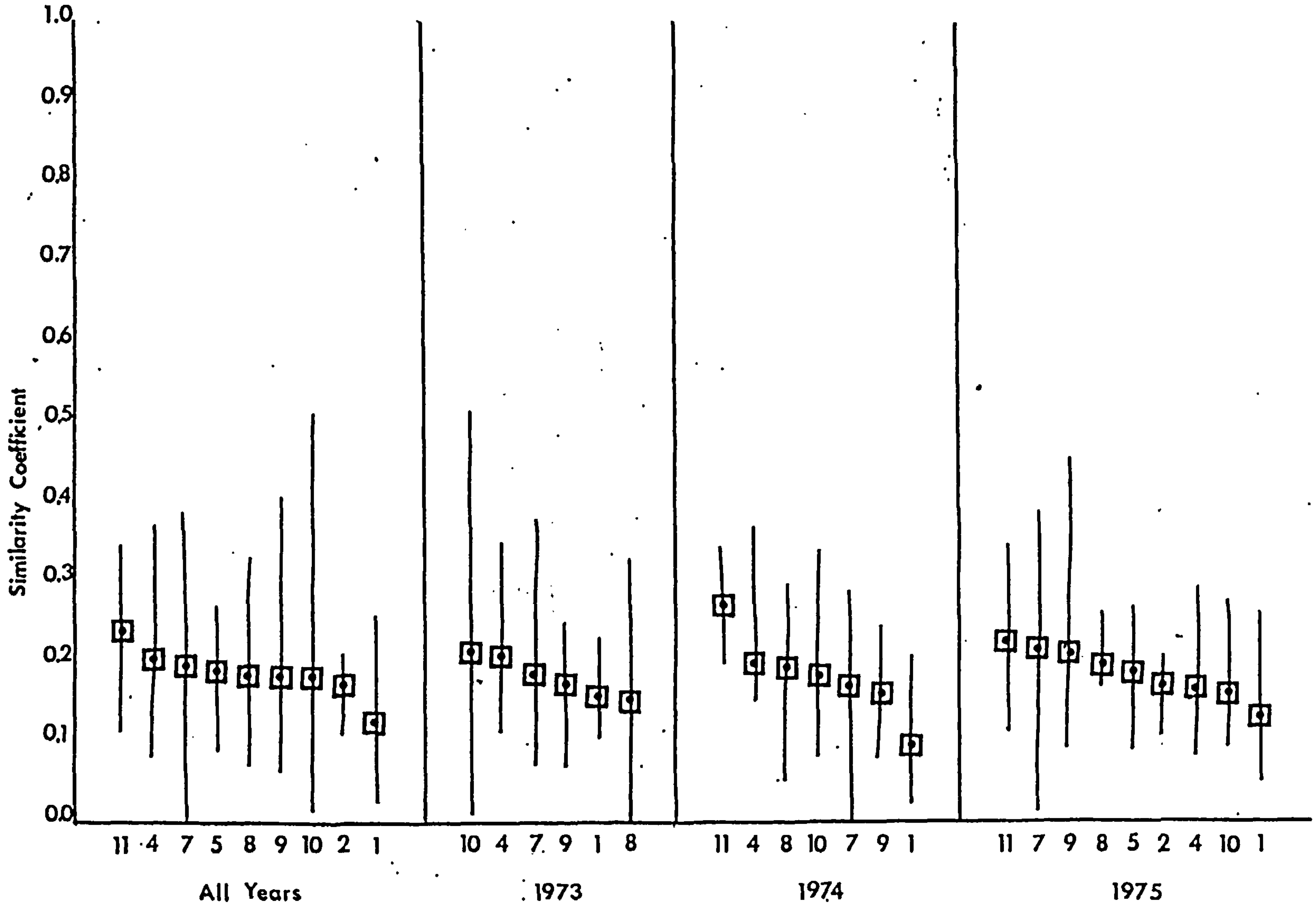


FIGURE 4.9-21 AVERAGE AND RANGE [illegible] YEARLY SIMILARITY COEFFICIENTS FOR STATION 6 DURING A[illegible], 1973, THROUGH DECEMBER, 1975

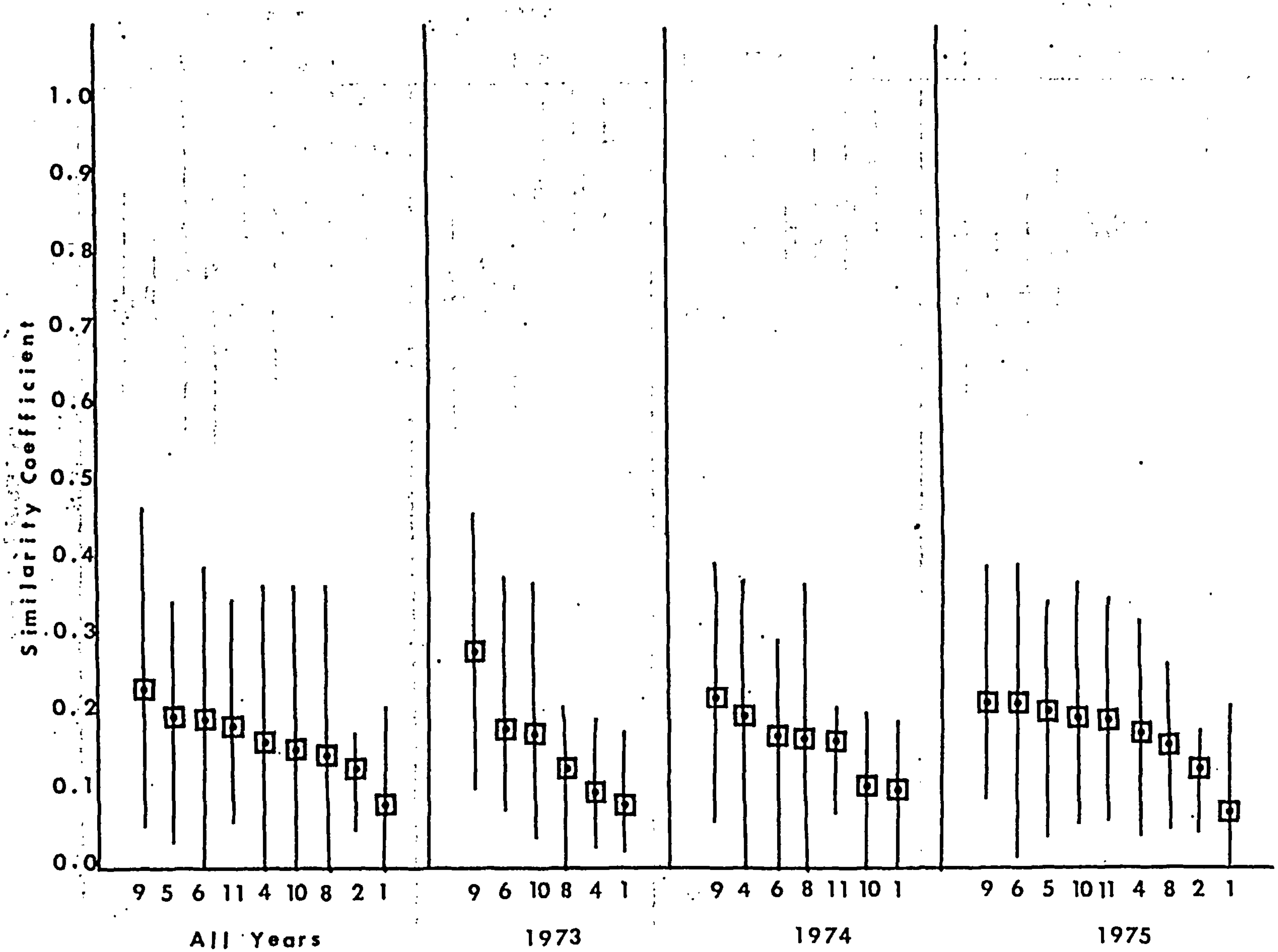


FIGURE 4.9-22 AVERAGE AND RANGE OF YEARLY SIMILARITY COEFFICIENTS FOR STATION 7 DURING APRIL, 1973, THROUGH DECEMBER, 1975

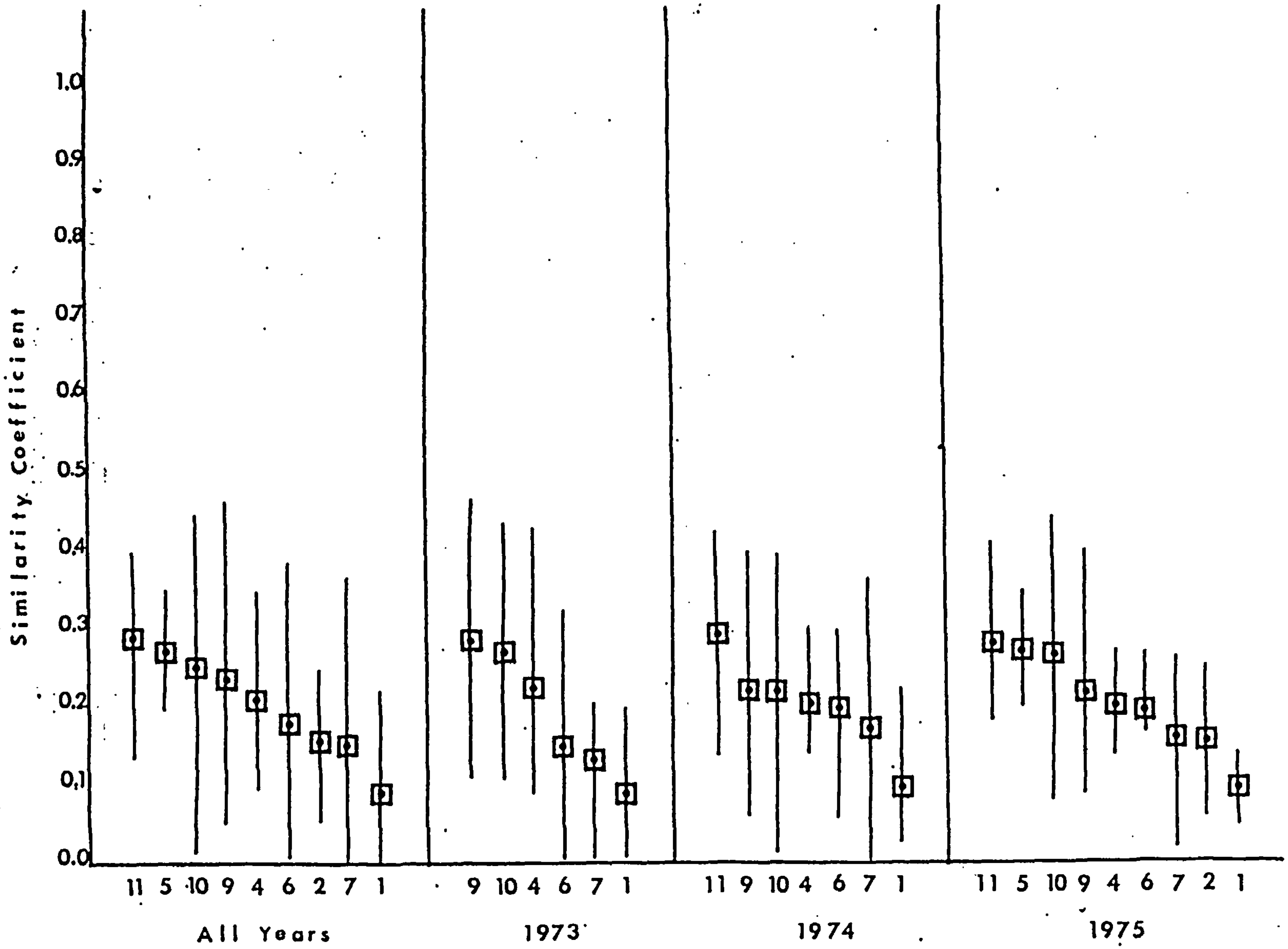


FIGURE 4.9-23 AVERAGE AND RANGE ' ' YEARLY SIMILARITY COEFFICIENTS FOR STATION 8 DURING A , 1973, THROUGH DECEMBER, 1975

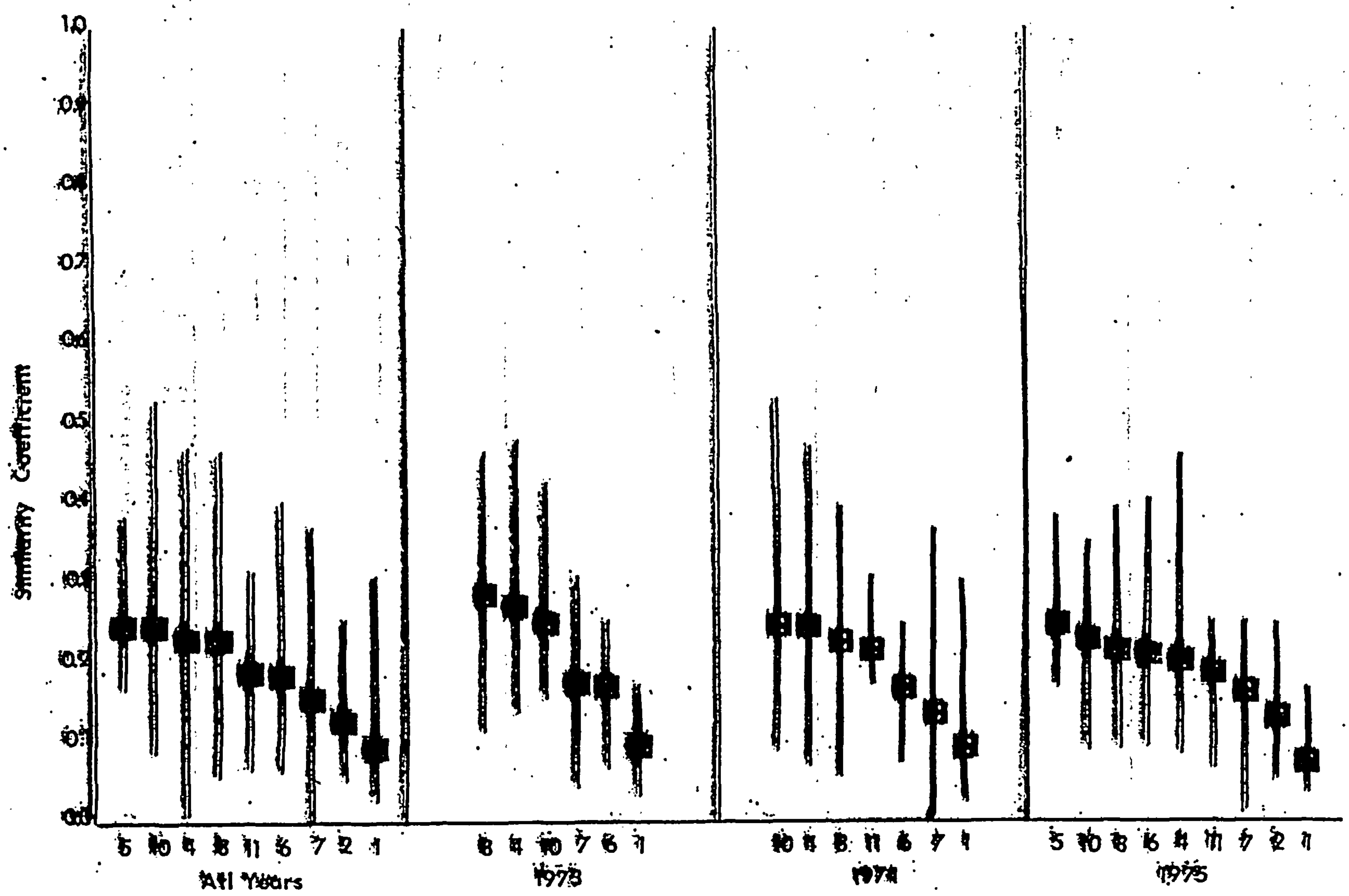


FIGURE 4.9-24 AVERAGE AND RANGE OF YEARLY SIMILARITY COEFFICIENTS FOR STATION 9 DURING APRIL, 1973, THROUGH DECEMBER, 1975

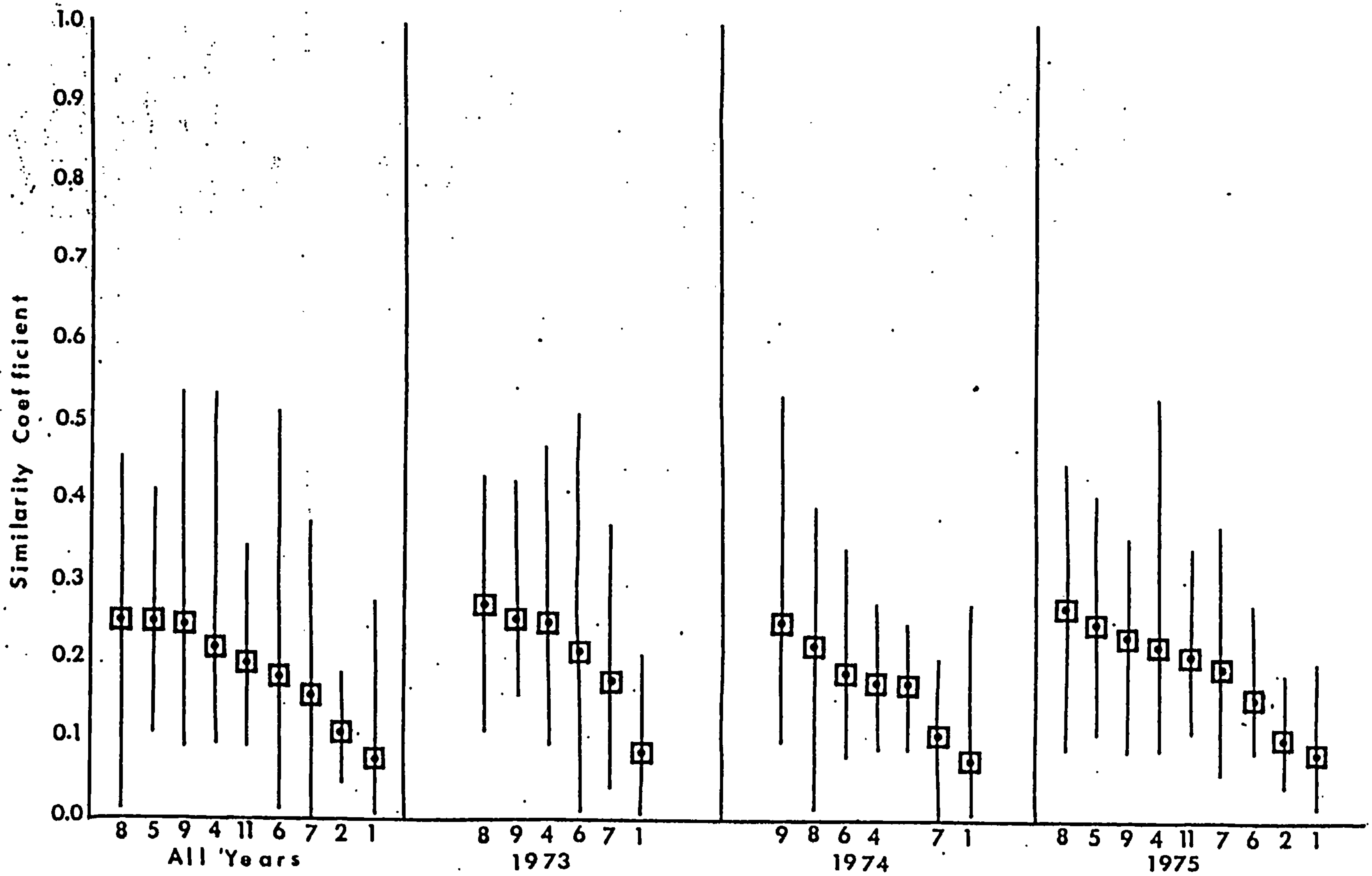


FIGURE 4.9-25 AVERAGE AND RANGE OF YEARLY SIMILARITY COEFFICIENTS FOR STATION 10 DURING APRIL, 1973, THROUGH DECEMBER, 1975

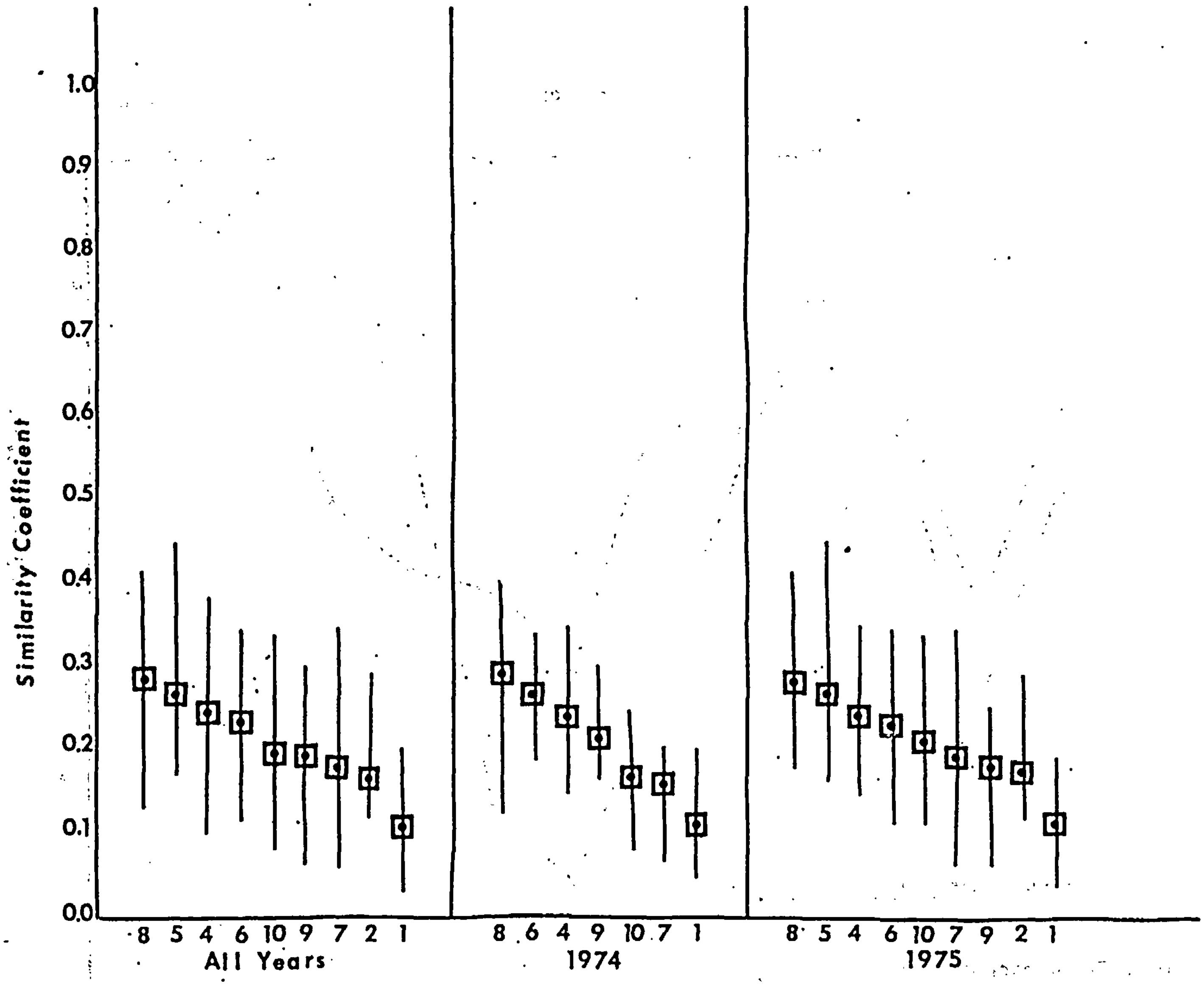


FIGURE 4.9-26 AVERAGE AND RANGE OF YEARLY SIMILARITY COEFFICIENTS FOR STATION 11 DURING APRIL, 1973, THROUGH DECEMBER, 1975

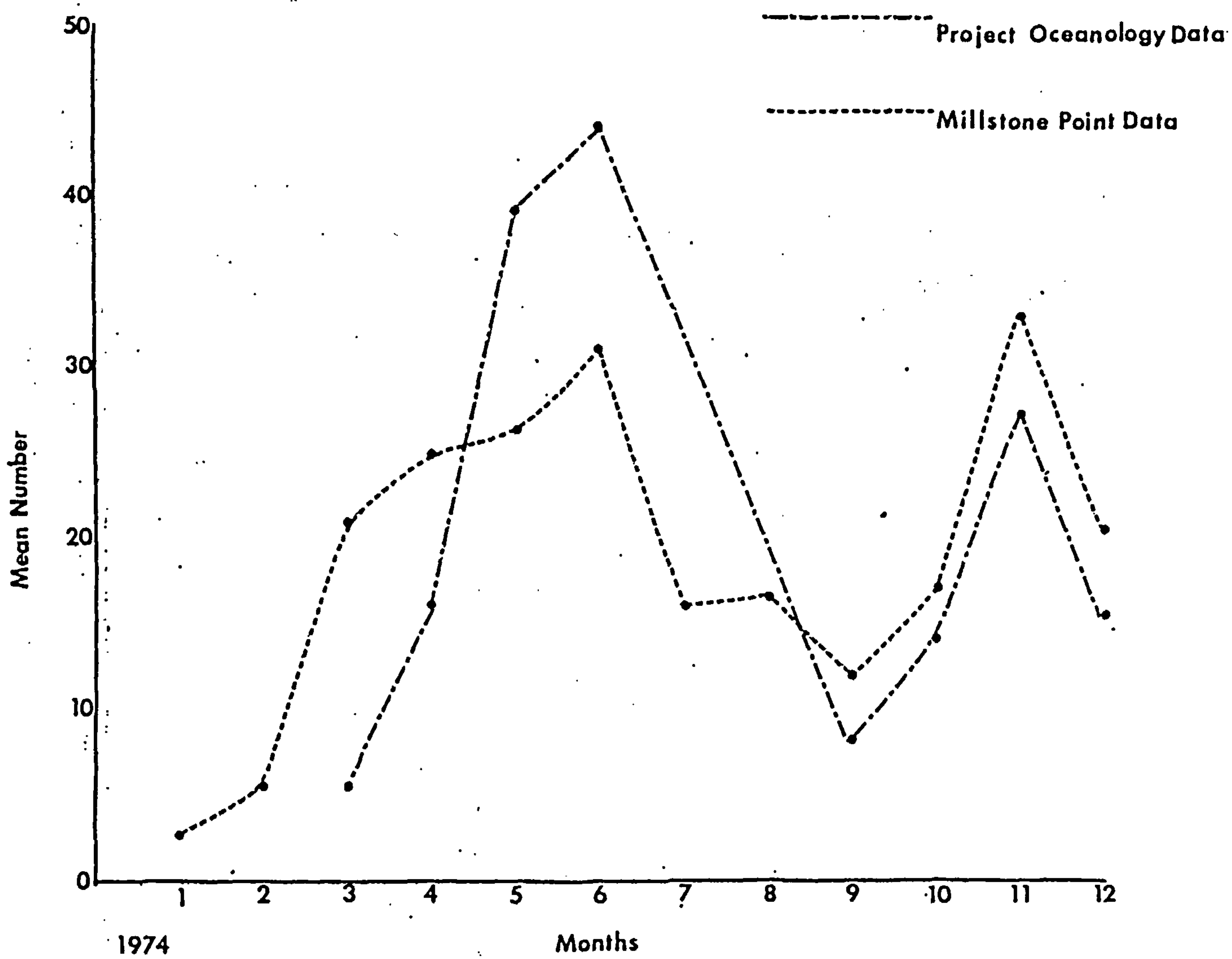


FIGURE 4.9-27 COMPARISON OF MONTHLY MEAN NUMBERS OF WINTER FLOUNDER PER FIFTEEN MINUTE TOW AT THE MILLSTONE POINT AREA AND THE THAMES RIVER AREA (PROJECT OCEANOLOGY DAT/` DURING 1974

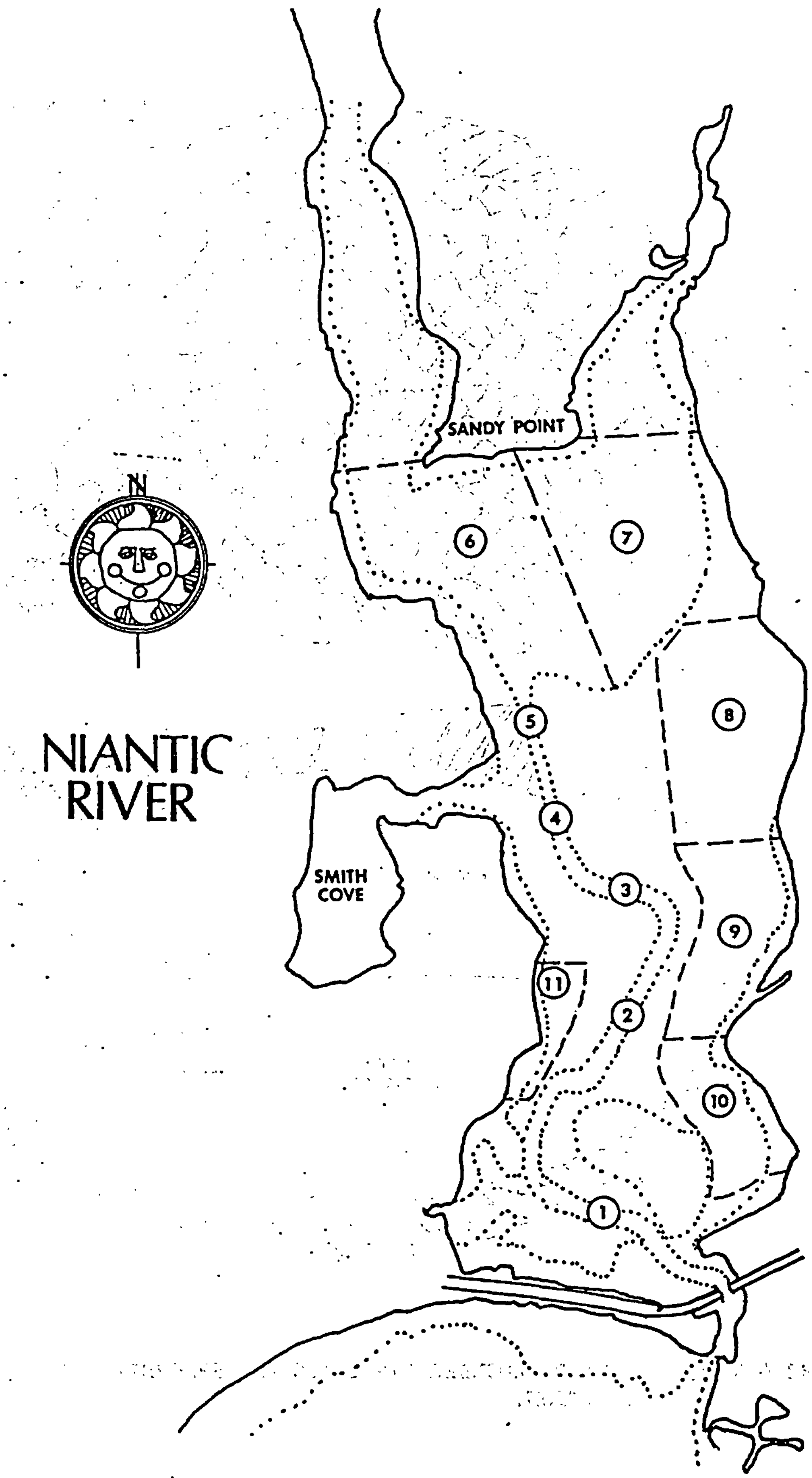


FIGURE 4.9-28 LOCATION OF WINTER FLOUNDER TRAWL STATIONS MARCH THROUGH JUNE, 1975

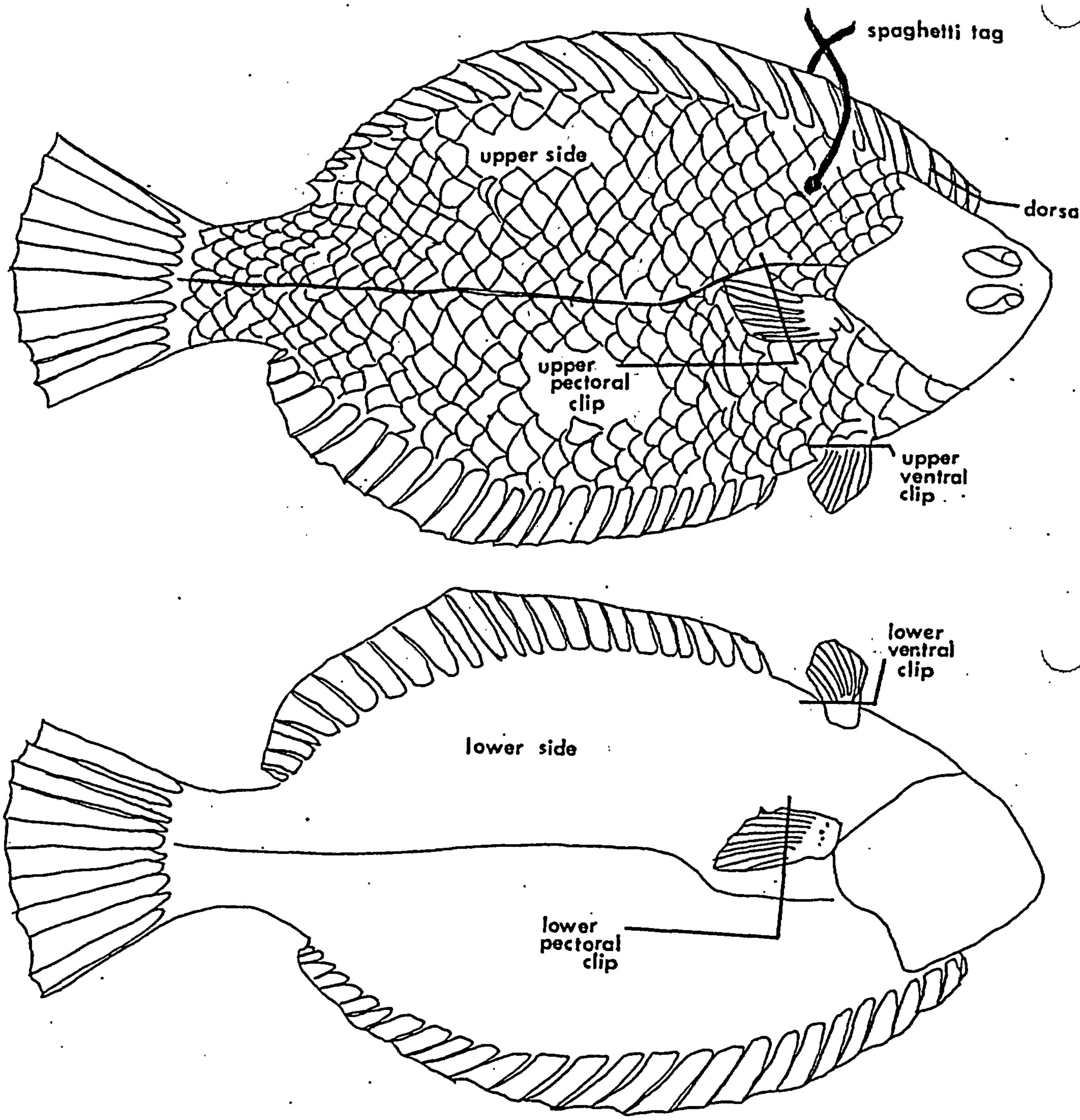


FIGURE 4.9-29 WINTER FLOUNDER FIN CLIPS AND SPAGHETTI TAG POSITION.

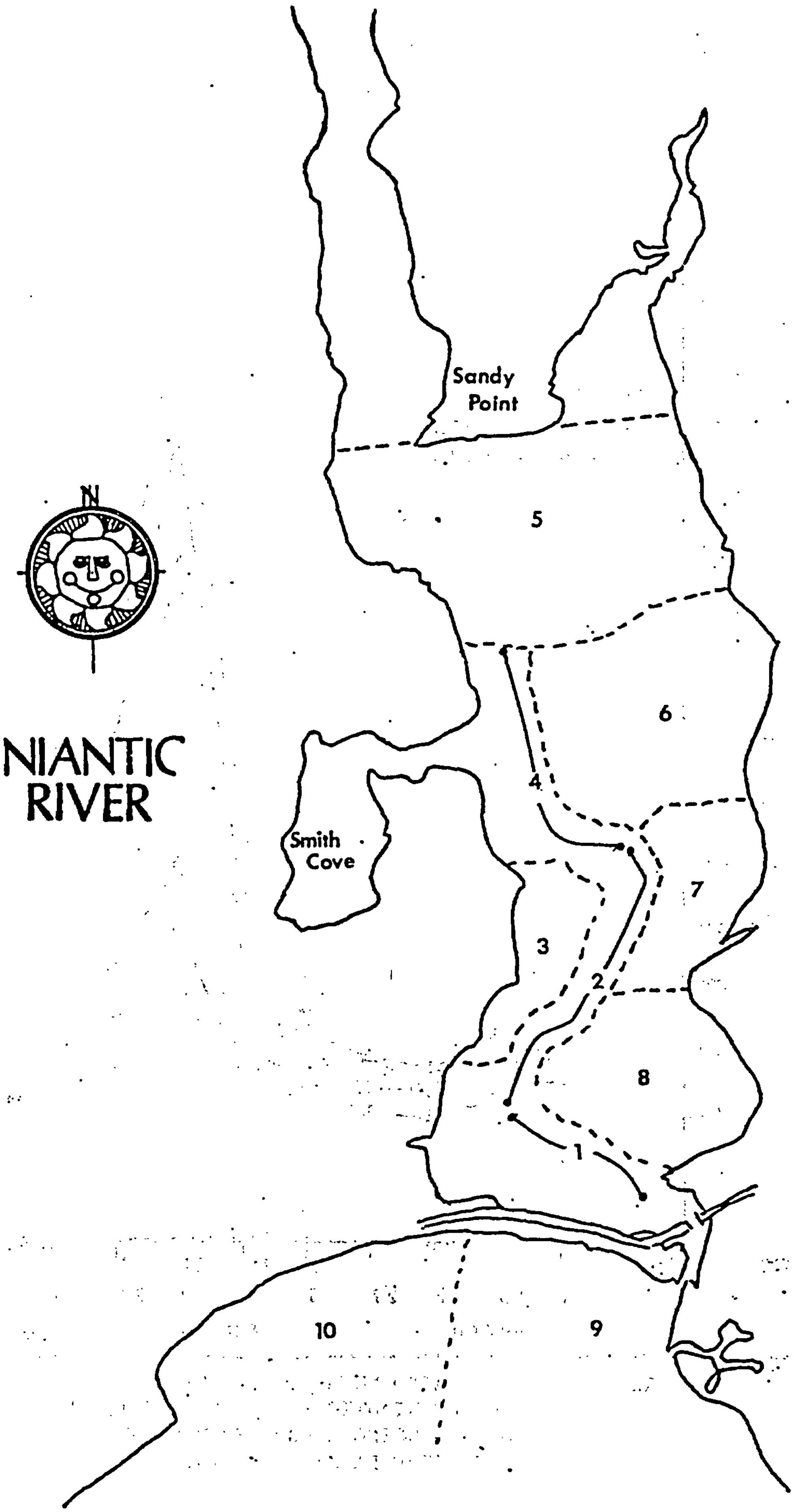


FIGURE 4.9-30 LOCATION OF WINTER FLOUNDER TRAWL STATIONS FOR JANUARY THROUGH JUNE, 1976.

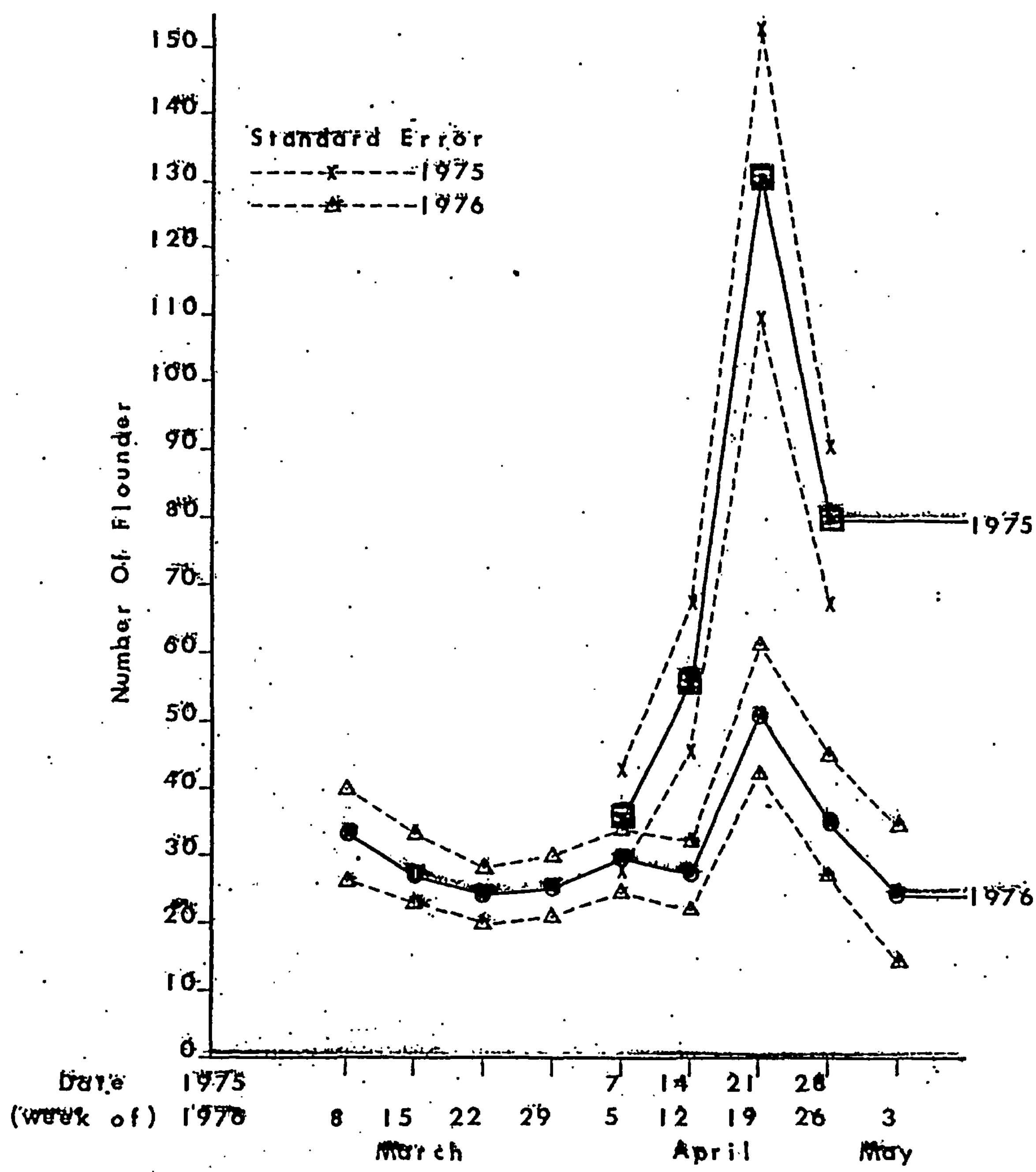


FIGURE 4.9-31 ESTIMATED NUMBERS OF WINTER FLOUNDER IN THE NIANTIC RIVER IN 1975 (JOLLY METHOD USING CORRECTED MARK-AND-RECAPTURE DATA) AND 1976.

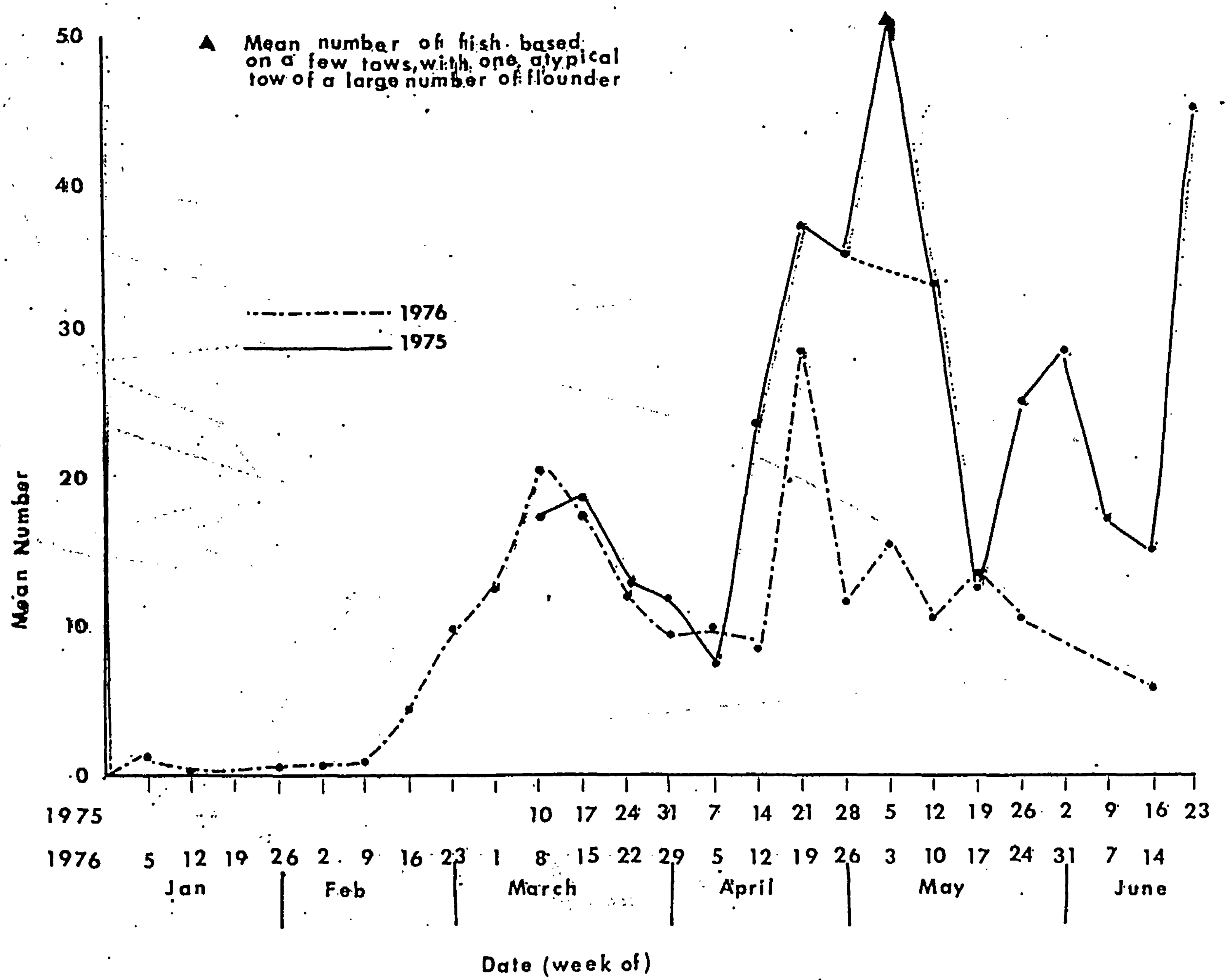


FIGURE 4.9-32 MEAN NUMBER OF WINTER FLOUNDER TAKEN PER FIVE MINUTE TOW AT ALL NIANTIC RIVER STATIONS DURING 1975 AND 1976.

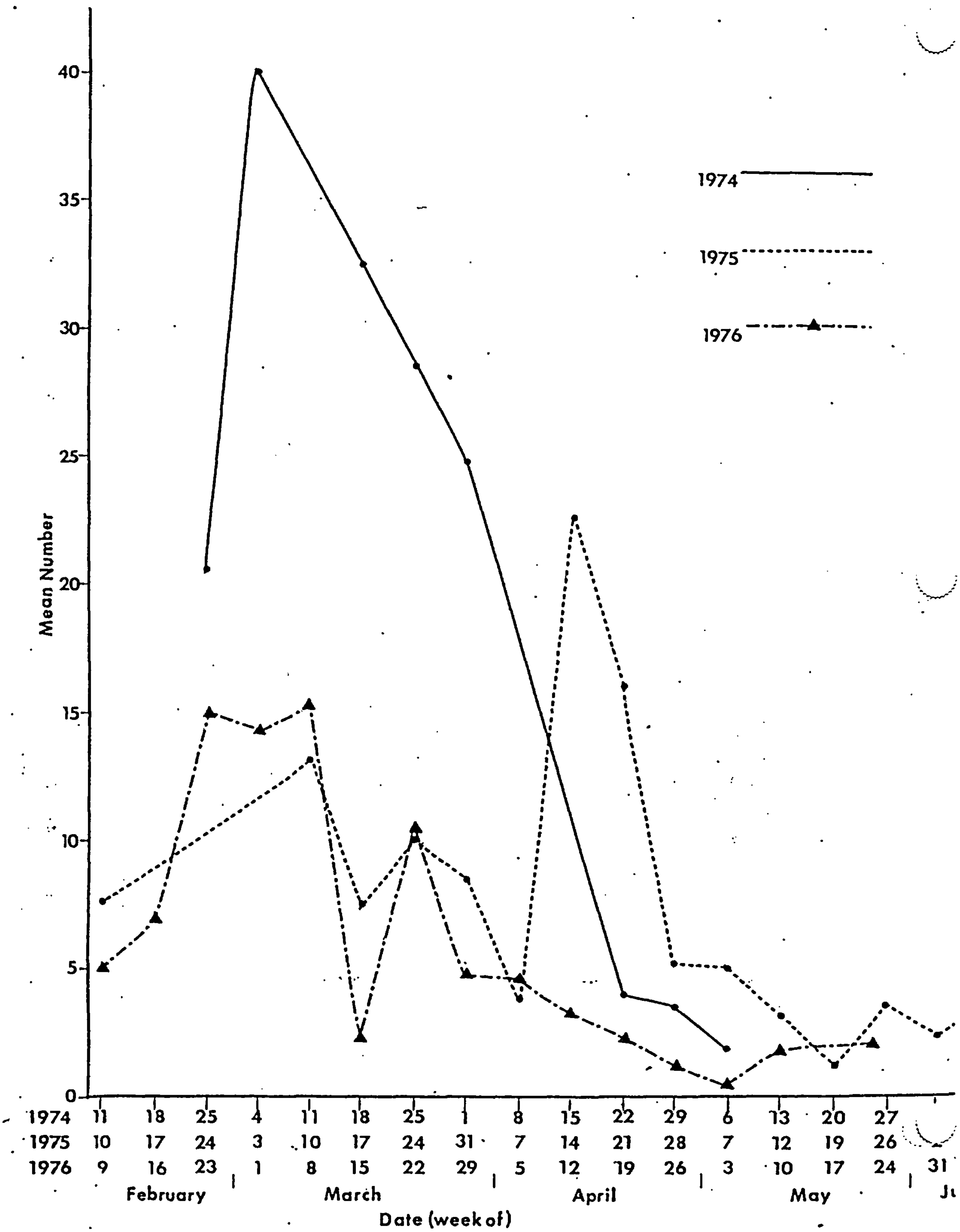


FIGURE 4.9-33 MEAN NUMBER OF WINTER FLOUNDER TAKEN PER FIVE MINUTE TOW AT

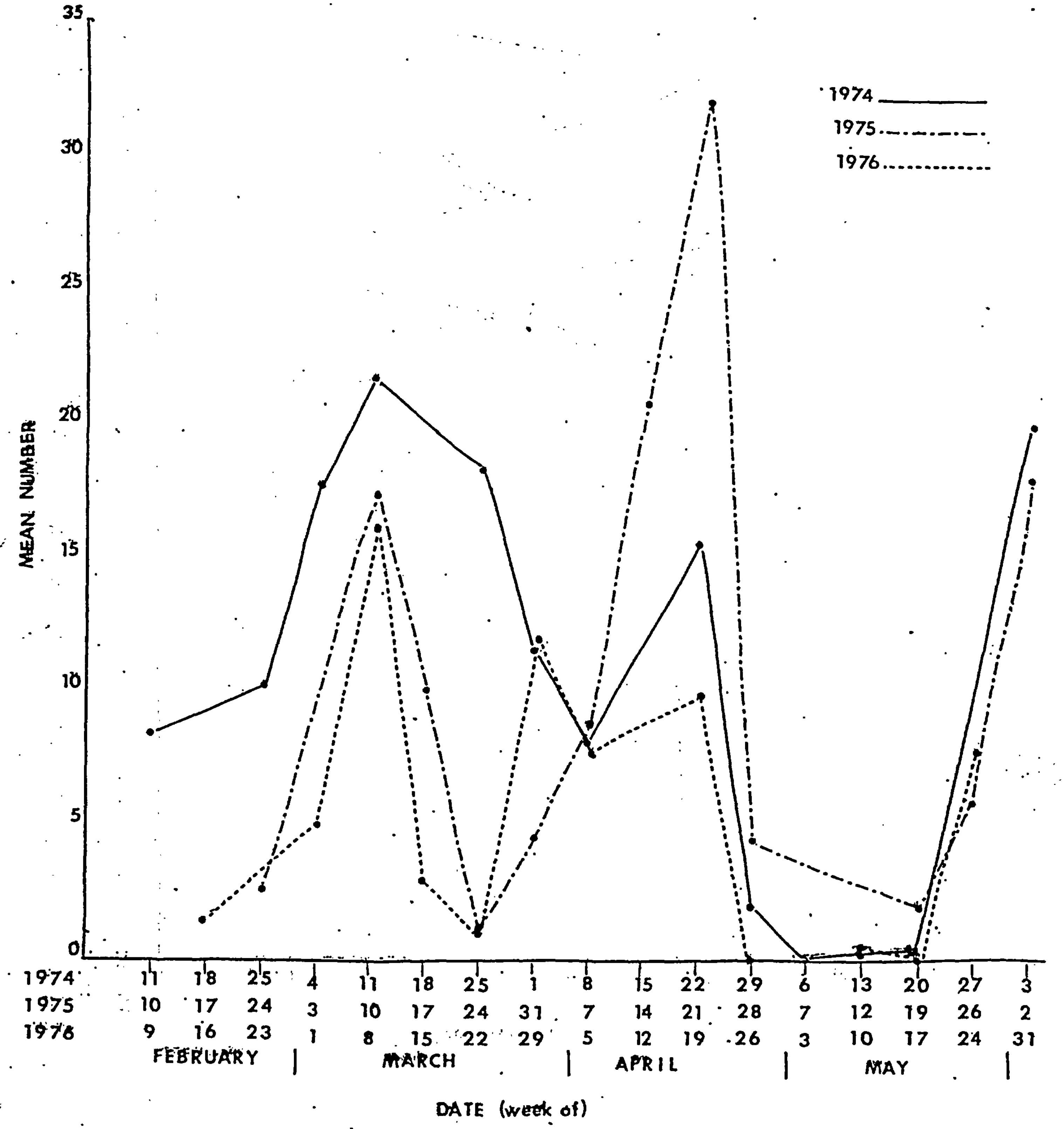
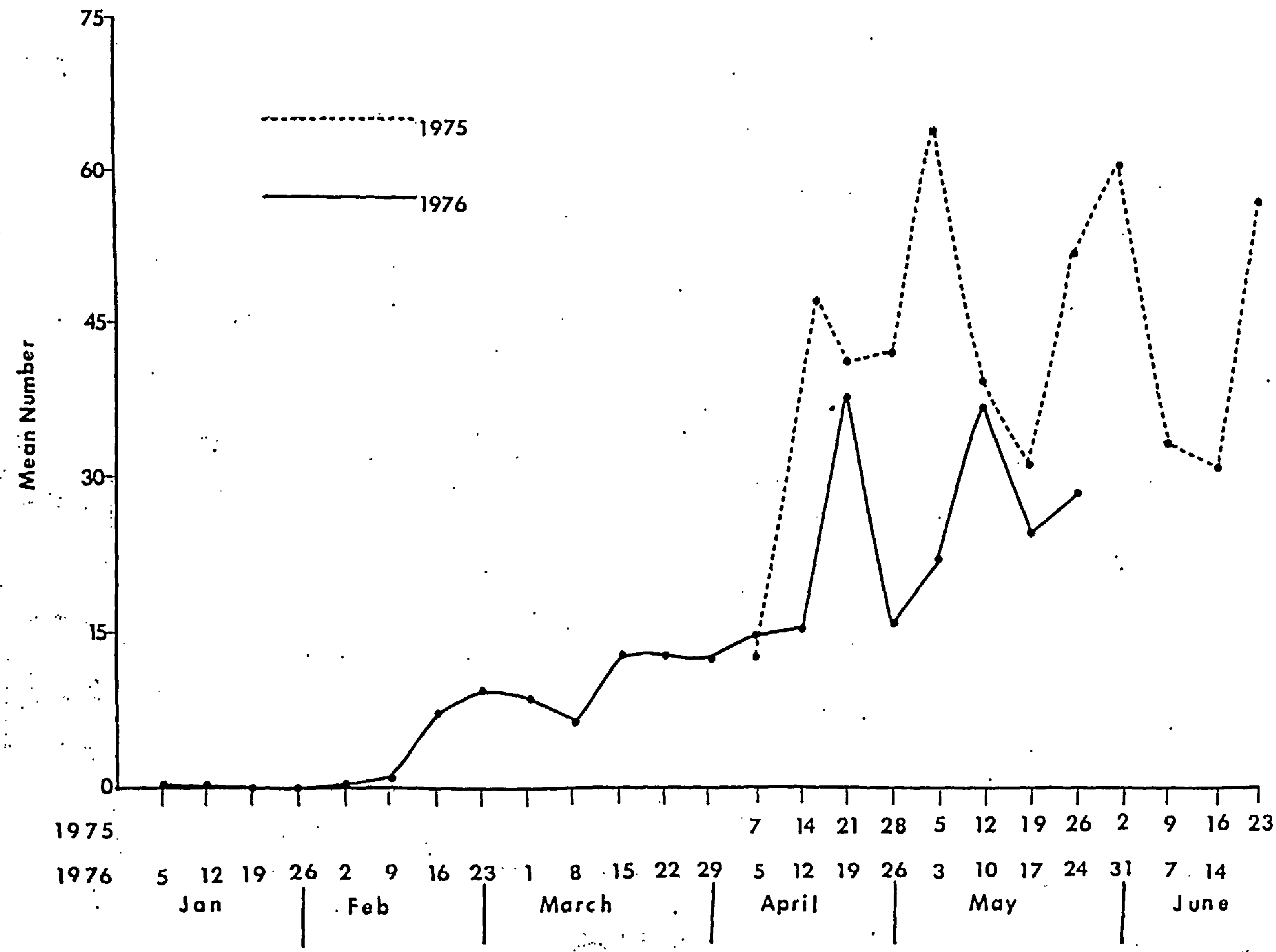


FIGURE 4.9 -34 MEAN NUMBER OF WINTER FLOUNDER TAKEN PER FIVE MINUTE TOW AT NIANTIC RIVER STATION 5 (1976) DURING 1974, 1975, AND 1976.



1975
1976
Mean Number
75
60
45
30
15
0
1975
7 14 21 28 5 12 19 26 2 9 16 23
1976
5 12 19 26 2 9 16 23 1 8 15 22 29 5 12 19 26 3 10 17 24 31 7 14
Jan
Feb
March
April
May
June

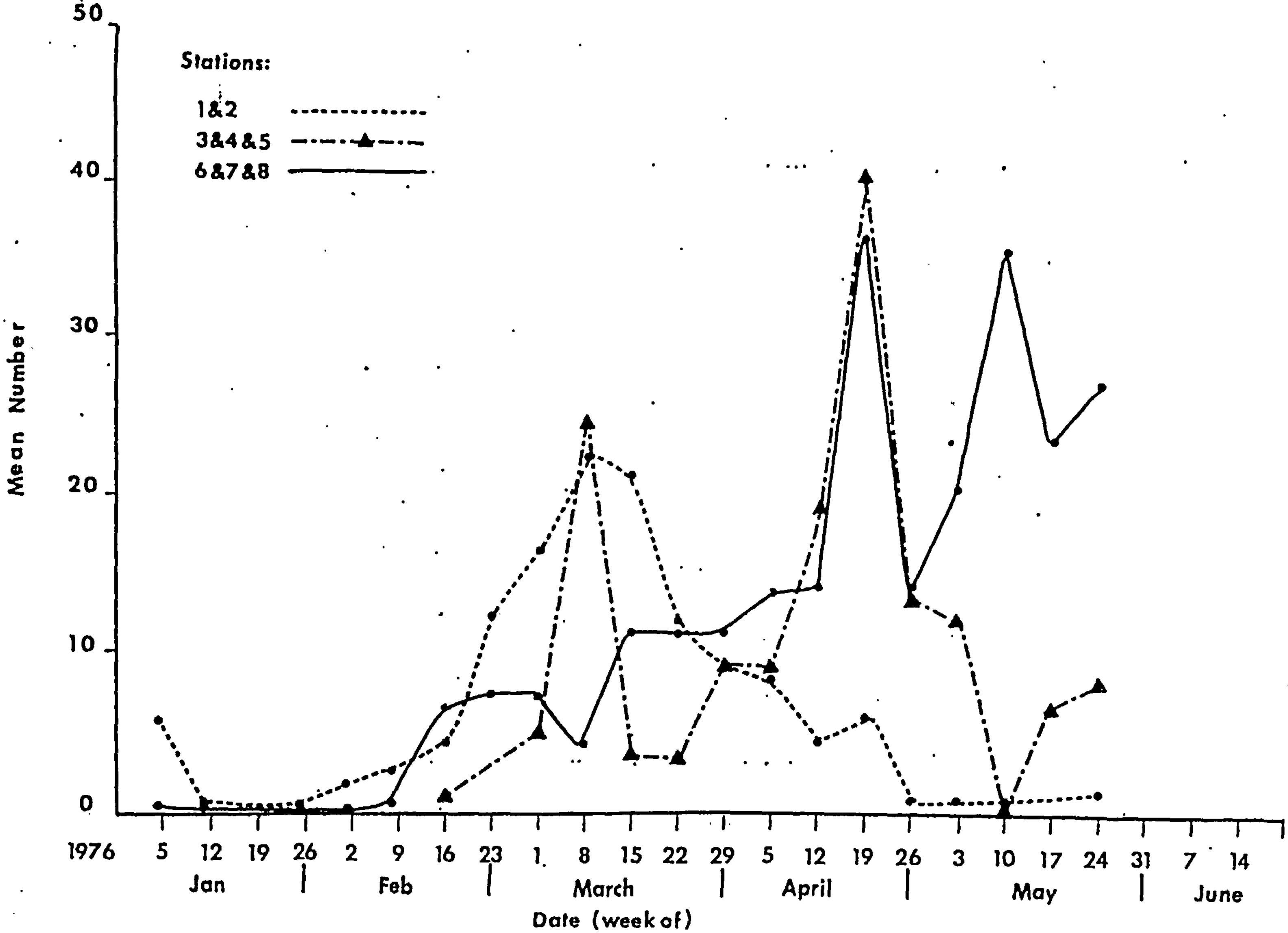


FIGURE 4.9-36 MEAN NUMBER OF WINTER FLOUNDER TAKEN PER FIVE MINUTE TOW AT COMBINED NIANTIC RIVER STATIONS 1 AND 2; 3, 4, AND 5; 6, 7, AND 8 DURING 1976.

TABLE 4.10-1. FISHES IMPINGED ON THE INTAKE SCREENS OF MILLSTONE UNIT NO. 1 MONTHLY DURING 1972

	January				February				March				April				May				June			
	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"
Pseudopleuronectes americanus	117	2	88	27	34	3	30	1	266	4	175	87	216	5	140	71	300		85	215	190	96	94	
Alosa aestivalis	31	2	29						38	17	21		22	12	10		3		1	2	4	1	3	
Scophthalmus aquosus									14		7	7	18		1	17	51		7	44	383		6	377
Menidia spp.	1		1		7	1	6		140	27	113		45	39	6		12		12		63	18	45	
Tautogolabrus adspersus	3	1	2						4		4		7		5	2	71	7	51	13	198	26	169	3
Tautoga onitis													3		3		136	15	78	43	123	7	97	19
Morone americana	3		3						2	1	1		24	1	7	16	112		2	110	258	1	3	254
Brevoortia tyrannus													7			7	362		1	361	15			15
Gasterosteus aculeatus									94	68	26		83	83			27	26	1		11	11		
Myoxocephalus aenaeus	11		11		14	4	10		70	13	54	3	67	16	49	2	38	7	31		13	5	7	1
Syngnathus fuscus									56	3	51	2	46	7	38	1	57		17	40	6		2	4
Pollachius virens																	5			5	42	3	36	3
Prionotus carolinus													33		2	31	28	1	1	26	40		12	28
Anguilla rostrata									1			1					17			17	35		1	34
Microgadus tomcod	6		4	2									3			3	14		4	10	29		8	21
Opsanus tau																	1			1	39		1	38
Sphoeroides maculatus																	1			1	49		21	28
Paralichthys dentatus																	1			1	51		2	49
Peprilus triacanthus																					18		18	
Raja spp.	1			1					2	9	0	2	5			5	2			2	1			1
Prionotus evolans																	1			1	20			20
Osmerus mordax													6		1	5	10		5	5	2			2
Cyprinodon variegatus	2	1	1						22	15	5	2	1	1										
Fundulus heteroclitus									4	3	1													
Myoxocephalus scorpius													2			2	9			9	1			1
Bairdiella chrysura					1			1	17	0	16	1	3		3						1		1	
Fundulus majalis													8	5	3						1		1	
Enchelyopus cimbrius																								
Trinectes maculatus																					6		6	
Pungitius pungitius									4	4			1	1										
Cyclopterus lumpus									2	2			1	1										
Fundulus diaphanus									3		3													
Chilomycterus schoepfi																								
Pholis gunnellus																					1		1	
Conger oceanicus																					1			1
Centropristis striata																					1			1
Stenotomus chrysops																	1			1				
Mustelus canis																					1			1
Aluterus schoepfi																								
Monacanthus spp.																								
Hemitripterus americanus																					1			1
Raja laevis									1			1												
Scomber scombrus																								
Unidentified																					2			2

	July				August				September				October				November				December			
	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"
Pseudopleuronectes americanus	82	2	26	54	148	2	72	74	106		14	92	249	2	17	230	37		9	28	119	5	39	55
Alosa aestivalis	5	1	4		750	750			188	163	24	1	453	403	50		66	62	4		2	2		
Scophthalmus aquosus	255		2	253	510	4	119	387	260	2	21	237	68		5	63					1			1
Menidia spp.	58	44	14		67	39	28		2		2		60	29	31		73	54	19		66	56	10	
Tautogolabrus adspersus	71	10	59	2	54	7	45	2	44	10	33	1	47	12	35		3		3					
Tautoga onitis	33	2	29	2	141	2	124	15	17		17		35	9	24	2	4	1	3					
Morone americana	26			26	2			2					3	1	7									
Brevoortia tyrannus	9			9	38			38	1			1												
Gasterosteus aculeatus					12	12																		
Myoxocephalus aenaeus	1	1																						
Syngnathus fuscus	1			1	19		9	1																
Pollachius virens	66		57	9	24	3	19	2	3		2	1												
Prionotus carolinus	21	1	5	15	17		2	15																
Anguilla rostrata	4			4	42			42	3			3	11			11	3			3	3			3
Microgadus tomcod	17		3	14	29	3	9	17	1			1	16		12	4	4		4		5		5	
Opsanus tau	14	1	3	10	3			3	11			11	4											
Sphoeroides maculatus	14		10	4	3		1	2																
Paralichthys dentatus	11			11					4			4												
Peprilus triacanthus	14	3	9	2	1		1		5	1	3	1	4	3	1									
Raja spp.					1			1	2			2	6			6	4		1	3	4			4
Prionotus evolans	6			6																				
Osmerus mordax	1			1	5	2	3																	
Cyprinodon variegatus																								
Fundulus heteroclitus																	2	1	1		11	9	2	
Myoxocephalus scorpius																								
Bairdiella chrysura																								
Fundulus majalis																								
Enchelyopus cimbrius	2			2	4			4																
Trinectes maculatus																								
Pungitius pungitius																								
Cyclopterus lumpus																								
Fundulus diaphanus																								
Chilomycterus schoepfi	2		1	1																				
Pholis gunnellus					1		1																	
Conger oceanicus																								
Centropristis striata																								
Stenotomus chrysops																								
Mustelus canis								1																
Aluterus schoepfi					1																			
Monacanthus spp.	1			1																				
Hemitripterus americanus																								
Raja laevis																								
Scomber scombrus					1		1																	
Unidentified									31	31														

TABLE 4.10-2. FISHES IMPINGED ON THE INTAKE SCREENS OF MILLSTONE UNIT NO. 1 MONTHLY DURING 1973

	January				February				March				April				May				June			
	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"
Pseudopleuronectes americanus	1171	589	422	164	1530	691	777	62	1625	654	547	424	810	237	209	364	276	98	68	110	150	30	24	96
Brevoortia tyrannus	79	79			43	43			10	7	3		45	5		40	4			4	1	1		
Gasterosteus aculeatus	116	116			287	287			386	385	1		351	351			7	7			1	1		
Myoxocephalus aenaeus	314	202	111	1	326	229	95	2	180	111	69		263	152	109	2	122	98	23	1	3	3		
Menidia spp.	44	19	25		87	44	43		103	16	61	26	188		84	102	80	15	65		180	9	171	
Tautogolabrus adspersus	1	1			8	7	1		6	6			38	37	1		93	91	2		210	194	12	4
Opsanus tau									19			19	13			13	693	1	617	75	69		32	37
Tautoga onitis	2	1	1						4	2	2		80	37	24	19	452	287	119	46	92	51	35	6
Morone americana	14	13		1	18	7	1	10	19	15		4	44	1	2	41	145		18	27	112		14	98
Scophthalmus aquosus	5	1	2	2	13	2	1	10	74	11	22	41	113	1	40	72	157	4	74	79	76	4	30	42
Syngnathus fuscus									81	4	13	64	162		1	161	61			61	3			3
Osmerus mordax	8	1	7		17	7	10		77	7	44	26	131		50	81	28		27	1	13		16	2
Microgadus tomcod	10	2	5	3	19	2	15	2	6		1	5	16		3	13	44	5		39	36	16		20
Peprilus triacanthus																								
Alosa aestivalis					1			1	13	7	2	4	20	3		17	10	4	3	3	3	1	1	1
Raja spp.	1			1	2	2			67	9		58	26			26	4			4				
Prionotus carolinus													11			11	126		3	123	33			33
Sphoeroides maculatus																	15		11	4	130	28	99	3
Paralichthys dentatus	3	3															45			45	27	0		27
Pollachius virens	7	3	4														22			22	30	18		12
Anguilla rostrata													10	5		5	19			19	28			28
Ammodytes spp.	1		1														1			1	2			2
Merluccius bilinearis																								
Cyclopterus lumpus	2	2			10	10			13	13			9	9			1	1						
Stenotomus chrysops																	6		4	2	24	16	8	
Liparis atlanticus	4	4			10	10			8	8			3	3										
Pholis gunnellus	1		1		6	3	3		10	3	7		1		1		7		3	4				
Clupea harengus																								
Enchelyopus cimbrius	3	3							5		1	4	10		1	9								
Mugil cephalus																								
Urophycis tenuis									2		2													
Merluccius spp.																								
Monacanthus spp.																								
Conger oceanicus																	5			3	4			4
Cynoscion regalis																								
Caranx hippos																								
Fundulus majalis					1	1			1	1														
Fundulus heteroclitus	1		1		1	1			1	1			1	1			1	1						
Selene vomer																								
Menticirrhus saxatilis																								
Trinectes maculatus																								
Pomatomus saltatrix																					1		1	
Vomer setapinnis																								
Hemitripterus americanus																								
Morone saxatilis																								
Etrumeus teres																	2			2				
Myoxocephalus spp.																								
Paralichthys oblongus																					2			2
Mustelus canis													2			2								
Aulostomus maculatus																					1			1
Sphyraena borealis																								
Scomber scombrus																								
Myoxocephalus octodecemspinosus																								
Pristigenys alta																								
Lophius americanus																								
Alosa pseudoharengus																								
Aluterus schoepfi																								
Centropristis striata																	1			1				
Cyprinodon variegatus																	1	1						

	July				August				September				October				November				December			
	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"
Pseudopleuronectes americanus	35	25	4	6	71	12	13	46	64	10	26	28	92	19	13	60	96	8	12	76	273	5	52	216
Brevoortia tyrannus	16	16			743	671	70	2	111	70	38	3	212	44	167	1	240	215	23	2	82	78	3	1
Gasterosteus aculeatus													5	5			59	59			97	97		
Myoxocephalus aenaeus	4	4			1		1						4	1	3		9	9			69	39	29	1
Menidia spp.	190	92	98		5	3	2		31	31			68	42	26		53	22	31		45	13	32	
Tautogolabrus adspersus	85	76	9		208	110	92	6	139	80	57	2	77	54	22	1	57	39	18		35	35		
Opsanus tau	5		4	1	1			1	9			9	10			10	2			2				
Tautoga onitis	25	11	10	4	32		13	19	39	1	30	8	50	5	26	19	19	6	11	2	4		3	1
Morone americana	58	3	7	48					18	6	9	3	77	45	21	11	91	34	12	45	149	45	31	73
Scophthalmus aquosus	46	1	4	41	59		1	58	36			36	48			48	64		2	62	30	2		28
Syngnathus fuscus	2			2	3			3	3			3	11			11	14			14	3			3
Osmerus mordax	36		32	4									2		1	1								
Microgadus tomcod	18	15		3	11			11	42	2	9	31	13		2	11	55		42	13	316		71	245
Peprilus triacanthus	2	2			90	70	15	5	33	24	7	2	57	42	15		6	3	3		91	68	28	
Alosa aestivalis	2	1	1		34	11	19	4	32	11	20	1	86	2	28	56	55		45	10	10		10	
Raja spp.					1			1	3			3	106	100		6	14	14			2		1	1
Prionotus carolinus	19	1		18	8			8	4		1	3	11		2	9	2		2					
Sphoeroides maculatus	2	1	1										11	11			3	3			2	2		
Paralichthys dentatus	26		4	22	14			14	4			4	3			3								
Pollachius virens	44	31	12	1	5	1	4		8		8		1		1									
Anguilla rostrata	8			8	5			5	1			1	4			4	9			9	7			7
Ammodytes spp.													6			6	12			12	36			36
Merluccius bilinearis																	10	4	3	3	44	15	8	21
Cyclopterus lumpus																					1	1		
Stenotomus chrysops	1		1						1			1												
Liparis atlanticus																					1	1		
Pholis gunnellus																								
Clupea harengus																	3			3	20			20
Enchelyopus cimbrius	2		1	1					1			1									1	1		
Mugil cephalus													18		17	1	1		1					
Urophycis tenuis	1		1										5	3		2	6	4	2					
Merluccius spp.	1		1						1			1	7			7	4			4				
Monacanthus spp.					1	1			3	1	2		3	2	1						4	4		
Conger oceanicus																								
Cynoscion regalis									4	1	3		5		5									
Caranx hippos									3	1	2		5		5									
Fundulus majalis																	2	2			2	2		
Fundulus heteroclitus													2	2			1	1						
Selene vomer					1	1			5	5			1	1										
Menticirrhus saxatilis																	4		2	2	2			2
Trinectes maculatus																					2		2	
Pomatomus saltatrix	2		2										1		1									
Vomer setapinnis					4	3	1		2		1	1												
Hemitripterus americanus					1	1							1	1			3	3			1			1
Morone saxatilis																4								
Etrumeus teres	1			1	1			1					1			1					1		1	
Myoxocephalus spp.									2	2			1	1										
Paralichthys oblongus																								
Mustelus canis																								
Aulostomus maculatus					1			1																
Sphyraena borealis													2			2	2			2				
Scomber scombrus																								
Myoxocephalus octodecemspinosus	1		1																		1			1
Pristigenys alta																	1	1						
Lophius americanus																	1			1				
Alosa pseudoharengus									1		1													
Aluterus schoepfi													1			1								
Centropristis striata																								
Cyprinodon variegatus																								

TABLE 4.10-3. FISHES IMPINGED ON THE INTAKE SCREENS OF MILLSTONE UNIT NO. 1 MONTHLY DURING 1974

	January				February				March				April				May				June				July				August				September				October				November				December			
	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"
Pseudopleuronectes americanus	883	684	314	85	859	317	263	279	921	80	220	621	326	52	67	207	199	86	40	73	39	18	1	20	85	45	18	22	23	8	6	9	16	6	3	7	20	4	1	15	221	17	62	142	146	34	43	69
Myoxocephalus aenaeus	414	203	210	1	395	149	136		115	81	34		144	126	16	4	77	67	10		25	21	4		2	2			9	8	1		1	1			3	3			28	12	16		172	93	74	5
Menidia spp.	44	4	34	6	69		67	2	178	1	127		143	1	142		634	272	362		45	27	18		3		3		2	2							1	1			24	8	16		96	27	69	
Gasterosteus aculeatus	106	106			223	223			176	176			170	170			2	2							1	1											1	1			119	119			315	315		
Morone americana	9	3	1	5	31	10	1	20	7	1		6	528	7	48	473	32	3	12	17	15	1	4	10	12			12									34	31	1	2	42	41		1	3			3
Tautogolabrus adspersus	12	11	1		46	43	3		55	54	1		58	44	13	1	74	29	44	1	102	70	30	2	133	112	20	1	20	16	3	1	7	6	1		3	1	2		36	22	14		23	13	8	
Anchoa spp.																					255	254	1		116	113	1		14	13	1						34	34			22	13	9		2	1	1	
Tautoga onitis	1	1											40	13	11	16	135	38	73	24	40	3	37	15	22		13	9	16		14	2	2	2							22	17	5		5	3		
Syngnathus fuscus					2			2	37			37	157			157	26			24					1			1	4			4	1			1					12		1	11	1			1
Osmerus mordax	17	1	16		29		26	3	68		60	8	65	8	53	4	37		12	5	1			1	5		3	2	2			2													9		8	2
Scophthalmus aquosus	10	4	2	4	27	6	3	18	13	1	1	11	17	1	6	10	17		4	13	26		2	24	46			44	11			11					3			3	17			17	25	1		24
Brevoortia tyrannus	36	28	8		82	69	13		26	25	1		4			4									1	1			1	1			8			8	1			1	30	27		3	7	4		3
Opsanus tau													1			1	88		38	50	29	7	12	10	15	1	9	5	3			3	2			1	3			3	7		2	5				
Microgadus tomcod	6		1	4	14		4	10	13		2	11	20		2	18					4	1	1	2	6		1	3	1			1									11			11	61		14	47
Pollachius virens																	3	3			24	7	16	1	90	32	57	1	16	2	13	1																
Cyclopterus lumpus	20	19		1	59	59			29	26	3		24	20	3	1																																
Prionotus carolinus					3		3																																									
Alosa aestivalis									3	1		2	2		1	1	4	1		3	1	1			9	4	5		48	47	1		8		8		10	1	9		23		23		5	2	2	1
Raja spp.	1	1			3			3	33	3		30																													10	2		8				
Pomatomus saltatrix																					13	13			57	56	1		25	18	7																	
Sphoeroides maculatus																	35		34	21	10		5	5																	1	1			1	1		
Urophycis tenuis																																									11	5	5	1	52	29	10	5
Clupea harengus	11			11	4			4	15			15	8			8	4			4																									2			2
Alosa pseudoharengus									3		1	2	7		3	4	3		3		3	3			15	15			10	10																		
Ophidiidae													3		1	2									12			12																				
Anguilla rostrata	1			1									18			18	13			13					3			3									1			1					1			1
Bairdiella chrysura	2		2																																						27			27	7	7		
Peprilus triacanthus																									4	4			15	12	2	1	13	10	3		1	1			1	1			1	1		
Paralichthys dentatus													3			3	2			2	21			21	4			4																				
Conger oceanicus													4			4	14			14																	1			1	1			1	1			1
Hemitripterus americanus					3			3	5			5	2			2	2			2																	5			5	2			2				
Ammodytes spp.	2		1	1	1			1									10		7	3																	2		2		3		1	2				
Stenotomus chrysops																	4	4			6	2	2		10	8	2																					
Merluccius bilinearis	3	3							1	1			2	2																															9	4	1	4
Brosme brosme																					2	2			7		3	4									5			3	13			13	14	6	6	2
Pholis gunnellus					5	3	2										9		8	1	1			1																								
Liparis atlanticus					10	10			1	1			1	1																																		
Monacanthus spp.																																									2	1	1		7	6	1	
Centropristis striata																	1			1	4			4	1			1					1			1												
Selar crumenophthalmus																																					5		1	4								
Cyprinodon variegatus																																					3	3							2	2		
Mugil cephalus	2		1	1	1			1	1			1																																				
Enchelyopus cimbrius					1			1	2			2																																				
Trinectes maculatus																									1			1									1		1		1		1					
Paralichthys oblongus													3			3																																
Aulostomus maculatus																																					3		1	2								
Lophius americanus																	2			2																												
Fundulus heteroclitus													1	1																															1		1	
Cynoscion regalis	1		1																																						1		1					
Caranx hippos																									1	1																						
Vomer setapinnis																													1	1																		
Mustelus canis																									1			1																				
Sphyraena borealis																																									1			1				
Menticirrhus saxatilis																																									1		1					
Hippocampus sp.																																									1	1						
Ulvaria subbifurcata									1		1																																					
Chondrichthyes																	1			1																												
Fundulus majalis	1	1			2		2		1	1																															3	1	2		1	1		
Rajidae													18		1	17																	9			9	6			6					24	5		39
Triglidae													27	2		25	67			67	10			10	8			8																	1	1		

TABLE 4.10-4. FISHES IMPINGED ON THE INTAKE SCREENS OF MILLSTONE UNITS NO. 1 AND 2* MONTHLY DURING 1975

	January				February				March				April				May				June				July				August				September				October				November				December			
	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"
Pseudopleuronectes americanus	447	367	153	147	477	240	88	149	506	216	93	199	159	23	12	115	149	7	55	87	55		18	37	55		21	34	23		9	14	105	4	34	67	40	1	5	34	106	3	25	78	586	36	119	429
Merluccius bilinearis																													1			1									11	2	9		1682	7	1645	29
Gasterosteus aculeatus	86	86			56	56			336	336			295	295			7	7																							94	94			578	578		
Myoxocephalus aenaeus	342	184	132	26	80	43	37		89	56	33		42	33	9		46	4	42		6		6		3	2	1		2			2	3	2	1						6		5	1	455	87	366	2
Menidia spp.	173	84	89		68	3	65		51	1	50		17		17		15		10		22	1	21										1			1	5		5		11	1	10		616		616	
Urophycis spp.	9	7		2	2	1		1													166	5	101	60													2	2			767	222	545					
Tautoga onitis	10	9		1					3	2		1	5	2		6	137	4	33	80					141	2	112	47	8		6	2	111	1	71	39	4		4		16	5	5	6	116	4	74	36
Morone americana					4	4			3		1	2	17		6	11	128		1	127	423			423	64			64	3	1		2	10			10					11	5	4	2	17	1	12	4
Tautogolabrus adspersus	56	56			4	2	2		17	17			15	11	6		38	9	29		129	17	96	16	85	15	61	9	10		9	1	59	1	37	21	11	1	4	6	22	7	13		134	43	81	10
Anchoa spp.																	20	8	12		173	11	162		161	20	141		2	1	1		3	1	2	8					37	5	32		84		84	
Scophthalmus aquosus	21	2		19	9	2		7	10	1	1	1	13		1	12	21			21	24			24	22			22	25			25	22			22	11			11	48			48	115		1	114
Brevoortia tyrannus	8	3		3	37	37			21	13	2	6	9			9									2	1		1					15			15	3			3	189	109	75	5	20	3	15	2
Raja spp.	29	4		25	18	3		15	27	1		26	30	1	8	29	13		1	12	3			3	1			1					3			3	14			14	45		2	43	80			80
Syngnathus fuscus									44			44	32			32	29		3	26	2			2	2			2	3			3					4			4	16		3	11	34		14	40
Alosa pseudoharengus	5			5	14			14	8			8	2		1	1	6	1		5	1		1		92	13	77	2	27	2	19	6	2		1	1					1			2	13	4	7	2
Microgadus tomcod	2			2													2			2	2		0	2									2			2	1			1	2			2	149		3	146
Prionotus spp.					1			1					3			3	74		1	73	43		1	42	16		1	15	1			1	12	6	2	4												
Alosa aestivalis	17	12		5					3	3			1			1	4		3	1	2		2		80	4	75	1	26		13	3	3	1	1	1	3		2	1	4	2		2	13	4	3	6
Gasterosteus spp.																					1	1							1	1		0									8	7	1		129	129		
Opsanus tau													2			2	40		1	39	33		2	31	10			10	2			2	11			11	1			1	9			9	4			4
Pomatomus saltatrix																					29	23	6		42	17	25		6		3	3	24		1	23	4			4	1			1				
Osmerus mordax	23		7	16	16		9	7	15		13	2	3		3		6		6		3		2		2		1	1					5			5					1			1	36		25	11
Paralichthys dentatus													1			1	9			9	67	1		46	29			20	8			8																
Peprilus triacanthus																	2			2	2		1	1	1	1			14	10	1	3	25			25	7		1	6	21	4	12	5	5		3	2
Cyclopterus lumpus	14	14			16	16			25	25			8	8																																		
Pollachius virens																	5		4	1	72	1	18	3	32		28	4	2		1	1	1			1												
Stenotomus chrysops	1		1														1		1		1		2	1	5		2	3	1			1	45	4	3	38	1			1								
Clupea harengus	5			5					3			3	19			19	7			7																									13			13
Cynoscion regalis	1		1										1			1													15	6	7	2	12		12		3		2	1	13		3	10	1			1
Raja ocellata																																																35
Anguilla rostrata	1			1																	4			4													1			1	10			10	18			18
Ammodytes spp.																					1			1																	7			7	13			13
Fundulus majalis	3		3																																										16	1	15	
Hemitripterus americanus									5			5	4			6	1			1																	5			5	1			1	1			1
Sphoeroides maculatus																	7			7	3		1	7	1		1														2	2						
Conger oceanicus																	2			2	8			8																					7			7
Pholis gunnellus	3			3					5		5						2		1	1	5		3	2																	1			1	1			1
Prionotus evolans																	13			13																					3			3				
Brosme brosme									2			2									7		2		5		2	3					1			1	1								3			3
Aluterus spp.																																													14	4	10	
Monacanthus spp.																																	1		1										13	1	12	
Fissola marginata																									5		1	4	4			4									1			1				
Morone saxatilis																	6			6	2			2									1			2												
Mugil cephalus					5			5																									4		3	1									1			1
Liparis atlanticus									8	8																																						
Anguilla spp.																	4			4																					3			3				
Trinectes maculatus																					1		1		1		1						3			3					2	1	1					
Caranx hippos																									5	5															1		1					
Scomber scombrus																					3		3										3			3												
Centropristis striata																					2			2																	1	1			1		1	
Vomer setapinnis																																									4	4						
Alectis crinitis																													1		1		2	1	1													
Selene vomer																																	2	1		1	1	1										
Squalus acanthias																	1			1	1			1																								
Lophius americanus																					1			1																	1			1				
Macrozoarces americanus													2			2																																
Fundulus heteroclitus																					1	1															1		1									
Dactylopterus volitans																													1	1			1	1														
Chilomycterus schoepfi																					1			1	1			1																				
Petromyzon marinus																									1			1																				
Mustelus canis																									1			1																				
Aulostomus maculatus																																									2			1				
Hippocampus sp.													1	1																																		
Selar crumenophthalmus																																									1			1				
Menticirrhus saxatilis																																									1		1					
Ammodytes americanus																									1		1																					
Paralichthys oblongus																																	1			1												
Prionotus carolinus																	1			1																												
Prostigonys alta																													1		1																	
Gasterosteidae																																					1	1										
Mugil sp.																																					1		1									
Sphyraena borealis																																													4			4

*Unit No. 2 became operational in September, 1975.

TABLE 4.10-5. INVERTEBRATES IMPINGED ON THE INTAKE SCREENS OF MILLSTONE UNIT NO. 1 MONTHLY DURING 1972

	January				February				March				April				May				June			
	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"
Callinectes sapidus																					220	3	169	50
Ovalipes ocellatus																					205	187	17	1
Homarus americanus									1			1	2		1	1	57		32	25	361	4	238	119
Libinia sp.																					122	102	20	
Cancer borealis																					6	2	4	
Carcinus maenas																					6	6		
Limulus polyphemus																					19	1	1	17
Pagurus sp.																								
Cancer irroratus																					4	3	1	

	July				August				September				October				November				December			
	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"
Callinectes sapidus	287	18	764	5	709	6	637	66	377	14	292	71	346	33	292	21	86	26	58					
Ovalipes ocellatus	504	487	17		471	461	8	2	185	174	11		189	158	31		207	173	34		138	136	2	
Homarus americanus	176		121	55	291		178	113	78		45	33	19		12	7	5		5		4		4	
Libinia sp.	253	238	14	1	278	265	13		98	93	5		18	17	1		1	1						
Cancer borealis	30	14	16		29	3	26		161	142	19		140	106	34		67	50	17		49	37	12	
Carcinus maenas	4	4			24	20	4		35	33	2		71	52	19		87	70	17		19	19		
Limulus polyphemus	4			4	1			1																
Pagurus sp.	3		3		1		1		5		5		10		10		2		2		1	1		
Cancer irroratus	3	1	2						1		1													

TABLE 4.10-6. INVERTEBRATES IMPINGED ON THE INTAKE SCREENS OF MILLSTONE UNIT NO. 1 MONTHLY DURING 1973

	January				February				March				April				May				June			
	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"
Loligo sp.													1			1	361	14	121	226	505	330	145	30
Ovalipes ocellatus													5	5			208	207	1		408	405	3	
Homarus americanus	1	1			2	2			22	3	19		130	109	21		308	308			185	185		
Cancer irroratus	112	103	9		79	70	9		136	133	3		200	187	13		206	189	17		99	99		
Callinectes sapidus																	18	9	6	3	78	25	48	5
Carcinus maenas	57	53	4		35	34	1		122	119	3		181	181			159	158	1		55	55		
Libinia sp.	1	1											2			1	64	23	29	12	29	28	1	
Limulus polyphemus													1			1	2			2	7			7
Pagurus sp.	1	1							2	2			1	1			3	3						

	July				August				September				October				November				December			
	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"
Loligo sp.	120	105	15		745	375	296	74	2334	778	1195	361	2273	379	1201	693	200	34	116	50	52	6	30	16
Ovalipes ocellatus	240	237	3		377	330	47		322	320	2		624	623	1		1798	1798			67	67		
Homarus americanus	137	130	6	1	181	179	2		38	37	1		117	115	2		91	88	3		20	20		
Cancer irroratus	31	31			60	58	2		37	5	2		22	22			11	11			18	17	1	
Callinectes sapidus	56	12	39	5	231	36	174	21	238	106	125	7	176	88	81	7	97	37	46	14	28	18	8	2
Carcinus maenas	38	37	1		43	43			38	38			44	44			40	40			24	24		
Libinia sp.	15	15			5	3	2		7	7			5	4	1		9	8	1		1	1		
Limulus polyphemus	1			1	2	1		1					4			4	3	3						
Pagurus sp.					2	2			1	1			1	1										

TABLE 4.10-7. INVERTEBRATES IMPINGED ON THE INTAKE SCREENS OF MILLSTONE UNIT NO. 1 MONTHLY DURING 1974

	January				February				March				April				May				June			
	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"
Ovalipes ocellatus													33	32	1		259	252	7		509	494	15	
Homarus americanus	2	2			2	2			45	42	3		90	87	3		151	148	3		243	241	2	
Loligo spp.													2		1	1	329	27	170	132	186	46	61	79
Callinectes sapidus																	20	3	11	6	136	27	56	53
Carcinus maenas	12	12			20	20			49	49			40	40			83	83			58	58		
Cancer irroratus	29	28	1		41	41			60	60			82	75		7	25	21	4		7	6	1	
Labinia sp.													24	11	13	0	57	31	25	1	79	19	59	
Limulus ployphemus																	26		3	23	27			27
Cancer borealis																								
Paguridae																								
Natantia																								

	July				August				September				October				November				December			
	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"	Total	0-2.9"	3-5.9"	>6"
Ovalipes ocellatus	460	460			173	173			128	128			113	113			417	417			17	16	1	
Homarus americanus	273	273			206	203	1		30	29	1		21	21			302	301	1		31	31		
Loligo spp.	116	44	43	29	265	35	111	119	83	32	50	1	314	153	134	27	85	1	55	29	2			2
Callinectes sapidus	181	71	71	39	166	37	101	28	125	39	56	30	50	22	23	5	143	72	38	33	15	4	4	7
Carcinus maenas	37	36	1		51	51			89	89			75	75			169	169			117	116		1
Cancer irroratus	38	37	1		15	15			96	96			63	63			111	111			31	31		
Labinia sp.	107	89	18		4	4			6	5	1		17	16		1	20	20			3	2	1	
Limulus ployphemus	1			1	3			3									2			2				
Cancer borealis	5	4	1		3	3			10	10							4	4						
Paguridae					3	3																		
Natantia										9	9		6		6		22		20	2				

TABLE 4.10-8. INVERTEBRATES IMPINGED ON THE INTAKE SCREENS OF MILLSTONE UNITS NO. 1 AND 2* MONTHLY DURING 1975

	January				February				March				April				May				June			
	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"
Loligo sp.																	805	10	501	294	1129	204	565	360
Ovalipes ocellatus													8		1	7	53	44	9		190	162	27	1
Homarus americanus	40	40			3	3			25	25			67	56	11		78	77	1		272	260	12	
Cancer irroratus	42	42			12	12			34	34			49	49			52	40	12		16	14	2	
Carcinus maenas	67	67			3	3			23	23			13	13			62	61	1		59	57	2	
Callinectes sapidus																	7		5	2	89	11	38	40
Libinia spp.									2	1	1		32	25	7		77	35	42		141	65	76	
Cancer borealis																					1		1	
Limulus polyphemus									1			1					9			9	27			27
Squilla empusa																								
Lysiosquillidae																								
Palaemonetes sp.																								
Natantia																								
P[illegible] spp.									1	1														

	July				August				September				October				November				December			
	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"	Total	0-3"	3-6"	>6"
Loligo sp.	651	241	392	18	661	144	442	75	641	423	202	16	312	42	226	44	999	98	676	225	91	32	34	25
Ovalipes ocellatus	241	217	24		354	336	18		444	436	8		143	134	9		508	499	9		83	83		
Homarus americanus	176	169	7		30	29	1		18	18			49	48	1		109	107	2		56	55	1	
Cancer irroratus	1	1			36	36			7	7			122	122			287	287			195	180	15	
Carcinus maenas	50	44	5	1	178	178			93	93			88	88			121	121			89	89		
Callinectes sapidus	76		37	39	133		53	80	132	2	64	66	89	4	33	52	147	19	71	57	8		5	3
Libinia spp.	115	61	54		62	53	9		26	26			69	69			6	6			7	7		
Cancer borealis	10	8	2		42	40	2		157	156	1		4	4			3	2	1					
Limulus polyphemus	15			15	5			5									3			3				
Squilla empusa																	32		26	6				
Lysiosquillidae																	8	1	6	1	5		4	1
Palaemonetes sp.																	3		3					
Natantia																	121	121						
P[illegible] spp.																	1	1						

*Unit No. 2 became operational in September, 1975.

TABLE 4.10-9. NUMBERS OF EACH FISH SPECIES IMPINGED ANNUALLY ON INTAKE SCREENS AT THE MILLSTONE NUCLEAR GENERATING STATION FROM 1972 THROUGH 1975

Species	1972	1973	1974	1975	Total	Percent	Cumulative Percent
Pseudopleuronectes americanus	1,864	6,193	3,738	2,917	14,712	28.0	28.0
Gasterosteus aculeatus	227	1,309	1,113	1,450	4,099	7.8	35.8
Myoxocephalus aenaeus	214	1,295	1,275	1,074	3,858	7.3	43.1
Menidia spp.	594	1,074	1,189	974	3,831	7.3	50.4
Scophthalmus aquosus	1,560	721	212	341	2,834	5.4	55.8
Tautogolabrus adspersus	502	951	569	580	2,608	4.9	60.7
Morone americana	435	745	713	680	2,573	4.9	65.6
Brevoortia tyrannus	432	1,586	196	304	2,518	4.8	70.4
Tautoga onitis	492	799	303	738	2,332	4.4	74.8
Alosa aestivalis	1,562	266	104	146	2,078	3.9	78.7
Merluccius bilinearis		54	15	1,693	1,762	3.3	82.0
Opsanus tau	72	821	147	112	1,152	2.2	84.2
Syngnathus fuscus	175	343	238	184	940	1.8	86.0
Anchoa spp.			441	480	921	1.7	87.7
Microgadus tomcod	124	306	136	160	726	1.4	89.1
Osmerus mordax	24	317	213	104	658	1.2	90.3
Raja spp.	28	226	104	228	586	1.1	
Prionotus carolinus	139	214	116	1	470	0.9	
Pollachius virens	140	117	133	62	452	0.9	
Peprilus triacanthus	42	279	35	77	433	0.8	
Sphoeroides maculatus	67	163	67	18	315	0.6	
Paralichthys dentatus	67	122	30	90	309	0.6	
Anguilla rostrata	119	91	37	34	281	0.5	
Cyclopterus lumpus	3	35	132	63	233	0.4	
Alosa pseudoharengus		1	41	171	213	0.4	
Pomatomus saltatrix		6	95	106	207	0.4	
Prionotus spp.				150	150	0.3	
Gasterosteus spp.				139	139	0.3	
Clupea harengus		23	44	47	114	0.2	
Stenotomus chrysops	1	32	18	57	108	0.2	
Ammodytes spp.		58	18	21	97	0.2	
Urophycis tenuis		14	63		77	0.1	
Pholis gunnellus	2	25	15	17	59	0.1	
Bairdiella chrysura	22		36		58	0.1	
Cynoscion regalis		9	2	46	57	0.1	
Merluccius spp.		13	41		54	0.1	
Conger oceanicus	1	9	21	17	48	0.1	
Liparis atlanticus		26	12	8	46	0.1	
Hemitripterus americanus	1	5	19	19	44	0.1	
Prionotus evolans	27			16	43	0.1	
Raja ocellata				35	35	0.1	
Fundulus majalis	9	7		19	35	0.1	
Monacanthus spp.	1	11	9	14	35	0.1	
Mugil cephalus		19	4	8	31	<0.1	
Enchelyopus cimbrius	6	22	3		31		
Cyprinodon variegatus	25		5		30		
Brosme brosme			15	14	29		
Fundulus heteroclitus	17	7	2	2	28		
Trinectes maculatus	6	6	3	7	22		
Caranx hippos		8	1	6	15		
Aluterus sp.				14	14		
Morone saxatilis		5		9	14		
Centropristis striata	1	1	7	4	13		
Myoxocephalus scorpius	12				12		
Rissola marginata				10	10		
Vomer setapinnis		5	1	4	10		
Selene vomer		7		3	10		
Scomber scombrus	1	1		6	8		
Menticirrhus saxatilis		6	1	1	8		
Sphyraena borealis		2	1	4	7		
Anguilla spp.				7	7		
Aulostomus maculatus		2	3	1	6		
Selar crumenophthalmus			5	1	6		
Paralichthys oblongus		2	3	1	6		
Lophius americanus		1	2	2	5		
Mustelus canis	1	2	1	1	5		
Pungitius pungitius	5				5		
Etrumeus teres		4			4		
Chilomycterus schoepfi	2			2	4		
Alectis crinitis				3	3		
Fundulus diaphanus	3				3		
Squalus acanthias				2	2		
Macrozoarces americanus				2	2		
Dactylopterus volitans				2	2		
Hippocampus sp.			1	1	2		
Prestigenys alta		1		1	2		
Aluterus schoepfi	1	1			2		
Myoxocephalus spp.		2			2		
Petromyzon marinus				1	1		
Ammodytes americanus				1	1		
Gasterosteidae				1	1		
Raja laevis	1				1		
Myoxocephalus octodecemspinosus		1			1		
Lumpenus medius			1		1		
Chondrichthyes			1		1		
Totals	9,127	18,297	11,750	13,513[1]	52,667		
Number of days of collections	278	363	356	474[1]			
Number of fish impinged/day	32.8	50.4	33.0	28.5			

1. Includes additional days of Unit No. 2 operation from September, 1975.

TABLE 4.10-10. TOTAL NUMBER OF INVERTEBRATES IMPINGED ANNUALLY ON INTAKE SCREENS AT MILLSTONE NUCLEAR GENERATING STATION FROM 1972 THROUGH 1975

Species	1972	1973	1974	1975	Total	Percent	Cumulativ Percent
Loligo sp.		6591	1382	5297	13270	32.9	32.9
Ovalipes ocellatus	1899	4049	2109	2016	10073	25.0	57.9
Homarus americanus	994	1232	1394	923	4543	11.3	69.2
Callinectes sapidus	2023	922	836	681	4462	11.1	80.3
Carcinus maenas	246	836	800	846	2728	6.8	87.1
Cancer irroratus	8	1011	598	853	2470	6.1	93.2
Libinia sp.	770	137	317	537	1761	4.4	97.6
Cancer borealis	482		22	217	721	1.8	99.4
Limulus polyphemus	24	20	59	60	163	0.4	99.8
Squilla empusa				38	38	0.1	9
Pagurus sp.	22	11	3		36	<0.1	
Lysiosquillidae				13	13	<0.1	
Palaemonetes sp.				3	3	<0.1	
Natantia			37	1	38	<0.1	
Total	6468	14809	7557	11485	40319		
No. days	278	363	356	474*			
Nos./day	23.3	40.8	21.2	24.2			

*Includes operating days for Units No. 1 and 2.

TABLE 4.10-11 DAY VERSUS NIGHT COLLECTIONS OF FISH FROM THE INTAKE SCREENS OF MILLSTONE UNIT NO. 1 FROM JULY, 1973, THROUGH JUNE, 1974

	Month	Day	Night	D/N
	JUL	64	248	.26
	AUG	124	905	.14
1973	SEP	250	986	.25
	OCT	627	695	.90
	NOV	195	489	.40
	DEC	144	478	.30
	JAN	161	398	.40
	FEB	215	774	.28
1974	MAR	207	463	.45
	APR	164	709	.23
	MAY	30	625	.05
	JUN	72	370	.19
		2253	7140	

	DAY	NIGHT
No. of Cases	12	12
Mean	187.7500	595.0000
Std. Dev.	153.3968	225.0475
Std. Error	44.2818	64.9656

		Corr.	P-Value	T-Value	DF	P-Value
Diff. Mean	-407.2500					
Std. Dev.	228.023					
Std. Error	65.825	.321	.309	-6.19	11	.000

TABLE 4.10-12. DAY VERSUS NIGHT COLLECTIONS OF INVERTEBRATES FROM THE INTAKE SCREENS OF MILLSTONE UNIT NO. 1 FROM JULY 1973 THROUGH JUNE 1974

	Month	Day	Night	D/N
	JUL	78	426	.18
	AUG	49	343	.14
1973	SEP	84	225	.37
	OCT	79	410	.19
	NOV	154	445	.35
	DEC	22	36	.61
	JAN	8	13	.61
	FEB	17	19	.89
1974	MAR	15	33	.45
	APR	27	67	.40
	MAY	10	169	.06
	JUN	59	391	.15
		602	2577	

	DAY	NIGHT
No. of Cases	12	12
Mean	50.1667	214.7500
Std. Dev.	43.3481	178.7101
Std. Error	12.5135	51.5892

		Corr.	P-Value	T-Value	DF	P-Value
Diff. Mean	-164.5833					
Std. Dev.	145.934					
Std. Error	42.128	.808	.001	-3.91	11	.002

TABLE 4.10-13 NUMBERS OF SURVIVORS OF FIVE MOST ABUNDANT FISH SPECIES IMPINGED ON UNIT NO. 1 INTAKE SCREEN MONTHLY DURING 1975

	P. americanus		*G. aculeatus*		*M. aenaeus*		*Menidia* spp.		*S. aquosus*	
Month	No. Impinged	No. Alive	No. Impinged	No. Alive	No. Impinged	No. Alive	No. Impinged	No. Alive	No. Impinged	No. Alive
JAN	667	465	84	5	0	--	173	1	21	3
FEB	477	172	56	4	80	11	68	1	9	0
MAR	506	143	336	39	89	14	51	0	10	5
APR	150	28	295	10	42	16	17	0	13	0
MAY	149	36	7	0	46	27	10	0	21	0
JUN	55	4	0	--	6	3	22	0	24	2
JUL	55	2	0	--	3	0	0	--	22	1
AUG	23	1	0	--	2	0	0	--	25	3
SEP	105	13	0	--	3	0	1	0	19	0
OCT	36	2	0	--	0	--	3	0	7	1
NOV	47	9	94	0	2	0	9	0	16	4
DEC	290	97	578	14	308	168	383	0	49	0

TABLE 4.10-14 NUMBERS OF SURVIVORS OF FIVE MOST ABUNDANT INVERTEBRATE SPECIES IMPINGED ON UNIT NO. 1 INTAKE SCREEN MONTHLY DURING 1975

	Loligo sp.		*O. ocellatus*		*H. americanus*		*C. sapidus*		*C. maenas*	
Month	No. Impinged	No. Alive	No. Impinged	No. Alive	No. Impinged	No. Alive	No. Impinged	No. Alive	No. Impinged	Nc Ali
JAN	0	–	0	–	40	28	0	–	67	6
FEB	0	–	0	–	3	2	0	–	3	
MAR	0	–	0	–	25	21	0	–	23	
APR	8	0	0	–	67	56	0	–	13	1
MAY	805	9	53	50	78	73	7	6	62	6
JUN	1129	22	190	168	272	194	89	87	59	5
JUL	651	3	241	209	176	143	76	74	50	4
AUG	661	5	354	243	30	19	133	121	178	17
SEP	632	0	444	232	18	15	130	127	93	9
OCT	184	21	93	93	29	26	75	74	77	7
NOV	616	5	278	262	83	72	124	123	77	7
DEC	59	0	47	47	46	35	8	8	65	6

TABLE 4.10-15 COMPARISONS OF MONTHLY WINTER FLOUNDER POPULATION ESTIMATES WITH NUMBERS OF WINTER FLOUNDER IMPINGED FROM APRIL 1973 THROUGH DECEMBER 1975

		Estimated Population	Number Impinged	Percent of Population
1973	APR	52,308	2,348	4.0
	MAY	225,500	276	1.0
	JUN	209,295	90	0.04
	JUL	247,934	35	0.01
	AUG	52,421	71	0.1
	SEP	47,794	64	0.1
	OCT	14,816	92	0.6
	NOV	46,700	96	0.2
	DEC	165,652	273	0.1
			$\bar{x}$ =	0.7
1974	JAN	13,318	883	6.0
	FEB	20,240	859	4.0
	MAR	103,410	921	0.8
	APR	116,663	326	0.2
	MAY	169,702	199	0.1
	JUN	155,134	39	0.02
	JUL	74,497	85	0.1
	AUG	134,848	23	0.01
	SEP	62,262	16	0.02
	OCT	86,338	20	0.02
	NOV	173,432	221	0.1
	DEC	109,451	146	0.1
			$\bar{x}$ =	0.9
1975	JAN	78,411	667	0.8
	FEB	45,727	477	1.0
	MAR	82,668	506	0.6
	APR	151,743	150	0.09
	MAY	139,975	149	0.1
	JUN	92,723	55	0.05
	JUL	63,771	55	0.08
	AUG	52,804	23	0.04
	SEP*	65,299	105	0.1
	OCT*	57,240	40	0.06
	NOV*	107,894	106	0.09
	DEC*	56,680	584	1.0
			$\bar{x}$ =	0.3

* Includes both Units No. 1 and 2.

TABLE 4.10-16. COMPARISONS OF MONTHLY LOBSTER POPULATION ESTIMATES WITH NUMBERS OF LOBSTERS IMPINGED FROM MAY, 1974, THROUGH MAY, 1975, AND OCTOBER THROUGH DECEMBER, 1975

		Estimated Population	Number Impinged	Percent of Population
	MAY	520	151	29.0
	JUN	846	243	28.7
	JUL	2,512	273	10.9
1974	AUG	3,737	204	5.4
	SEP	2,206	30	1.3
	OCT	3,254	21	0.6
	NOV	5,733	302	5.3
	DEC	6,584	31	0.5
				$\bar{x}$= 10.2
	JAN	3,618	40	1.1
	FEB	3,283	3	0.09
	MAR	1,881	25	1.3
1975	APR	33,777	67	0.2
	MAY	5,008	78	1.6
	OCT*	7,764	312	4.0
	NOV*	3,339	999	29.9
	DEC*	16,140	91	0.6
				$\bar{x}$= 4.8

* Includes both Units No. 1 and 2.

TABLE 4.10-17. COMPARISON OF COMMERCIAL LANDINGS (POUNDS) TO NUMBERS OF COMMERCIAL SPECIES IMPINGED DURING 1972 AND 1973

Commercial Species	1972 Pounds Landed	1972 Number Impinged	1973 Pounds Landed	1973 Number Impinged
Alosa pseudoharengus (alewife)	18,800	0	10,300	1
Pomatomus saltatrix (bluefish)	49,300	0	87,100	6
Gadus morhua (cod)	1,400	0	5,400	0
Pseudopleuronectes americanus (winter flounder)	56,400	1,864	19,600	6,193
Limanda ferruginea (yellowtail flounder)	0	0	0	0
Clupea harengus (Atlantic herring)	400	0	0	23
Brevoortia tyrannus (menhaden)	369,100	432	575,600	1,586
Scomber scombrus (mackerel)	8,000	1	21,400	1
Paralichthys dentatus (summer flounder)	600	67	3,600	122
Cynoscion regalis (weakfish)	400	0	2,000	9
Peprilus triacanthus (butterfish)	0	42	1,000	279
Menticirrhus saxatilis (northern kingfish)	0	0	0	6

TABLE 4.10-18. COMPARISON OF ESTIMATED POUNDAGE OF IMPINGED LOBSTERS TO COMMERCIAL* LANDINGS IN EASTERN LONG ISLAND SOUND FROM 1972 THROUGH 1975

Date	Commercial (lbs.)	Impinged (numbers)
1972	192,500	994
1973	217,017	1,232
1974	213,785	1,394
1975	240,374	923

*Data supplied by Connecticut Department of Environmental Protection.

TABLE 4.10-19 NUMBERS OF JUVENILE BREVOORTIA TYRANNUS COLLECTED BY SHORE-ZONE SEINE AROUND MILLSTONE POINT AND IMPINGED AT MILLSTONE UNIT 1 INTAKE STRUCTURE, 1969-1975

	1969	1970	1971	1972	1973	1974	1975	Total
Seining Station								
Seaside	-	-	-	-	0	2	0	2
White Point	752	96	754	77	0	0	0	1,679
Jordan Cove	796	377	2	4	0	1	0	1,180
Bay Point	2	1275	0	79	0	1	0	1,357
Crescent Reach	-	-	-	-	0	0	1	1
Gravils Neck	1	74	1	19	0	0	0	95
TOTALS	1551	1822	757	179	0	4	1	4,314
Number Impinged			$50x10^6$	0	1229	155	168	

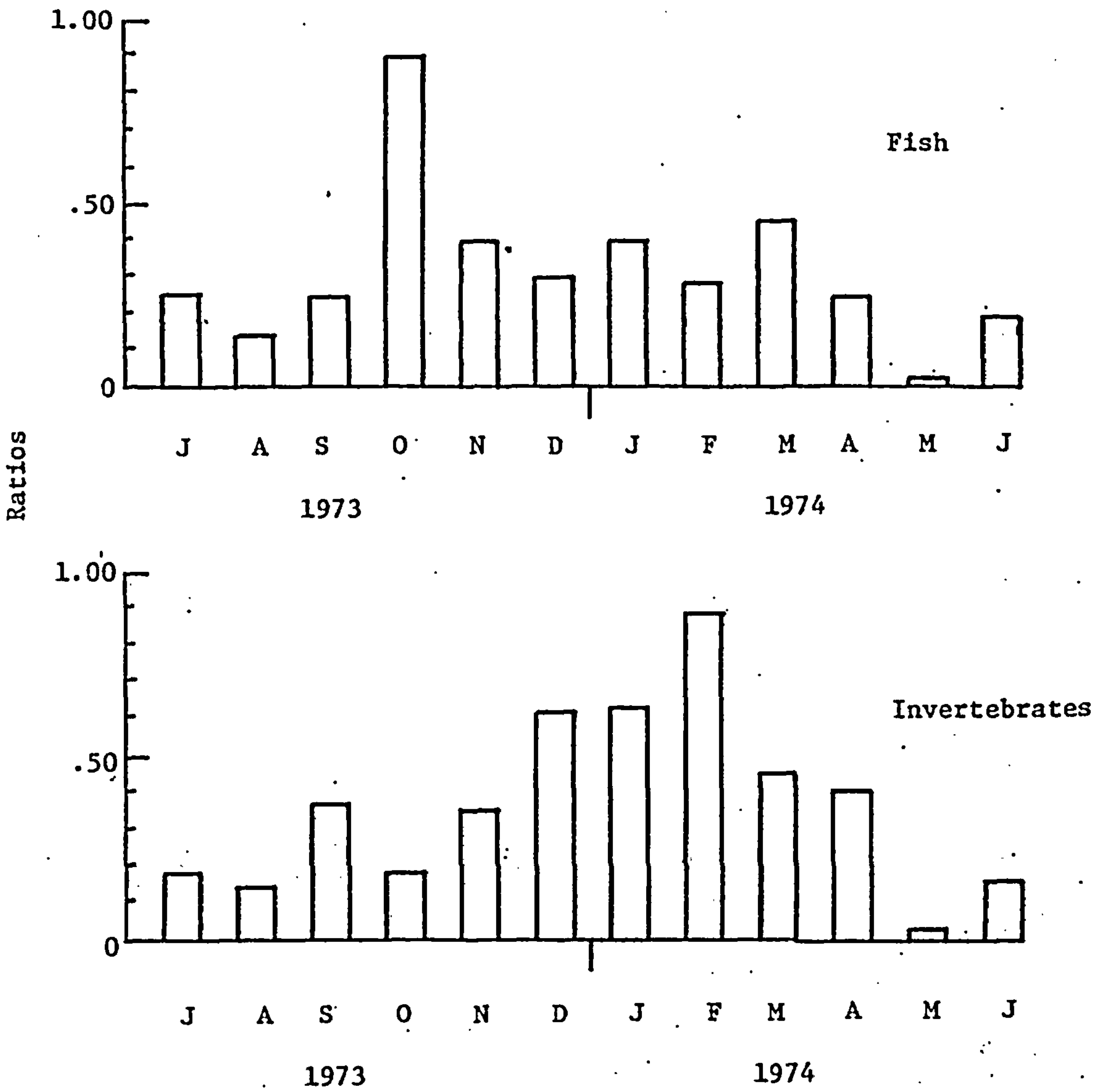


FIGURE 4.10-1. RATIOS OF DAY-TO-NIGHT COLLECTIONS OF FISH AND INVERTEBRATES FROM THE INTAKE SCREENS OF MILLSTONE UNIT NO. 1 FROM JULY, 1973, TO JUNE, 1974

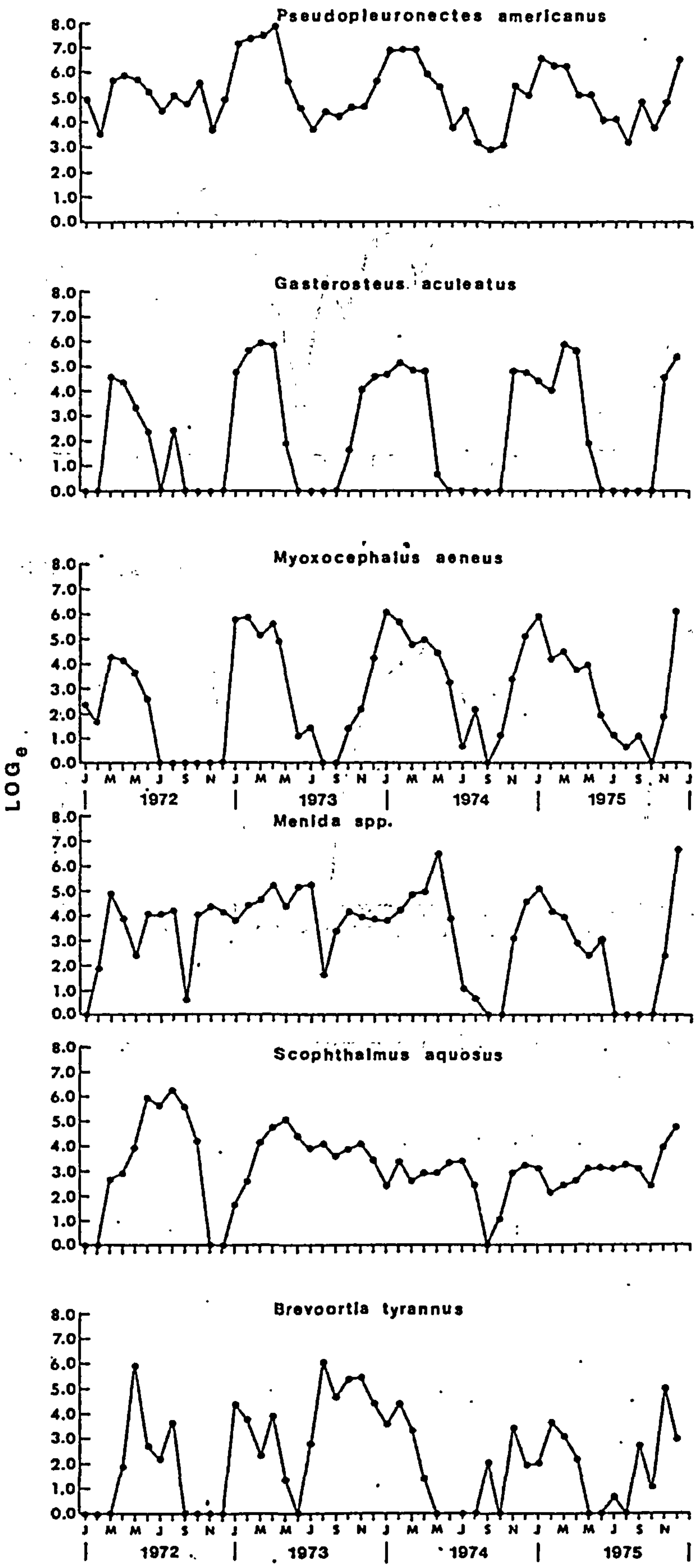


FIGURE 4.10-2. PATTERNS OF IMPINGEMENT OF FIVE MOST ABUNDANT FISH SPECIES AND MENHADEN COLLECTED FROM INTAKE SCREENS OF MILLSTONE UNITS NO. 1 AND 2* FROM 1972 THROUGH 1975

*Unit No. 2 began operation in September, 1975.

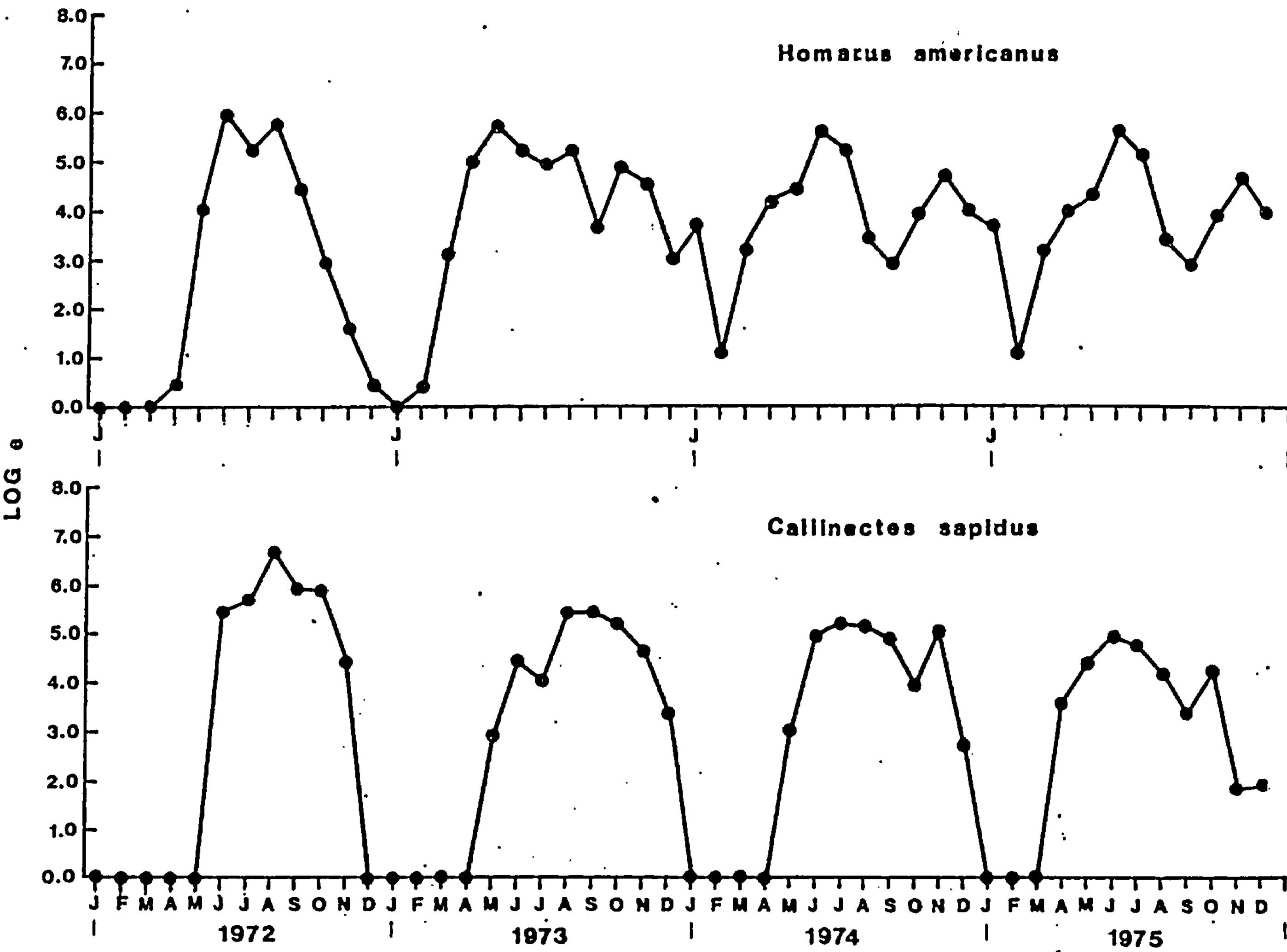


FIGURE 4.10-3. PATTERNS OF IMPINGEMENT OF LOBSTERS AND BLUE CRABS COLLECTED FROM INTAKE SCREENS OF MILLSTONE UNITS NO. 1 AND : FROM 1972 THROUGH 1975

*Unit No. 2 began operation in September, 1975.

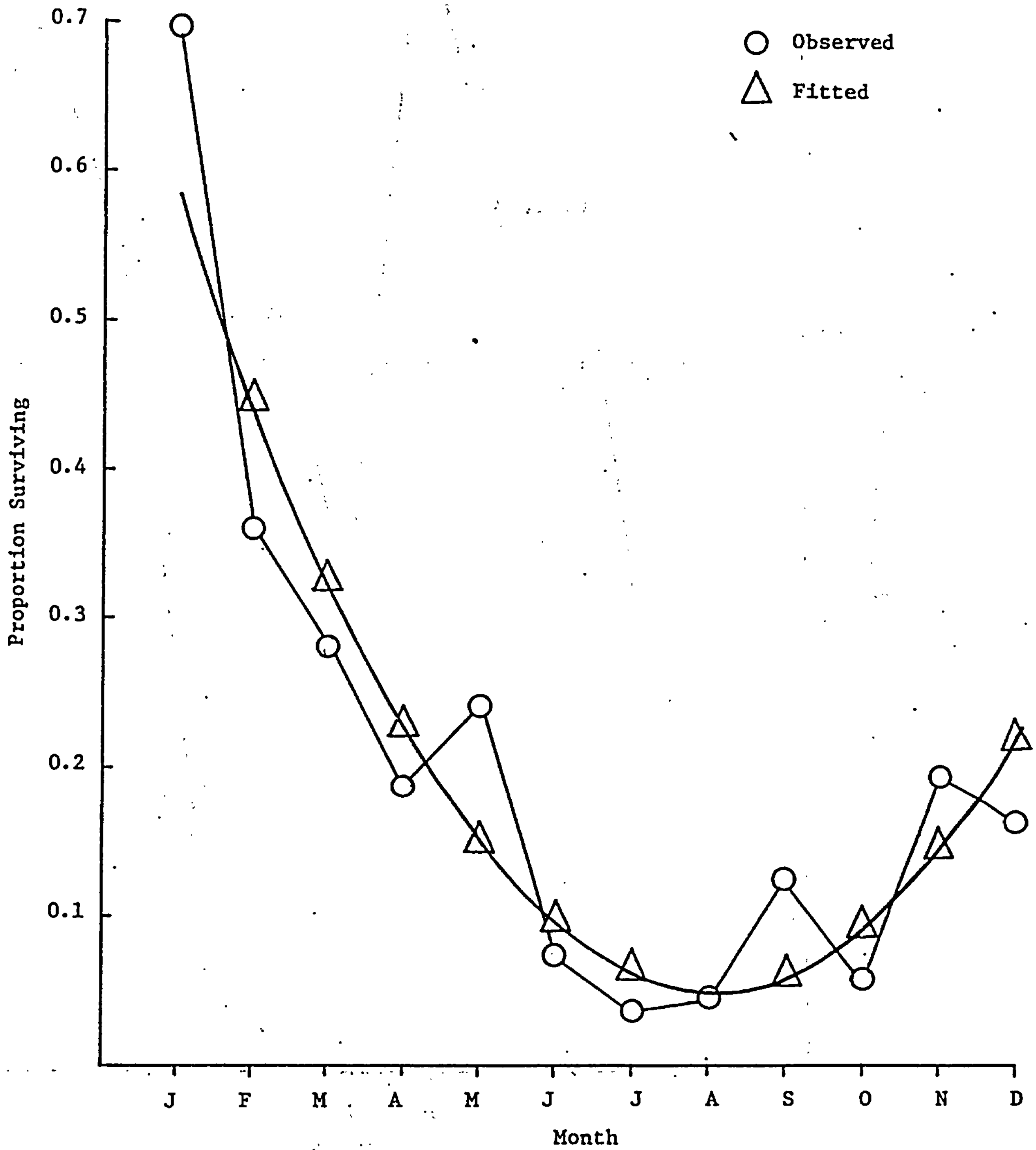


FIGURE 4.10-4. PATTERN OF *Pseudopleuronectes americanus* SURVIVAL ON INTAKE SCREENS OF MILLSTONE UNIT NO. 1 DURING 1975

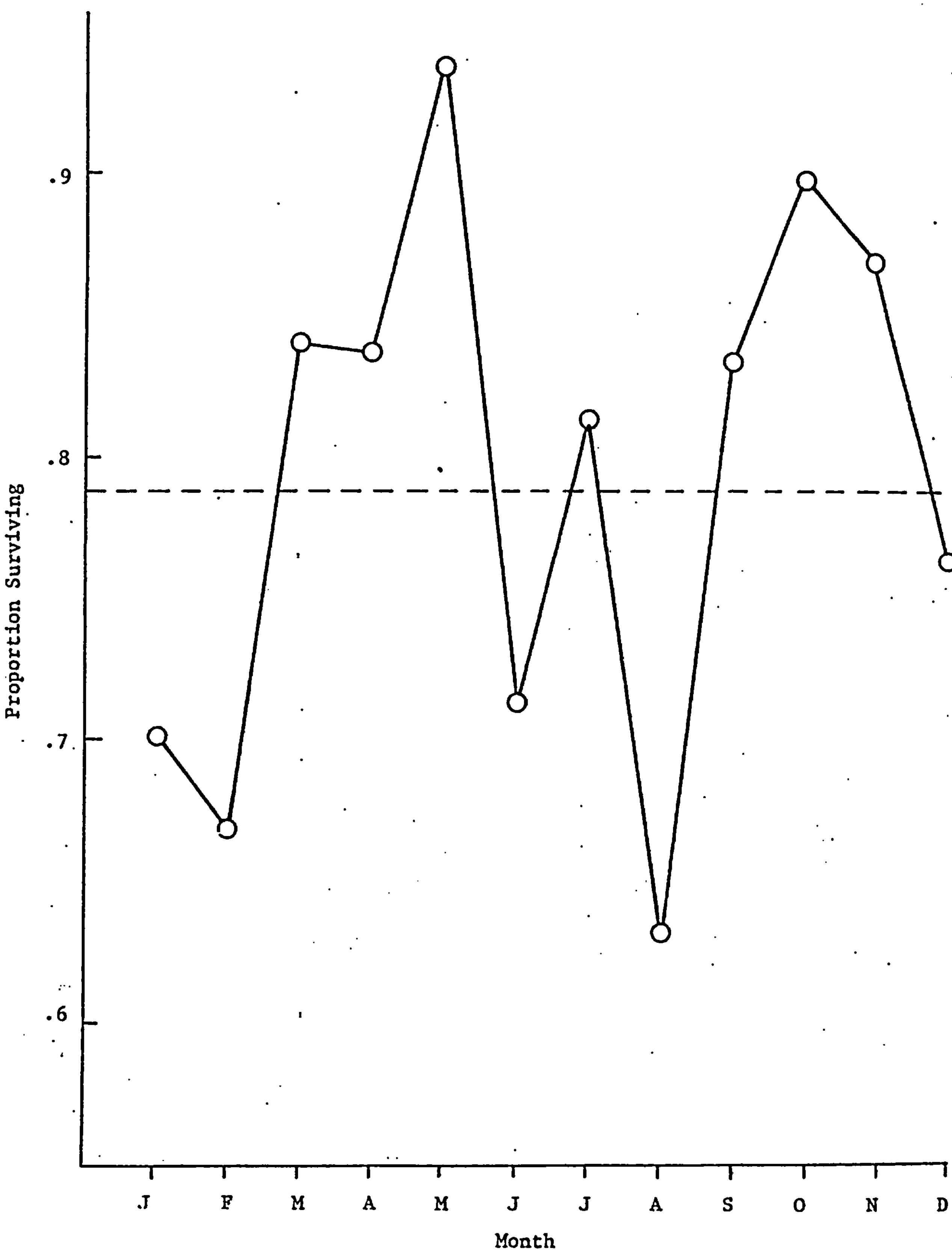


FIGURE 4.10-5. PATTERN OF *Homarus americanus* SURVIVAL ON INTAKE SCREENS OF MILLSTONE UNIT NO. 1 DURING 1975

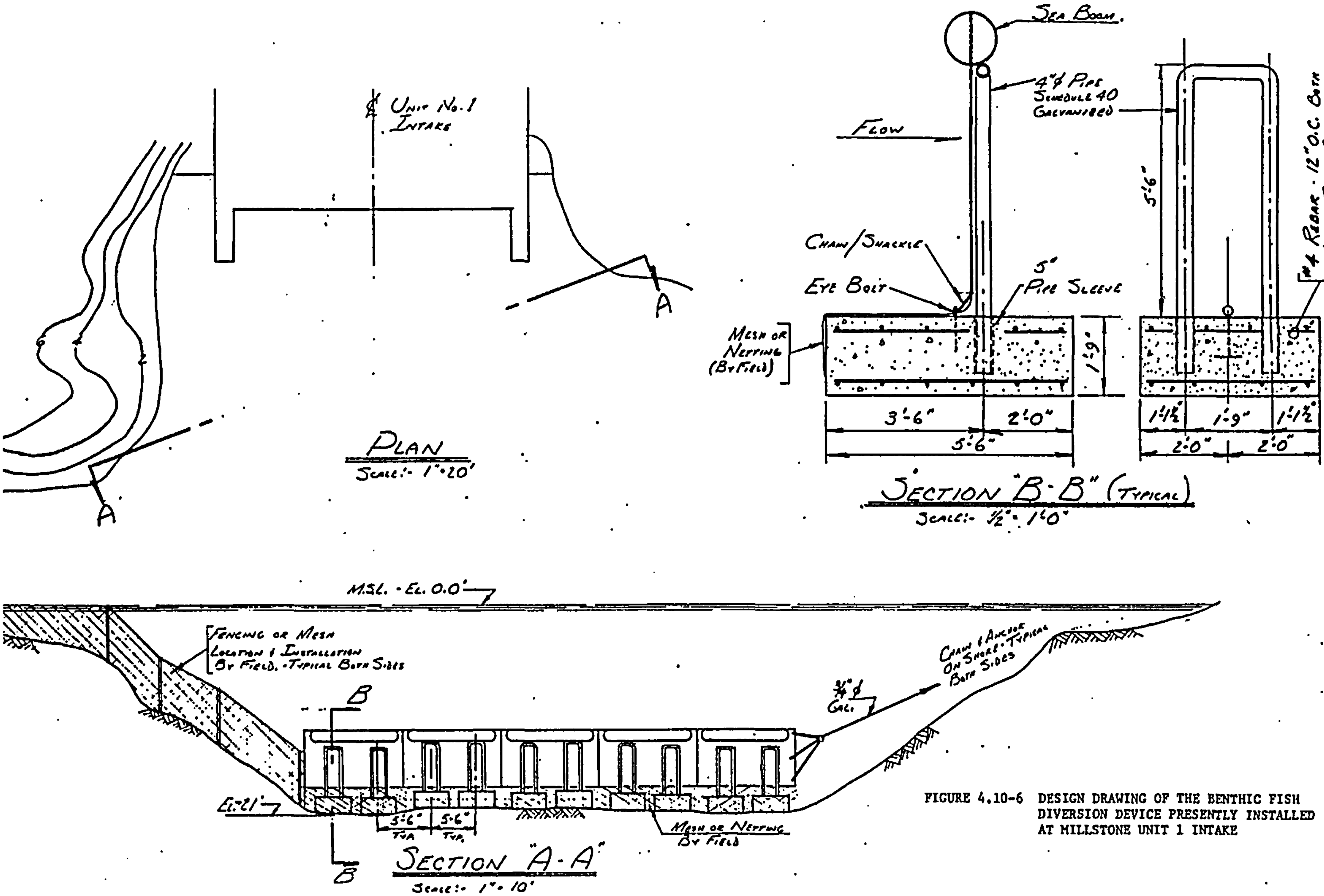


FIGURE 4.10-6 DESIGN DRAWING OF THE BENTHIC FISH DIVERSION DEVICE PRESENTLY INSTALLED AT MILLSTONE UNIT 1 INTAKE

TABLE 4.11-1. TOTAL PHYTOPLANKTON SPECIES LIST FROM ALL STUDIES AT MILLSTONE. ASTERISKED SPECIES WERE ADDED DURING THE ONGOING PROGRAM.

CLASS: BACILLARIOPHYCEAE

Actinoptychus undulatus *
Actinoptychus scenarius
Amphiprora spp.
Amphiprora alata
Amphora spp.
Asterionella formosa *
Asterionella japonica
Asteromphalus spp.
Bacteriastrum delicatulum *
Biddulphia aurita *
Ceratulina bergonii (= pelagica)
Chaetoceros affinis
Chaetoceros brevis
Chaetoceros borealis *
Chaetoceros compressus *
Chaetoceros curvisetus
Chaetoceros danicus *
Chaetoceros debilis *
Chaetoceros decipiens *
Chaetoceros diadema *
Chaetoceros didymus
Chaetoceros gracilis
Chaetoceros laciniosus *
Chaetoceros simplex
Chaetoceros socialis *
Chaetoceros subtilis
Chaetoceros spp.
Cocconeis spp.
Cocconeis scutellum *
Corethron hystrix (now *C. Criophilum)*
Coscinodiscus spp.
Coscinodiscus centralis *
Coscinodiscus lineatus
Cyclotella spp.
Cyclotella kutzingiana
Cyclotella nana (now *Thalassiosira pseudonana)*
Cylindrotheca closterium (formerly *Nitzschia closterium)*
Detonula confervacea *
Ditylum brightwellii
Eucampia zoodiacus

Continued

TABLE 4.11-1. (Continued)

CLASS: BACILLARIOPHYCEAE (Continued)

Fragillaria spp. *
Grammatophora spp.
Grammatophora marina *
Gyrosigma spp.
Gyrosigma/Pleurosigma spp. *
Guinardia flaccida *
Hemiaulus membranicus
Hemiaulus sinensis
Lauderia borealis *
Licmophora spp.
Licmophora abbreviata
Lithodesmium undulatum
Melosira spp.
Melosira monoliformis
Melosira munnuloides *
Melosira sulcata
Nitzschia spp.
Nitzschia paradoxa *
Nitzschia reversa *
Nitzschia seriata
Pinnularia spp. *
Pleurosigma fasciola *
Pleurosigma spp.
Porosira spp. *
Porosira glacialis *
Rhabdonema spp. *
Rhabdonema adriaticum *
Rhaphoneis spp. *
Rhizosolenia spp. *
Rhizosolenia delicatula
Rhizosolenia fragilissima
Rhizosolenia hebetata *
Rhizosolenia setigera
Schroederella delicatula *
Skeletonema costatum (now *Stephanopyxis costata)*
Stephanopyxis palmeriana *
Stephanopyxis turris
Surirella spp.
Thalassionema spp.
Thalassionema nitzschoides
Thalassiosira spp.
Thalassiosira decipiens
Thalassiosira nordenskioldii
Thalassiosira rotula
Thalassiothrix frauenfeldii *
Unknown Centrales
Unknown Pennales

Continued

TABLE 4.11-1. (Continued)

CLASS: CHLOROPHYCEAE

Ankistrodesmus falcatus
Dunaliella spp.
Scenedesmus spp.
Volvox spp.
Unknown green single cell
Unknown green filament

CLASS: CHRYSOPHYCEAE

Isochrysis spp.
Pseudopedinella pyriforme
Prymnesium parvum

CLASS: CRYPTOPHYCEAE

Cryptomonas spp.
Hemiselmis spp.
Katablepharis ovalis
Pyramimonas spp.
Rhodomonas amphioxeia
Rhodomonas minuta

CLASS: DINOPHYCEAE

Amphidinium spp.
Ceratium bucephalum
Ceratium tripos
Dinophysis acuminata
Dinophysis spp.
Gymnodinium spp.
Gyrodinium estuariale
Gyrodinium dominans
Gyrodinium metum
Gyrodinium spirale
Katodinium rotundatum
Peridinium spp.
Peridinium triquetrum
Peridiopsis rotundata
Prorocentrum minimum
Unknown dinoflagellates

Continued

TABLE 4.11-1. (Continued)

CLASS: EUGLENOPHYCEAE	
	Euglena spp.
	Eutreptia spp.
CLASS: HAPTOPHYCEAE	
	Calycomonas ovalis
	Calycomonas gracilis
	Distephanus speculum
CLASS: XANTHOPHYCEAE	
	Olisthodiscus spp.
	Olisthodiscus luteus *
MISCELLANEOUS	
	Unknown microflagellates
	Unknown filament
	Unknown flagellate
CLASS: CYANOPHYCEAE	
	Coccoid bluegreen
	Merismopedia spp. *
	Unknown bluegreen

TABLE 4.11-2. PHYTOPLANKTON SPECIES OR TYPES COMPRISING MORE THAN 5% OF THE SPECIES COMPOSITION BY NUMBERS FOR THE ANNUAL CYCLE APRIL 30, 1975 TO APRIL 28, 1976.

	SAMPLE DATES																								
SPECIES OR TYPE	APRIL 30	MAY 13	MAY 27	JUNE 10	JUNE 24	JULY 8	JULY 23	AUGUST 6	AUGUST 20	SEPTEMBER 3	SEPTEMBER 17	OCTOBER 22	NOVEMBER 12	NOVEMBER 26	DECEMBER 10	DECEMBER 24	JANUARY 7	JANUARY 22	FEBRUARY 4	FEBRUARY 18	FEBRUARY 25	MARCH 12	MARCH 24	APRIL 7	APRIL 28
Unknown microflagellates	21	24	7	21					6			5	10												
Navicula spp.	19	26	8	26	28				11	13	16	20		40											
Thalassionema nitzschoides	17															22	11	10	16	17	61	13			
Distephanus speculum	10																								
Melosira sulcata		17											6												
Rhizosolenia delicatula			51								6														19
Leptocylindrus minimus			9										7												
Cylindrotheca closterium									6	16			24												
Skeletonema costatum				12	24		87	71	29	36	25	7	24	18	16	45		60	41	69		13	11		30
Unidentified blue green				11	7					17		6		9											
Gymnodinium spp.				6																					
Unidentified green					7			15																	
Chaetoceros affinis						92																			
Asterionella japonica								5	33						21	24		13	17	5	5				
Ceratulina pelagica											46						37								12
Chaetoceros debilis												11	6												
Nitzschia spp.			7		6							10													
Paralia sulcata															29						6				6
Thalassiosira nordenskioldii															14	7	13	7	7			53	47	21	6
Order Pennales															7				7		7				11
Chaetoceros brevis																								8	
Chaetoceros debilis																								28	
Nitzschia seriata																								8	
Chaetoceros affinis																								9	

TABLE 4.11-3. ZOOPLANKTON SPECIES TYPE LIST COVERING BOTH WHOI AND NAI MONITORING STUDIES FROM 1970 TO PRESENT.

AMPHIPODA

Caprellids
Unidentified

ANNELIDA

Polychaete
Oligochaete
Autolytus sp.
Harmothoe imbricata
Nephtys sp.
Paranoitis
Polychaete larvae
Tomopteris helgolandica
Spionid eggs

CHAETOGNATHA

Sagitta elegans
Krohnitta sp.

CIRRIPEDIA

Cirriped juvenile or nauplii
Cypris larvae

CLADOCERA

Evadne sp.
Podon sp.

COELENTERATE (Medusae)

Anthozoan larvae
Bougain villa britannica
Ephyra
Hybocodon prolifer
Hydroid polyp (free)
Laodicea sp.
Melicertum sp.
Nemopsis sp.
Obelia sp.
Podocoryne sp.
Physonectids
Rathkea octopunctata
Sarsia mirabilis
Tiaropsis diadesmata

COPEPODA: Calanoida

Acartia clausi
Acartia longiremis
Acartia tonsa
Calanus finmarchicus
Caligus sp.
Centropages hamatus
Centropages typicus
Candacia armata
Copepod nauplii
Eurytemora americana
Eurytemora affinia
Eurytemora herdmani
Eurytemora lacustris
Labidocera aestiva
Metridia lucens
Paracalanus crassirostris
Paracalanus parvus
Pseudocalanus minutus (elongatus)
Pseudodiaptomus coronatus
Temora longicornis
Tortanus sp. *(discaudatus)*

COPEPODA: Cyclopoida

Oithona colcarva (=brevicornis)
Oithona similis (=helgolandica)
Oithona spinirostris

COPEPODA: Harpacticoida

Alteutha depressa
Amphiascus sinautus
Amphiascus sp.
Dactylopusia vulgaris
Harpacticus chelifer
Harpacticus sp.
Harpacticus uniremis
Idya furcata
Idya sp.
Laophonte sp.
Longipedia coronata
Microarthridion litterale
Microthalestris forficula
Monostrilla angelica
Parathalestris jacksoni
Phyllothaleathris mysis

TABLE 4.11-3. (Continued)

COPEPODA: Harpacticoida

Rhynchothalestris rafountia
Thalestris longimona
Unknown harpacticoid
Westwoodia nobidia

CTENOPHORA

Cydippid larvae
Pleurobrachia pileus

CUMACEA

Diastylis quadrispinosa
Leptocuma sp.
Leucon sp.
Oxyurostylis smithi

EUPHAUSID - Calytosis larvae
Furcilia larvae

FORAMINIFERA

ISOPODA

Chiridotea tufts
Epicaridean
Idotea americana
Idotea balthica
Unknown isopod

MOLLUSCA

Bivalvia larvae (lamellbranch)
Mussel juvenile

GASTROPOD

Littorina littorea eggs
Littorina littorea veligers
Mitrella lunata
Pteropoda
Veliger larvae (Bivalve & Gastropod)

MYSIDACEA

Heteromysis formosa
Mysidopsis bigelowi
Neomysis americana
Unidentified

NEMATODA

Pilidium larvae

PYCNOGONIDA

Halacaridae - *Halacarus* sp.

STOMATOPODA

ASSORTED LARVAE STAGES

Actinotroch larvae
Actinula larvae
Appendicularia
Clandina larvae
Oikopleura larvae
Auricularia larvae
Bipunnaria larvae
Brachyuran adult
Brachyuran megalopa
Brachyuran zoea
Caridea
Caridean zoea (larvae)
Crangon septemspinosus
Cyphonautes larvae
Echinopluteus larvae
Lysiosquilla larvae
Polytroch larvae
Porcellanid zoea
Thalassinoidean larvae
Tunicate (pelagic)

TABLE 4.11-4. SPECIES LIST OF ZOOPLANKTON FOUND FROM NOVEMBER 8, 1973 THROUGH JULY 1, 1975 IN DESCENDING ORDER BY PERCENT SPECIES COMPOSITION. THOSE CONTRIBUTING LESS THAN 0.05% OF TOTAL SPECIES COMPOSITION HAVE BEEN ELIMINATED FROM THE LIST.

SPECIES OR TYPE	%
Acartia tonsa	18.6884
Acartia clausi	16.8681
Temora longicornis	12.0015
Pseudocalanus minutus	10.5651
Centropages hamatus	5.8275
Acartia spp. *copepodite*	4.2965
Eurytemora americana	3.5142
Littorina littorea eggs	3.1464
Cirripedia nauplii	2.9494
Pseudodiaptomus coronatus	2.4791
Cirripedia cypris	2.3638
Polychaete larvae	2.0519
Pseudodiaptomus coronatus copepodite	2.0166
Podon spp.	1.5523
Temora longicornis copepodite	1.2125
Evadne spp.	1.1552
Ctenophora cydippid larva	0.9582
Copepod nauplii	0.8061
Eurytemora affinis	0.6083
Brachyuran zoea	0.6006
Harpacticoida unidentified	0.5659
Centropages spp. copepodite	0.5643
Oithona similis	0.5591
Pseudocalanus minutus copepodite	0.5247
Amphipoda unidentified	0.5187
Gastropod egg	0.4887
Gastropod veliger	0.4773
Hydromedusa	0.2401
Paracalanus crassirostris	0.2248
Caridean zoea	0.2055
Bivalve veliger	0.1880
Oithona spinirostris	0.1850
Tortanus discaudatus	0.1847
Sagitta elegans	0.1535
Centropages typicus	0.1524
Acartia longiremis	0.1264
Bryozoan cyphonautes larva	0.1134
Polychaeta	0.0997
Oikopleura dioica	0.0777
Obelia spp.	0.0675

TABLE 4.11-5. SPECIES LIST OF ZOOPLANKTON FOUND BETWEEN NOVEMBER 10, 1970 AND NOVEMBER 14, 1971 IN DESCENDING ORDER BY PERCENT SPECIES COMPOSITION.

SPECIES OR TYPE	%
Acartia clausi	31.0799
Acartia tonsa	11.0095
Littorina littorea eggs	9.5282
Pseudocalanus minutus	9.3277
Cirripedia cypris	5.1849
Cirripedia nauplii	3.7738
Temora longicornis	3.4938
Copepod nauplii	3.4611
Polychaete larvae	3.3574
Rathkea octopunctata	3.3175
Centropages hamatus	2.4158
Pseudodiaptomus coronatus	1.9525
Eurytemora americana	1.5366
Veliger larvae	1.4378
Amphipods unidentified	1.3198
Evadne spp.	1.2314
Podon spp.	1.1422
Paracalanus parvus	0.6267
Obelia spp.	0.4872
Harpacticoida	0.4150
Cladocera	0.3930
Polychaeta	0.3481
Brachyruan zoea	0.3161
Tortanus spp.	0.2794
Eurytemora herdmani	0.2044
Oikopleura dioica	0.1958
Caridean zoea	0.1656
Hydromedusa	0.1636
Hybocodon prolifer	0.1634
Sagitta elegans	0.1529
Ctenophora cydippid larva	0.1251
Centropages typicus	0.1074
Harpacticus spp.	0.0956
Oithona similis	0.0887
Oithona spp.	0.0821
Eurytemora affinis	0.0642
Oithona spinirostris	0.0612
Tisbe (Idya) furcata	0.0582
Alteutha depressa	0.0573
Labidocera aestiva	0.0554
Bryozoan cyphonautes larva	0.0541
Bivalve veliger	0.0482

TABLE 4.11-6. ABUNDANCE ($\#/m^3$) AND DRY WEIGHT BIOMASS (mg/m^3) OF TOTAL ZOOPLANKTON TAKEN IN AN INTENSIVE COMPARABILITY STUDY OF NAI AND WHOI .333mm NETS AT THE DISCHARGE OF UNIT 1.

DATE	ABUNDANCE $\#/m^3$				DRY WEIGHT mg/m^3			
	DAY		NIGHT		DAY		NIGHT	
	NAI	WHOI	NAI	WHOI	NAI	WHOI	NAI	WHOI
September 2, 1975	3432	4986	2302	2951	70.62	43.60	29.19	45.66
September 3, 1975	8789	2894	2534	3371	60.07	35.18	26.00	37.58
September 5, 1975	3059	997	4207	3234	27.97	15.21	92.55	29.11
September 8, 1975	2395	4243	1773	1424	36.82	30.42	27.21	16.13
September 10, 1975	2007	1522	2906	2878	28.60	28.54	69.29	40.27
September 12, 1975	833	457	1726	1129	62.37	33.19	45.80	45.50
September 15, 1975	1010	708	909	1028	15.80	24.03	---	---
September 17, 1975	686	2208	405	1019	3.29	63.62	11.80	23.27
September 19, 1975	8429	105	68	672	11.80	16.42	11.40	24.79
September 22, 1975	405	608	920	989	17.31	24.05	15.73	21.68
September 24, 1975	1746	2197	1164	1990	23.22	41.05	24.75	33.56
September 26, 1975	---	---	502	1213	---	---	10.48	35.22
September 29, 1975	326	302	---	---	8.41	9.79	---	---

TABLE 4.11-7. ZOOPLANKTON AVERAGE MAXIMUM ABUNDANCE (#/m^3) AT MILLSTONE POINT, ADJACENT OFFSHORE STATIONS AND TWO OTHER SITES IN LONG ISLAND SOUND. MONTH OF MAXIMUM ABUNDANCE IS GIVEN IN ROMAN NUMERALS.

SPECIES	YEAR	MILLSTONE MILLSTONE ENTRAINMENT[a]	MILLSTONE OFFSHORE STATION 5[b]	MILLSTONE OFFSHORE STATION 11[b]	SHOREHAM[c]	NEW HAVEN[d]
Total zooplankton	1973	ND	6,123 (VIII)	ND	7,564 (VIII)	ND
	1974	249,856 (IX)	5,712 (IX)	4,865 (VII)	ND	178,035 (IX)
	1975	31,296 (VII)	8,891 (IX)	6,492 (IX)	ND	284,730 (V)
Acartia tonsa	1973	ND	5,221 (VIII)	ND	7,430 (VIII)	ND
	1974	185,600 (IX)	5,276 (IX)	3,697 (X)	ND	6,279 (VIII)
	1975	4,914 (IX)	8,439 (IX)	8,042 (IX)	ND	15,840 (VIII)
Acartia clausi	1973	ND	713 (VI)	ND	3,036 (VI)	ND
	1974	43,584 (VI)	1,885 (VI)	1,606 (VI)	ND	40,604 (IV)
	1975	6,080 (VII)	296 (III)	215 (III)	ND	21,650 (IV); 27,180 (VI)
Temora longicornis	1973	ND	1,725 (V)	ND	1,408 (V)	ND
	1974	48,192 (VI)	2,440 (V)	2,171 (VII)	ND	2,520 (VI)
	1975	4,032 (VII)	1,081 (IV)	625 (V)	ND	15,250 (V)
Pseudocalanus minutus	1973	ND	612 (V)	ND	257 (III)	ND
	1974	35,328 (VI)	654 (V)	549 (VII)	ND	223 (II)
	1975	2,944 (VII)	376 (V)	192 (V)	ND	916 (IV)

a) Millstone entrainment studies, intake or discharge of Unit 1, Fonteneau (1976) and NAI unpublished data.
b) Millstone ecological monitoring offshore Station 5 or 11, Battelle (1976) and unpublished
c) Shoreham, Austin and Caplan (1974)
d) New Haven Harbor, Offshore Station 20, NAI (1976).

ND=no comparable data available

TABLE 4.11-8. TOTAL SPECIES LIST OF FISH LARVAE OR EGGS FOUND IN ENTRAINMENT STUDIES AT MILLSTONE POINT.

SPECIES	COMMON NAME
Alosa sp.	Unidentified herring
Alosa aestivalis	blueback herring
Alosa pseudoharengus	alewife
Ammodytes sp.	sand lance (unidentified)
Ammodytes americanus	American sand lance
Anchoa sp.	anchovy
Anchoa hepsetus	striped anchovy
Anchoa mitchilli	bay anchovy
Anguilla rostrata	American eel
Apeltes quadracus	fourspine stickleback
Brevoortia tyrannus	Atlantic menhaden
Brosme brosme	cusk
Centropristes striata	black sea bass
Clupeidae	Clupeid family
Clupeiformes	Clupeid/engrauilid order
Clupea harengus	Atlantic herring
Conger oceanicus	conger eel
Cynoscion regalis	weakfish
Cyprinodon variegatus	sheepshead minnow
Enchelyopus cimbrius	fourbeard rockling
Engraulidae	engraulid family
Etropus microstomus	smallmouth flounder
Fundulus sp.	unidentified
Fundulus majalis	striped killifish
Gadus morhua	Atlantic cod
Gadidae	cod family
Gasterosterus aculeatus	threespine stickleback
Glyptocephalus cynoglossus	witch flounder
Gobiidae	goby family
Gobiosoma ginsburgii	seaboard goby
Hemitripterus americanus	sea raven
Hippocanthus erectus	lined seahorse
Hippoglossoides platessoides	American plaice
Labridae	labrid family
Limanda ferruginea	yellowtail flounder
Liparis liparis	striped sea snail
Lumpenus lumpretaeformis	snakeblenny
Melanogrammus aeglefinus	haddock
Menidia sp.	silverside unidentified
Menidia beryllina	tidewater silverside
Menidia menidia	Atlantic silverside
Menticirrhus saxatilis	northern kingfish
Merluccius bilineâris	silver hake

Continued

TABLE 4.11-8. (Continued)

SPECIES	COMMON NAME
Microgadus tomcod	Atlantic tomcod
Morone americana	white perch
Morone saxatilis	striped bass
Mugil cephalus	striped mullet
Myoxocephalus sp.	sculpin
Myoxocephalus aenaeus	grubby sculpin
Myoxocephalus octodecemspinosus	longhorn sculpin
Myoxocephalus scorpius	shorthorn sculpin
Paralichthys oblongus	fourspot flounder
Paralichthys dentatus	summer flounder
Peprilus triacanthus	butterfish
Pholis gunnellus	rock gunnel
Pollachius virens	pollock
Pomatomus saltatrix	bluefish
Prionotus sp.	searobin
Prionotus carolinus	northern searobin
Pseudopleuronectes americanus	winter flounder
Rissola marginata	striped cusk-eel
Scomber scombrus	Atlantic
Scophthalmus aquosus	windowpane flounder
Sphoeroides maculatus	northern puffer
Stenotomus chrysops	scup
Syngnathus fuscus	northern pipefish
Tautoga onitis	tautog
Tautogolabrus adspersus	cunner
Trinectes maculatus	hogchoker
Ulvaria subbifurcata	radiated shanny
Urophycis sp.	hake unidentified
Urophycis chuss	red hake

TABLE 4.11-9. FISH EGGS FOUND AT ALL STATIONS BETWEEN APRIL 3, 1973 AND MAY 27, 1975 IN DESCENDING ORDER OF PERCENT SPECIES COMPOSITION. THE CORRECTED PERCENT COLUMN DISTRIBUTES UNIDENTIFIED EGGS OVER THE WHOLE IN THE RELATIVE PROPORTIONS GIVEN IN THE INITIAL PERCENT COLUMN.

EGG SPECIES OR TYPE	INITIAL %	CORRECTED %
Total eggs (unidentified)	44.3986	---
Tautogolabrus adspersus	44.3608	79.7836
Tautoga onitis	5.5019	9.8953
Scomber scombrus	2.0652	3.7143
Prionotus sp.	.7066	1.2708
Scophthalmus aquosus	.6640	1.1942
Limanda ferruginea	.5927	1.0660
Stenotomus chrysops	.5443	.9790
Enchelyopus cimbrius	.2643	.4753
Anchoa mitchilli	.2446	.4399
Brevoortia tyrannus	.1445	.2600
Gadus morhua	.9865	.1556
Anchoa sp.	.9828	.1489
Clupeiformes *	.0505	.0908
Anchoa hepsetus	.0461	.0829
Peprilus triacanthus	.0458	.0823
Prionotus carolinus *	.0255	.0459
Pseudopleuronectes americanus (d)	.0121	.0218
Pholis gunnellus	.0086	.0155
Pollachius virens	.0045	.0081
Morone saxatilis *	.0042	.0076
Urophycis chuss	.0040	.0072
Paralichthys oblongus	.0033	.0059
Labridae *	.0020	.0036
Ulvaria subbifurcata (d)	.0018	.0032
Gadidae	.0012	.0022
Alosa aestivalis *	.0006	.0011
Alosa pseudoharengus	.0004	.0007
Menticirrhus saxatilis *	.0003	.0005
Labird/L. ferruginea type eggs	.0003	.0005
Cynoscion regalis *	.0003	.0005
Morone americana	.0002	.0004
Clupea harengus (d)	.0002	.0004
Engraulidae *	.0001	.00018
Hippoglossoides platessoides	.0001	.00018
Etropus microstomus *	.00009	.00016
Paralichthys dentatus *	.00002	.00004
Urophycis sp. *	.00002	.00004
Cyprinodon variegatus (d) *	.00002	.00004
Microgadus tomcod (d)	.00001	.00002

(d) = demersal egg
* = not found at discharge or cut

TABLE 4.11-10. PERCENT SPECIES COMPOSITION OF FISH EGGS AT THE DISCHARGE COMPARED TO INTAKE 1, 3 AND 5 m FOR THE PERIOD APRIL 3, 1973 TO JANUARY 15, 1974.

SPECIES OR TYPE	DISCHARGE	INTAKE 1m	INTAKE 3m	INTAKE 5m
T. adspersus	76.04	74.41	63.13	71.00
T. onitis	10.80	12.18	14.86	14.39
S. scombrus	4.24	4.29	3.10	2.66
Anchoa spp.	3.04	1.22	1.35	1.77
Prionotus spp.	1.95	4.07	4.38	3.26
Total eggs (unidentified)	1.45	1.62	3.59	4.77
S. aquosus	0.53	0.72	0.31	0.36
P. carolinus	0.52	0.01	---	---
B. tyrannus	0.37	0.53	0.58	0.79
P. americanus	0.36	0.01	0.02	0.01
E. cimbrius	0.23	0.11	0.19	0.22
L. ferruginea	0.16	0.32	0.25	0.18
P. triacanthus	0.11	0.02	---	0.03
G. morhua	0.06	0.02	0.03	0.07
S. chrysops	0.03	0.03	---	0.27
P. oblongus	0.03	0.17	0.05	0.01
A. pseudoharengus	0.02	0.004	0.02	0.01
Gadidae	0.02	0.01	0.02	0.06
U. chuss	0.02	0.14	0.09	---
U. subbifurcata	0.02	---	---	---
M. saxatilis	---	---	0.02	0.03
C. regalis	---	0.01	0.02	0.01
C. harengus	---	---	---	0.03
P. virens	---	---	0.003	---
P. dentatus	---	0.002	---	---
Labridae	---	0.10	0.17	---
Clupeiformes	---	---	7.71	---
A. aestivalis	---	---	0.10	---
C. variegatus	---	---	0.003	---

TABLE 4.11-11. PERCENT SPECIES COMPOSITION FOR FISH EGGS FOUND AT ALL STATIONS AND DATES FOR ENTRAINMENT STUDIES IN 1973 AND 1974. ASTERISK INDICATES THESE PERCENTAGES HAVE BEEN CORRECTED BY DISTRIBUTING UNIDENTIFIED EGGS EVENLY OVER THE 1974 DATA AFTER JULY.

EGGS	1973	1974*
T. adspersus	73.39%	80.20%
T. onitis	11.27%	9.75%
S. scombrus	3.40%	3.75%
Prionotus spp.	2.73%	1.14%
Eggs (unidentified)	2.12%	2.67%
A. mitchilli	1.79%	0.48%
L. ferruginea	1.74%	1.01%
Clupeiformes	1.09%	0.08%
B. tyrannus	0.74%	0.22%
S. aquosus	0.54%	1.25%
S. chrysops	0.07%	1.06%
E. cimbrius	0.18%	0.50%

TABLE 4.11-12. PERCENT SPECIES COMPOSITION OF FISH LARVAE AT THE DISCHARGE COMPARED TO INTAKE 1, 3 AND 5 m FOR THE PERIOD APRIL 3, 1973 TO JANUARY 15, 1974.

SPECIES OR TYPE	DISCHARGE	INTAKE 1m	INTAKE 3m	INTAKE 5m
Anchoa spp.	39.59	42.71	24.07	45.31
T. adspersus	9.39	3.71	13.94	15.58
P. americanus	8.29	8.59	9.27	4.69
A. americanus	8.23	2.83	2.81	2.64
Clupeiformes	6.52	11.54	7.12	3.77
T. onitis	5.67	3.20	7.58	5.46
B. tyrannus	5.61	5.87	13.73	2.79
S. scombrus	2.47	5.15	6.42	2.98
U. subbifurcata	1.73	1.26	1.19	0.46
P. triacanthus	1.30	0.78	0.75	2.41
S. aquosus	1.28	1.79	0.31	2.67
E. cimbrius	1.01	2.28	1.20	0.93
S. fuscus	0.88	0.76	0.75	0.97
Prionotus spp.	0.78	0.07	0.70	1.87
Liparis spp.	0.72	1.49	0.34	0.33
Clupeidae	0.68	0.98	0.17	1.35
P. gunnellus	0.66	0.07	1.11	0.05
G. ginsburgi	0.63	0.85	0.95	1.02
S. chrysops	0.59	0.25	0.32	0.40
P. oblongus	0.34	0.69	0.96	0.55
M. aenaeus	0.33	0.27	0.34	0.29
A. rostrata	0.28	0.07	0.04	0.03
L. ferruginea	0.28	0.34	0.14	0.03
U. chuss	0.15	---	0.41	0.35
C. regalis	0.15	---	---	0.04
S. maculatus	0.14	0.58	0.17	0.04
Fundulus spp.	0.10	0.44	0.35	0.52
Menidia spp.	0.10	0.28	0.40	0.64
G. morhua	0.06	---	---	0.13
E. microstomus	0.05	---	---	---
Labridae	---	0.16	---	0.35
M. saxatilis	---	0.46	0.14	---
M. bilinearis	---	0.06	0.16	0.08
Myoxocephalus spp.	---	---	0.18	---
M. octodecemspinosus	---	---	0.06	---

TABLE 4.11-13. PERCENT SPECIES COMPOSITION OF FISH LARVAE AT THE DISCHARGE COMPARED TO INTAKE 1, 3 AND 5 m SAMPLES FOR THE PERIOD OCTOBER 15, 1974 THROUGH MAY 27, 1975.

SPECIES	DISCHARGE	INTAKE 1m	INTAKE 3m	INTAKE 5m
P. americanus	52.22	58.46	46.89	46.22
A. americanus	15.25	9.03	10.90	8.58
M. aeneus	13.99	8.54	7.39	3.79
P. gunnellus	4.60	0.83	1.70	1.32
S. scombrus	3.70	10.06	11.94	21.18
U. subbifurcata	2.55	2.31	4.69	0.19
B. tyrannus	1.19	1.13	0.95	1.22
Liparis spp.	1.14	0.11	0.64	1.47
Gobiidae	1.04	0.70	0.25	0.20
E. cimbrius	0.97	3.09	8.59	7.80
S. aquosus	0.66	0.32	0.91	2.69
A. rostrata	0.37	0.10	0.15	0.28
P. dentatus	0.27	0.03		
M. octodecimspinosus	0.27	0.26	0.11	0.98
L. ferruginea	0.21	0.53	0.13	1.96
G. morhua	0.14	0.48	0.30	0.12
S. fuscus	0.14	0.10		0.02
Clupeidae	0.13	0.10		0.08
M. tomcod	0.11	0.16	0.11	0.02
Anchoa spp.	0.10		0.01	0.86
Menidia spp.	0.08		0.18	
C. harengus	0.05		0.05	0.07
Fundulus spp.	0.04			
T. onitis	0.02			0.07
Gadidae	0.01	0.05		
A. quadracus	0.01	0.05	0.01	

TABLE 4.11-14. PERCENT SPECIES COMPOSITION FOR FISH LARVAE FOUND AT ALL STATIONS AND DATES FOR ENTRAINMENT (NAI, WHOI) AND ECOLOGICAL (BATTELLE) MONITORING STUDIES OVER THE SPECIFIED YEARS. ASTERISKS INDICATE SUBSTITUTION OF *ANCHOA* SP. FOR ENGRAULIDAE AND *B. TYRANNUS* FOR CLUPEIDAE IN BATTELLE FIGURES.

LARVAE	NAI 1975	BATTELLE 1975	WHOI 1974	BATTELLE 1974	WHOI 1973
Anchoa sp.	38.6348%	18.683*	11.3929%	22.712*	33.4864%
P. americanus	18.3108	6.593	19.8090	6.706%	14.7987
S. scombrus	18.0672	39.827	1.7862	16.270	3.6325
A. americanus	4.2563	3.091	8.0583	3.774	2.2943
B. tyrannus	3.0729	2.956	0.3017	2.064	6.0521
M. aeneus	2.8757	0.837	1.7052	2.110	0.8334
Clupeiformes	2.7134	2.756*	1.0242	2.064*	6.1433
E. cimbrius	2.0262	1.829	1.2943	3.087	1.6543
S. aquosus	1.6850	18.043	6.0884	6.422	1.5328
P. gunnellus	0.9669	0.187	0.1435	0.112	0.0411
T. adspersus	0.8789	2.163	19.2134	12.417	9.3383
T. onitis	0.8089	2.774	6.3190	9.442	4.8470
U. subbifurcata	0.8237	0.286	1.1066	1.728	3.7177
S. fuscus	0.5166	0.142	1.4968	1.244	0.8550
Liparis spp.	0.4423	0.128	0.8111	0.304	0.6671
Gobiidae	0.3296	0.181	0.5317	0.184	0.8496
Engraulidae	0.2492	18.683	2.4072	22.712	---
L. ferruginea	0.2438	0.258	0.0158	0.459	0.1348
P. triacanthus	0.2276	1.013	1.6163	4.354	---
Menidia spp.	0.1951	0.037	0.4610	0.979	0.2056
S. chrysops	0.1335	0.297	0.9567	1.491	0.3235
A. rostrata	0.1068	0.001	0.3242	0.007	0.0372

TABLE 4.11-15. PERCENTAGE SPECIES COMPOSITION OF FISH LARVAE IN DAY VERSUS NIGHT SAMPLES AMONG ALL STATIONS FOR 1973, 1974 AND 1975.

LARVAE	1975 DAY	1975 NIGHT	1974 DAY	1974 NIGHT	1973 DAY	1973 NIGHT
Anchoa sp.	30.09	44.64	5.86	17.61	24.48	42.76
P. americanus	25.42	13.31	11.51	29.14	13.39	16.24
S. scombrus	14.65	20.47	2.76	0.69	2.38	4.96
A. americanus	5.97	3.05	4.51	10.94	2.01	4.85
B. tyrannus	1.30	4.32	0.21	0.41	7.89	4.15
M. aeneus	3.51	2.43	2.47	0.85	0.78	0.89
Clupeiformes	3.22	2.36	0.11	2.06	4.86	7.47
E. cimbrius	3.84	0.75	1.67	0.87	1.78	1.52
S. aquosus	1.89	1.54	9.66	2.07	1.98	1.07
P. gunnellus	1.02	0.93	0.20	0.08	---	0.08
T. adspersus	0.89	0.87	34.99	1.46	14.62	3.89
T. onitis	1.01	0.67	8.22	4.19	7.41	2.20
U. subbifurcata	1.59	0.28	0.95	1.29	4.46	2.95
S. fuscus	0.67	0.42	1.55	1.43	1.17	0.54
Liparis spp.	0.47	0.43	0.61	1.04	0.48	0.86
Gobiidae	0.34	0.32	0.14	0.98	---	---
Engraulidae	0.48	0.08	0.35	4.72	---	---
L. ferruginea	0.53	0.04	0.01	0.02	0.08	0.19
P. triacanthus	0.34	0.15	1.97	1.22	1.11	1.02
Menidia spp.	0.17	0.21	0.26	0.80	0.22	0.92
S. chrysops	0.14	0.13	1.68	0.15	0.51	0.13
A. rostrata	0.004	0.18	0.14	0.53	---	---

TABLE 4.11-16. COMPARISON OF ABUNDANCE (#/m^3) OF DIFFERENT IMPORTANT AND REPRESENTATIVE TYPES OF ICHTHYOPLANKTON FROM MILLSTONE ENTRAINMENT STUDIES, MILLSTONE AREA AND OTHER AREAS AROUND OR ADJACENT TO LONG ISLAND SOUND. MONTHS OF MAXIMUM OCCURRENCE ARE IN ROMAN NUMERALS.

SPECIES/TYPE	YEAR	A MILLSTONE PLANT MAXIMUM #/m^3	B MILLSTONE PLANT MAX. DAILY AVE. #/m^3	C MILLSTONE AREA	D SHOREHAM	E CHARLESTOWN	F NARRAGANSETT BAY	G NORTHPORT	H NEW HAVEN HARBOR
Total Eggs	1973	46 (IV/V)	23 (V/VI)	90 (VI)	513 (VI)		53 (VI)	--- ---	
	1974	30 (V)	11 (V)	43 (VII)		39 (V)		--- ---	
	1975	92 (VI)	63 (VI)	19 (VI)		27 (V)		--- ---	49 (V)
Total Larvae	1973	1.632 (VIII)	.896 (VIII)	6.99 (VII)	38 (VI/VII)		2.98 (VII)	--- ---	
	1974	1.00 (V/VI)	.689 (VIII)	2.82 (VII)		5.722 (V)		--- ---	
	1975	17.77 (VI)	10.9 (VI)	23.23 (VI)		8.646 (VI)		--- ---	12.655 (VI)
P. americanus	1973	0.108 (IV)	0.079 (IV)	0.036 (V)	2.8 (III)		0.250 (V)	0.039 (IV)	
	1974	0.690 (V)	0.282 (V)	0.170 (IV)		0.198 (V)			
	1975	1.048 (IV)	1.002 (IV)	0.377 (IV)		0.224 (IV)			.010 (V)
T. adspersus	1973	0.417 (VI/VII)	0.200 (VI)	0.170 (VII)	1.0 (VI/VII)		0.888 (VII)	1.348 (VI)	
	1974	0.138 (V)	0.046 (V)	0.722 (VII)		1.12 (VII)			
	1975	0.118 (VI)	0.118 (VI)	0.256 (VII)		3.69 (VI)			.025 (VI)
T. onitis	1973	0.205 (VI)	0.114 (VI)	0.377 (VI)	3.0 (VI/VII)		0.226 (VII)	1.057 (VI)	
	1974	0.091 (VII)	0.077 (VII)	0.438 (VII)		0.368 (VI)			
	1975	0.128 (VII)	0.128 (VII)	0.353 (VII)		1.074 (VII)			.052 (VIII)
Ammodytes sp.	1973	0.234 (XII)	0.164 (XII)	0.396 (XII)	0.21 (XII)		0.201 (IV)	0.035 (I)	
	1974	0.236 (I)	0.121 (I)	0.106 (IV)		0.336 (IV)			
	1975	0.462 (IV)	0.373 (IV)	0.0843 (III)		0.341 (IV)			.262 (IV)
Anchoa sp.	1973	1.526 (VIII)	0.831 (VIII)	6.663 (VII)	22 (VII)		1.37 (VII)	1.281 (VII)	
	1974	0.958 (VIII)	0.500 (VIII)	1.348 (VII)		1.332 (VII)			
	1975	6.240 (VIII)	5.631 (VIII)	4.009 (VII/VIII)		1.766 (VII)			2.632 (VII)
S. scombrus	1973	0.070 (V)	0.065 (V)	0.0083 (VII)	1.165 (VI)		0.568 (V)	.009 (V)	
	1974	0.077 (VI)	0.030 (VI)	0.714 (VI)		2.751 (VI)			
	1975	16.50 (VI)	9.98 (VI)	20.670 (VI)		0.983 (V)			.010 (V)
B. tyrannus	1973	0.194 (VI)	0.130 (VI)	1.493 (VII)	7.8 (VII)		0.390 (VI)	13.934 (VI)	
	1974	0.047 (XI)	0.025 (XI)	0.058 (VI)		0.125 (VII)			
	1975	0.441 (VI)	0.337 (VI)	1.028 (VI)		0.242 (VI)			.093 (VI)
S. aquosus	1973	0.0391 (VI)	0.025 (VI)	0.280 (VI)	0.209 (VI/VII)		0.056 (VI)	0.186 (V)	
	1974	0.069 (V/VI)	0.036 (V/VI)	0.233 (VI)		0.089 (V)			
	1975	0.692 (VI)	0.399 (VI)	0.7046 (VI)		0.255 (VI)			.008 (VI)

A = Millstone entrainment absolute maximum (Discharge 1) (Fonteneau, (1976)

B = Millstone entrainment maximum daily average (one station - discharge 1) (NAI, unpublished data)

C = Millstone offshore maximum weekly average (all stations) (Battelle, 1976)

D = Shoreham maximum weekly average (all stations) (Austin, 1974)

E = Charlestown maximum monthly average (all stations) (MRI, 1975)

F = Narragansett Bay maximum monthly average (all stations - Section 10) (MRI, 1974)

G = Northport maximum biweekly average (one station - intake lagoon) (Austin et al., 1973)

H = New Haven Harbor maximum monthly average (one station - (20 ebb) (NAI, 1976)

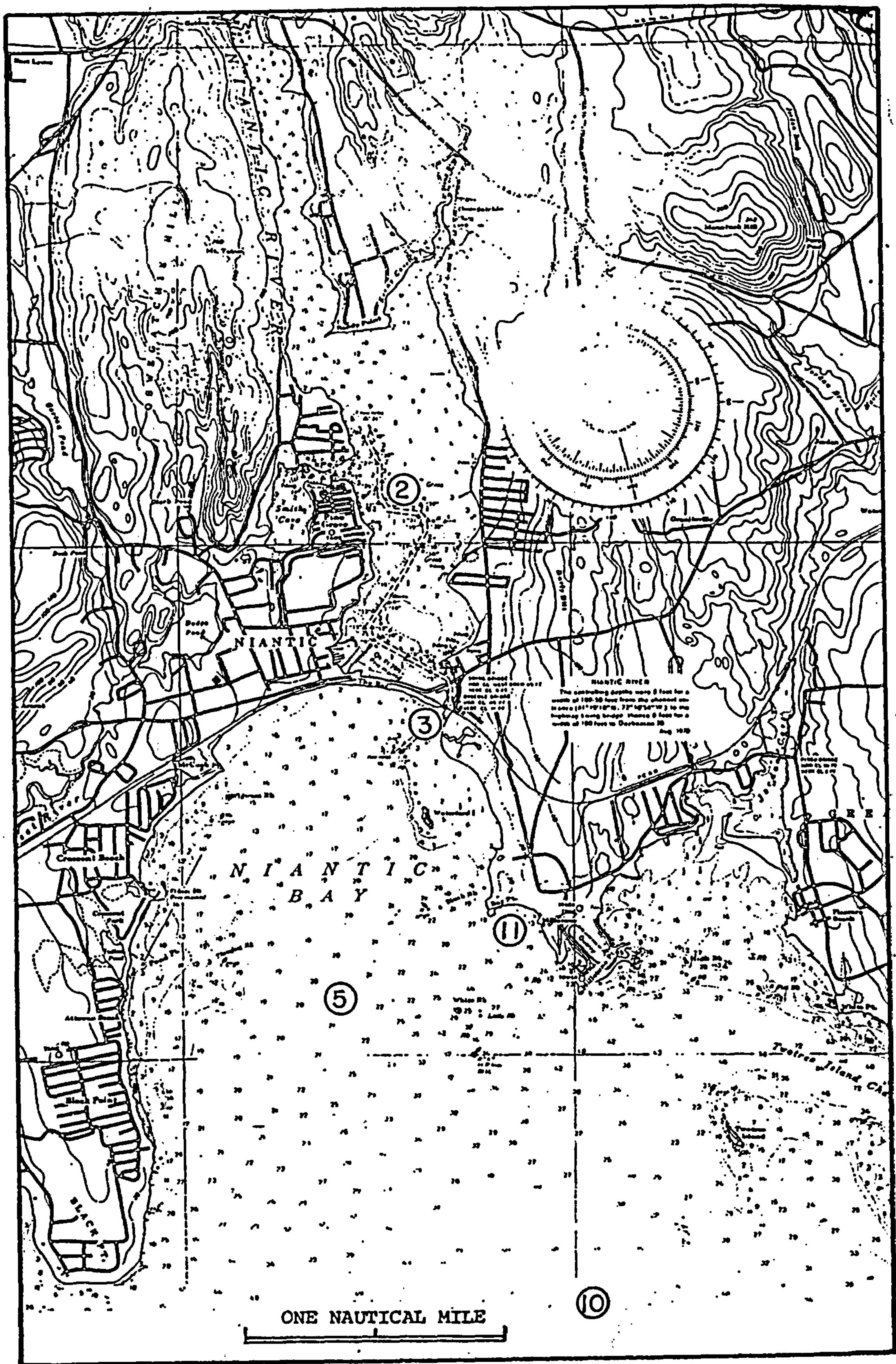


Figure 4.11-1. Chart showing location of selected Battelle offshore plankton monitoring stations.

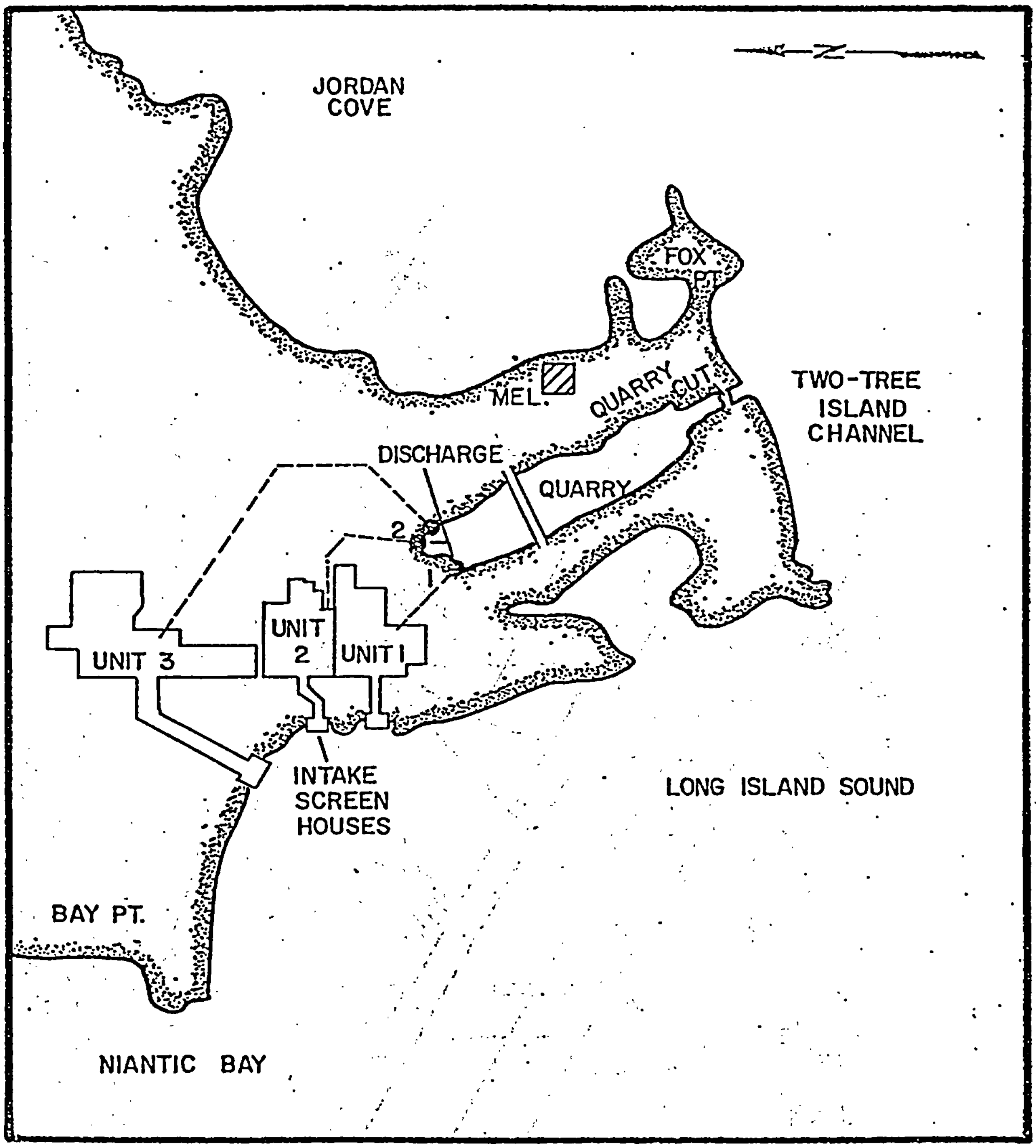


Figure 4.11-2. Location of intake, discharge and quarry cut stations in relation to the Millstone site.

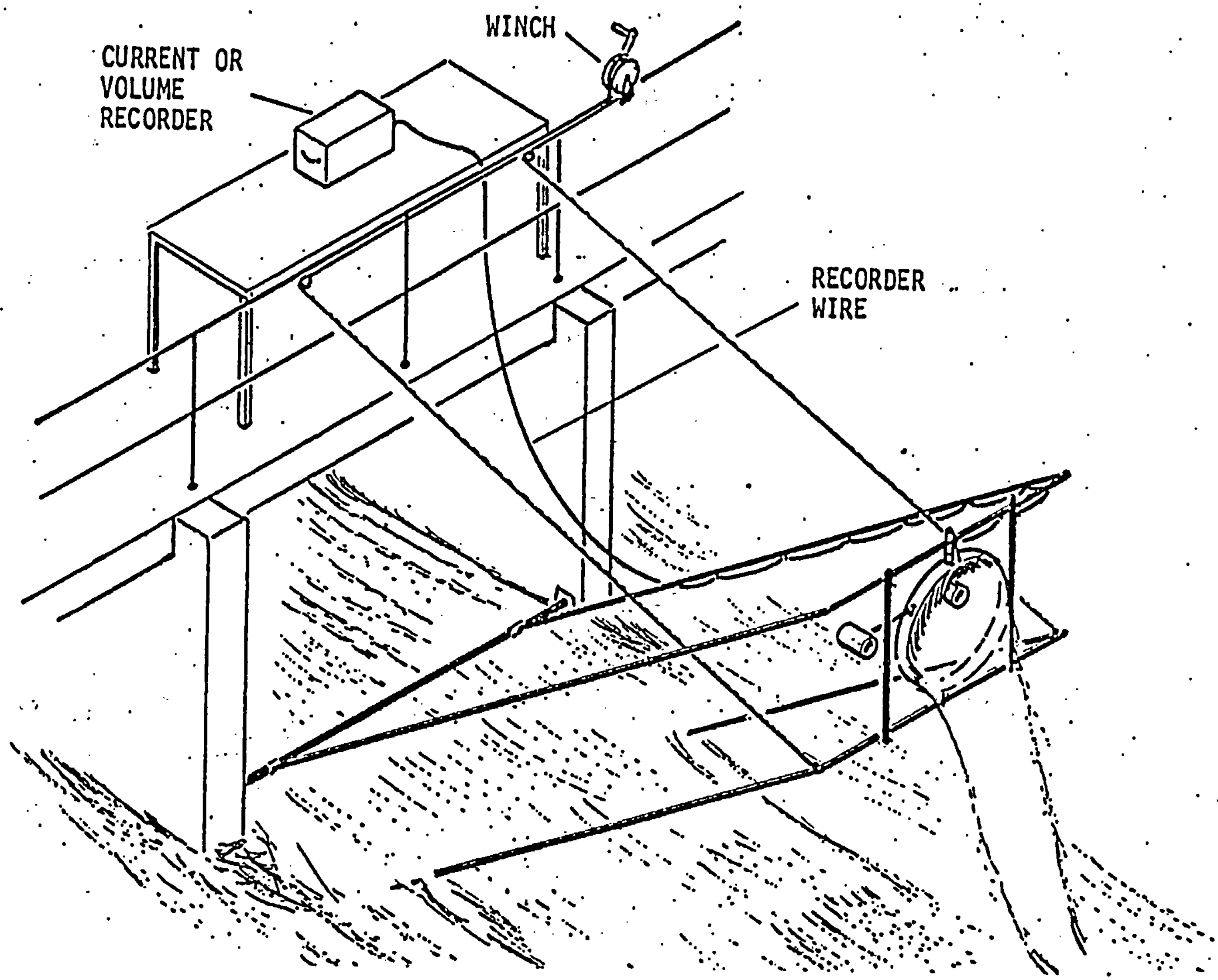


Figure 4.11-3. Discharge Unit 1 gantry system for raising and lowering one-meter diameter plankton net (333μm mesh, 3.6m long) and curr t meter sensors. Unit 2 has a similar gantry.

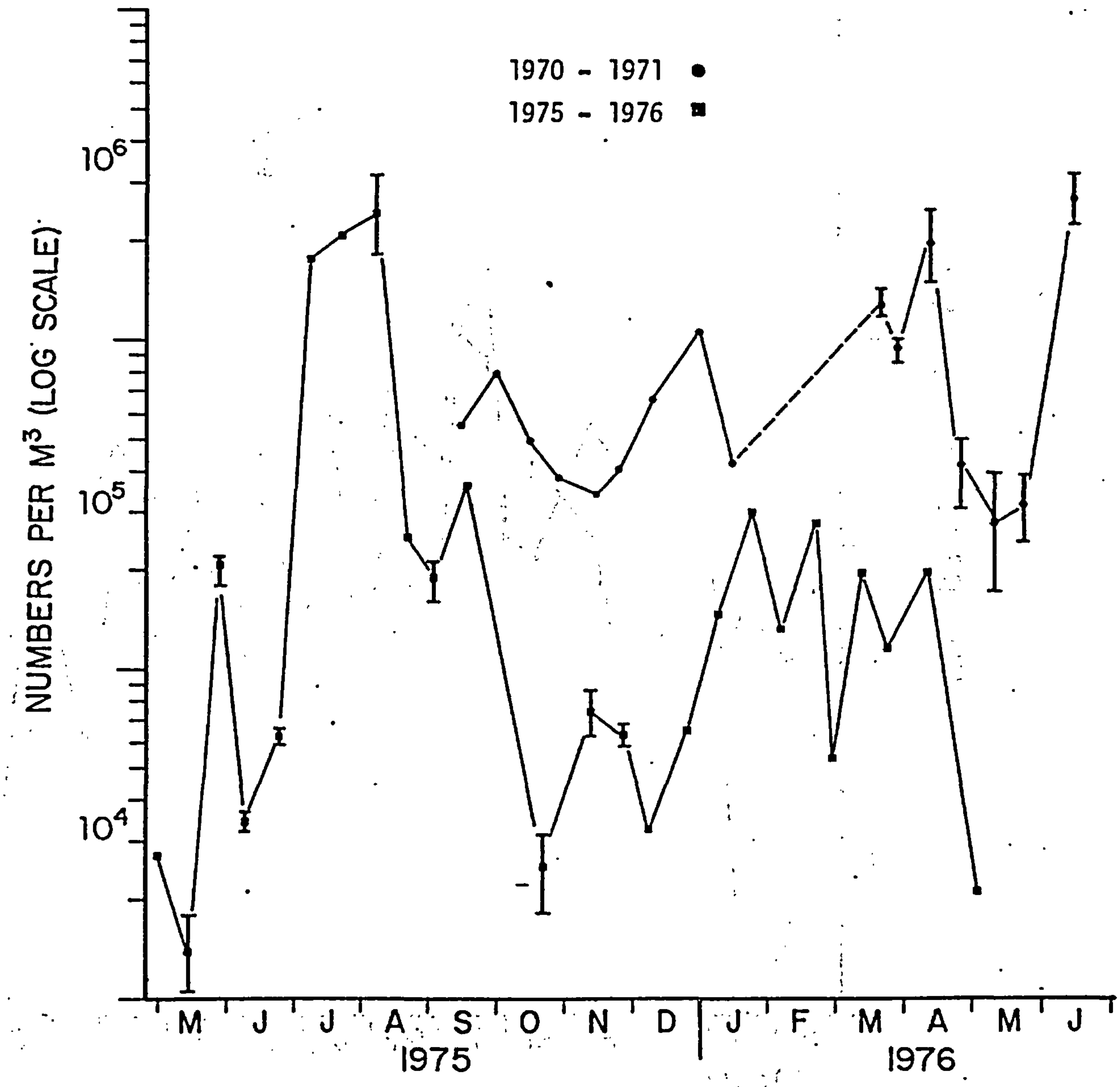


Figure 4.11-4. Abundance of total phytoplankton (cells/liter) at the intake 1970-1971 (WHOI) and at the discharges 1975-1976 (NAI).

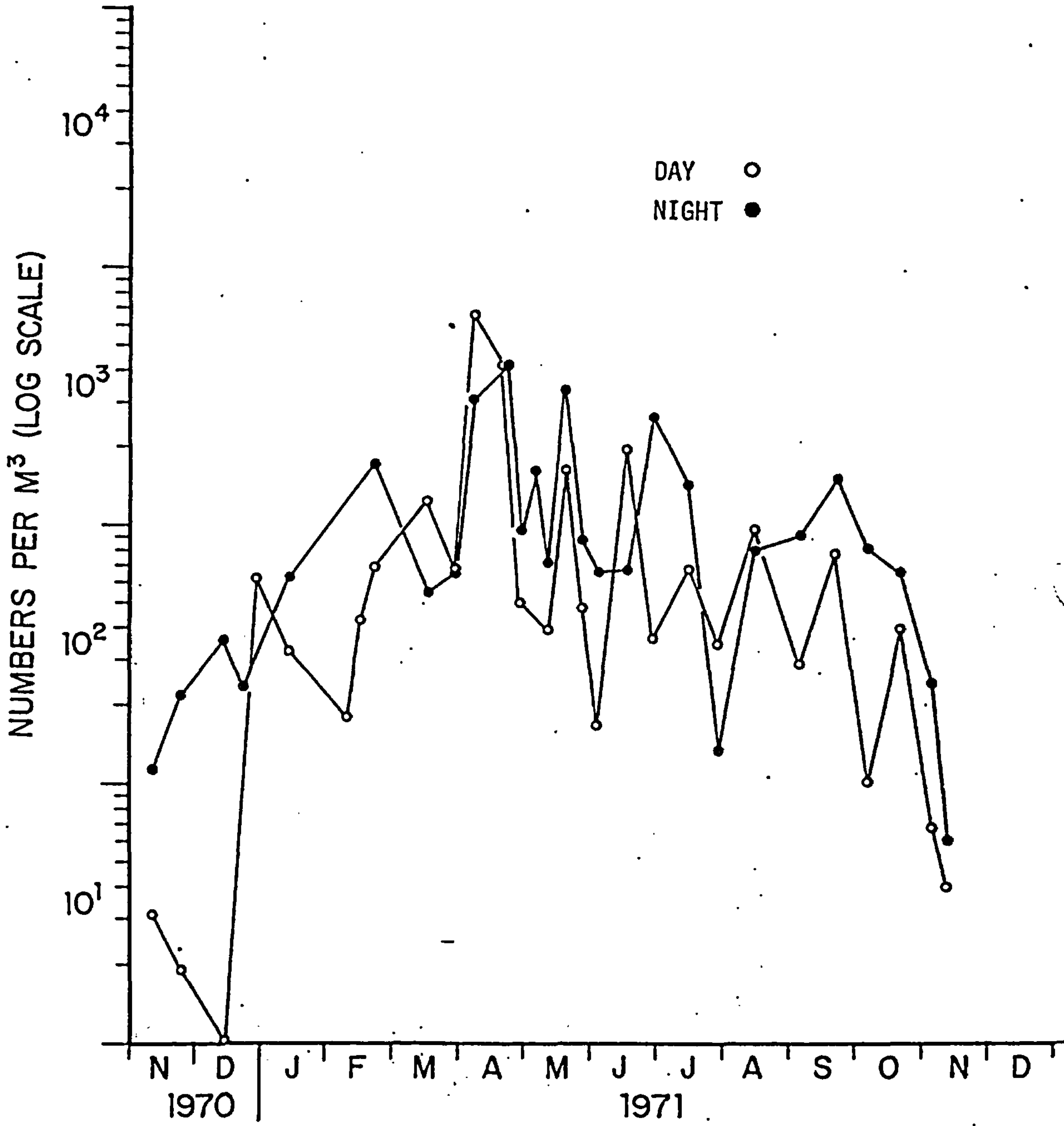


Figure 4.11-5. Day and night abundance of total zooplankton at the intake in 1971.

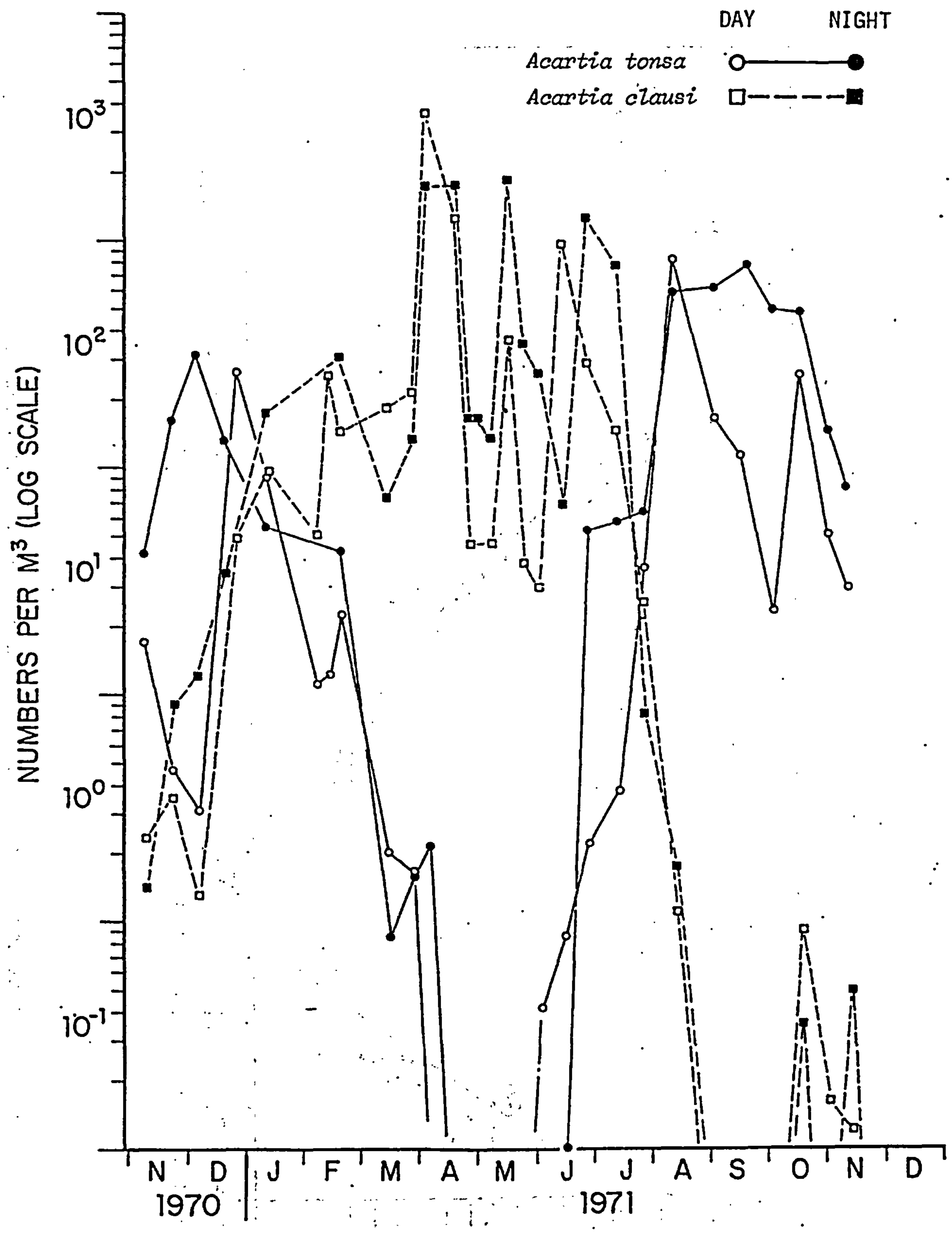


Figure 4.11-6. Day and night abundance per m^3 of *Acartia tonsa* and *A. clausi* at the intake in 1971.

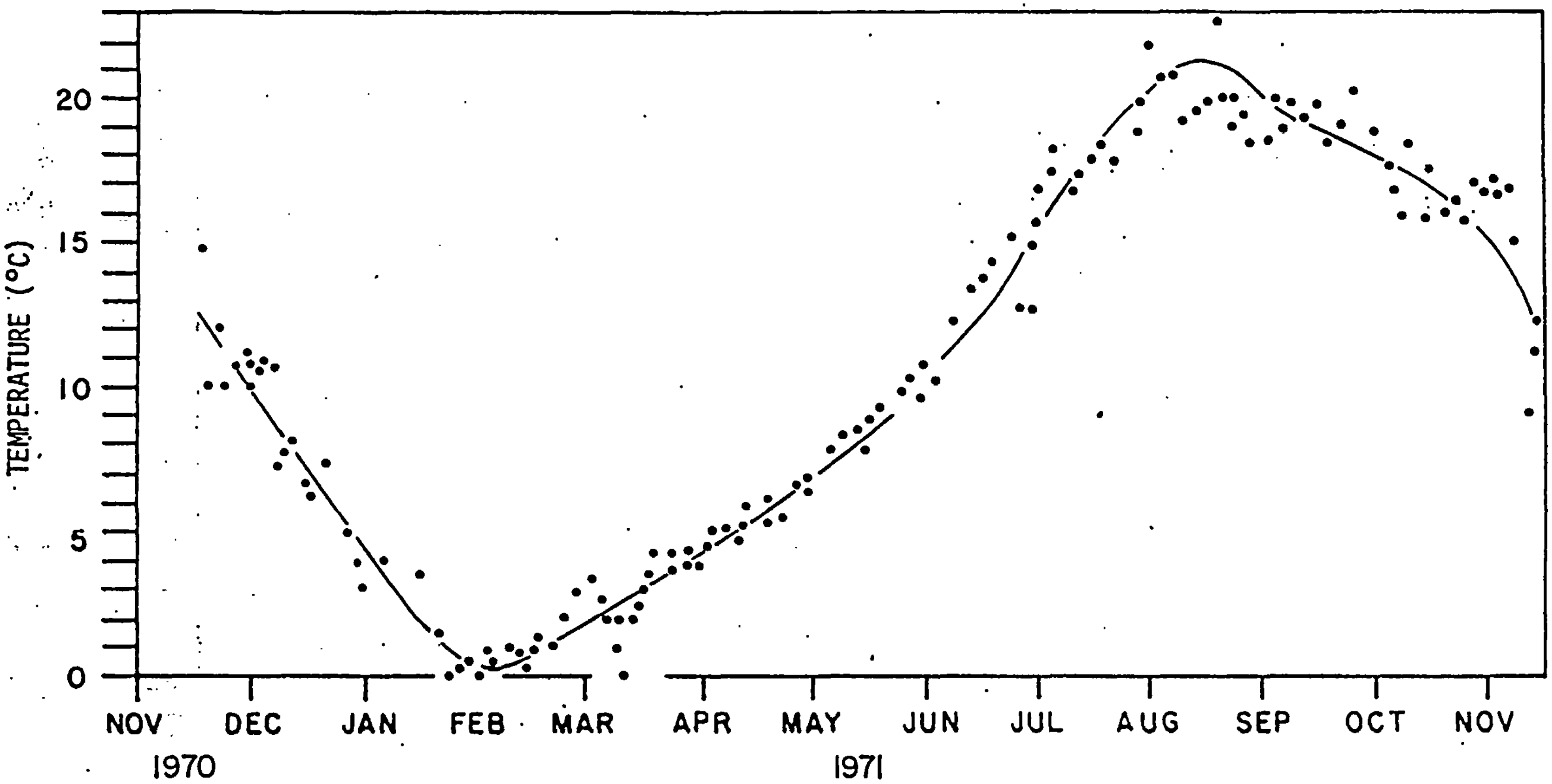


Figure 4.11-7. Ambient temperature (°C) for surface water at Unit 1 intake for November 1970 to November 1971.

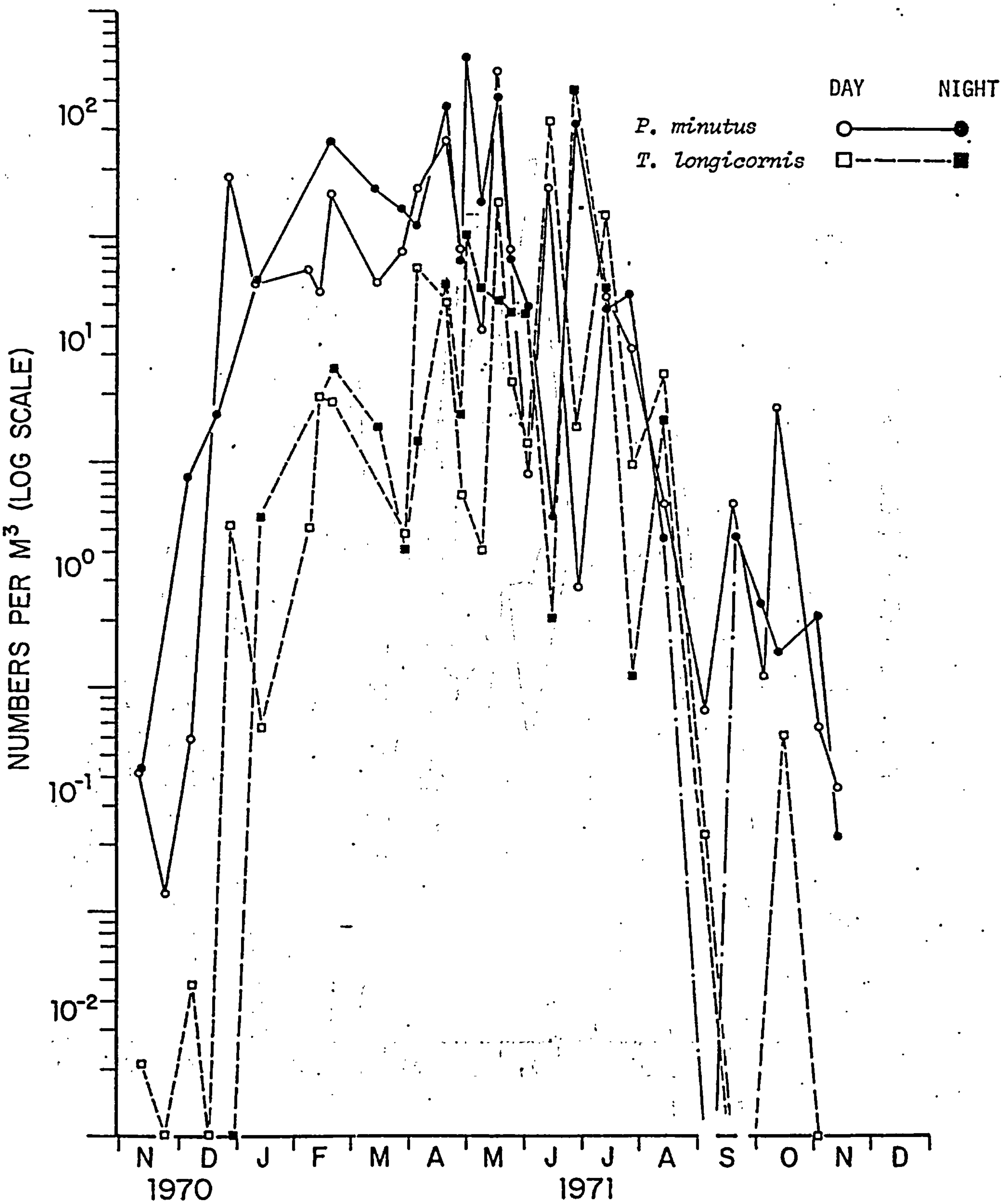


Figure 4.11-8. Day and night abundance per m^3 of *Pseudocalanus minutus* and *Temora longicornis* at the intake in 1971.

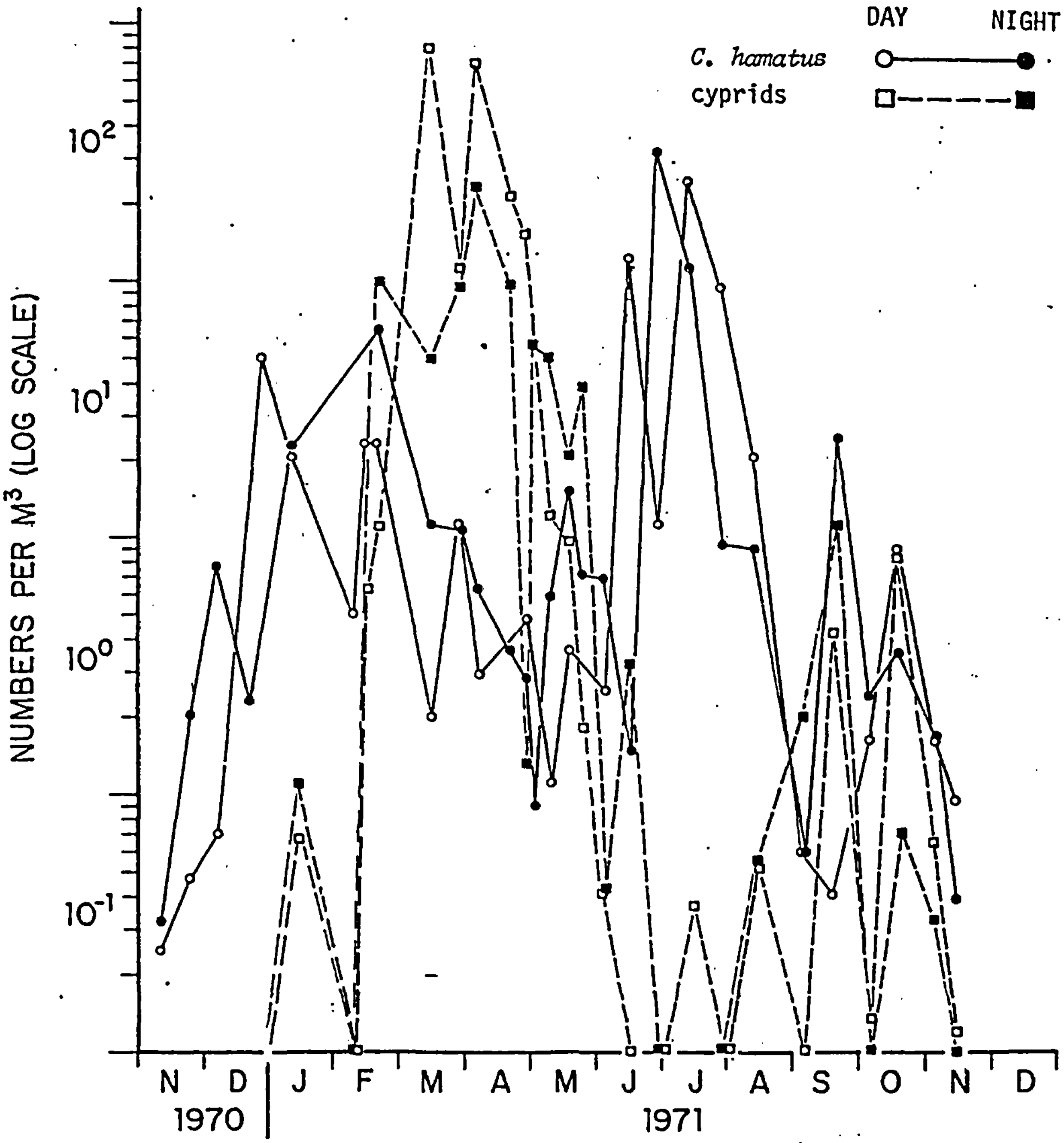


Figure 4.11-9. Day and night abundance per m^3 of *Centropages hamatus* and cirripede cyprids at the intake in 1971.

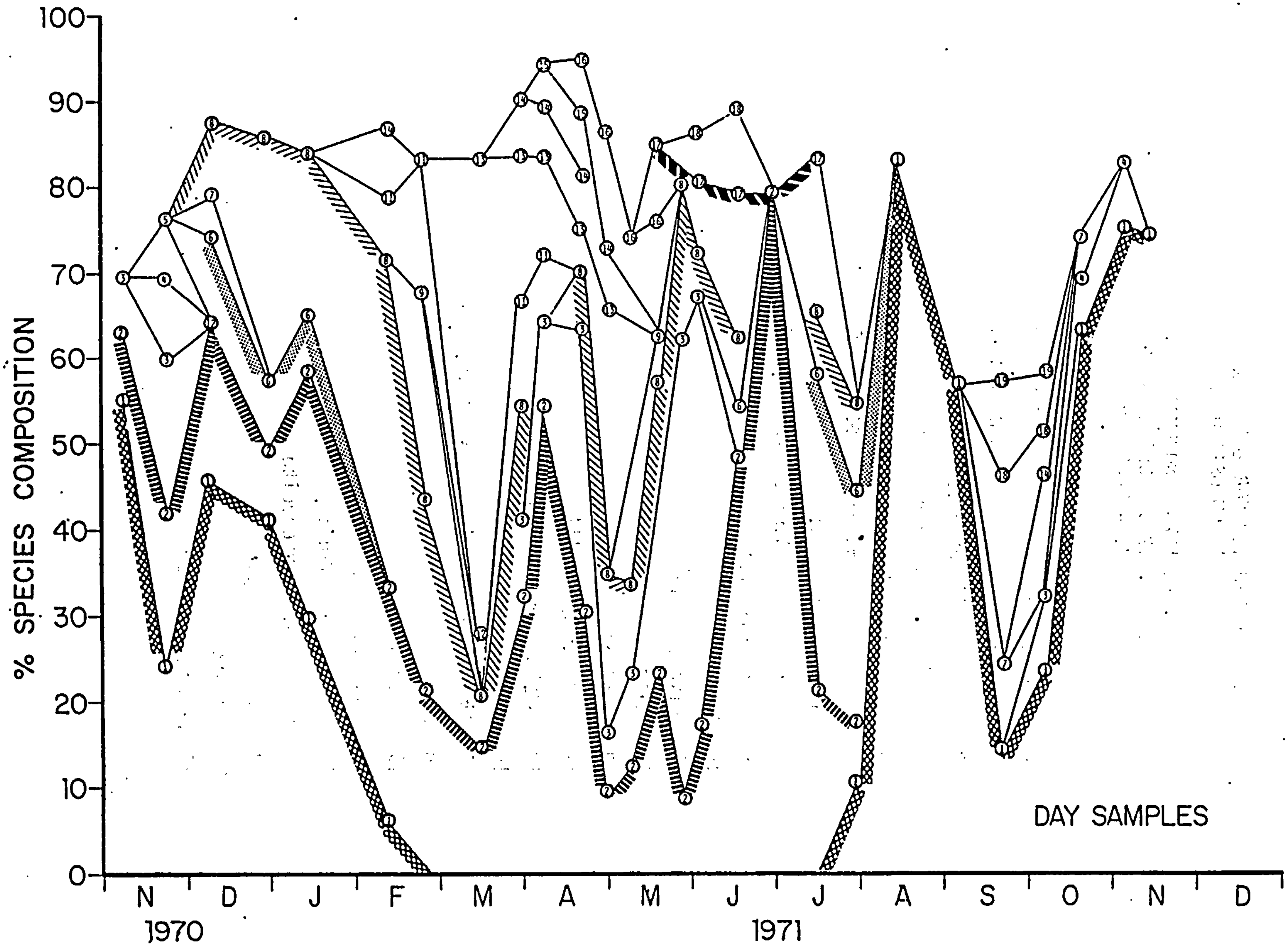


Figure 4.11-10. Percent species composition for day 333 μm zooplankton at the intake, November 1970 to November 1971. Species dominance by date is proportional to vertical width of geometric figure enclosed under numbered lines. See key for species designations.

NUMBER CONVENTION FOR ZOOPLANKTON GRAPH,
PERCENT COMPOSITION FOR

NOVEMBER 1970 - NOVEMBER 1971
NOVEMBER 1973 - DECEMBER 1974
JANUARY - DECEMBER 1975

1 *Acartia tonsa*
2 *Acartia clausi*
3 *Littorina littorea* eggs
4 *Pseudodiaptomus coronatus*
5 Harpacticoida
6 *Centropages hamatus*
7 *Paracalanus parvus*
8 *Pseudocalanus minutus*
9 Copepod nauplii
10 Void number
11 Polychaete larvae
12 Veliger larvae
13 Cirripedia cypris
14 Cirripedia nauplii
15 *Eurytemora americana*
16 *Rathkea octopunctata*
17 *Temora longicornis*
18 *Evadne* spp.
19 *Podon* spp.
20 Polychaeta
21 *Eurytemora affinis*
22 *Acartia* spp. copepodite
23 Gastropod eggs
24 Amphipoda
25 Brachyuran zoea

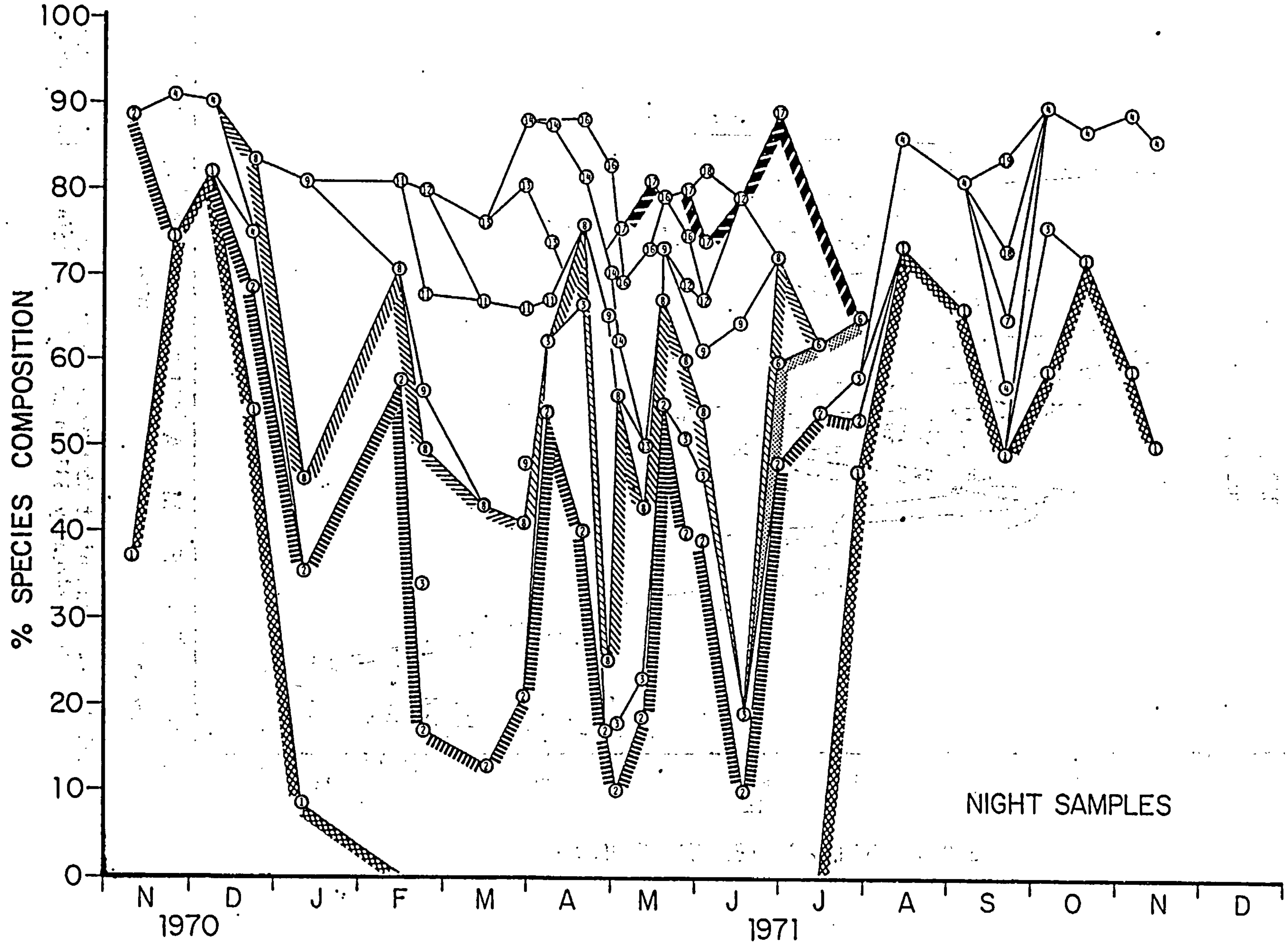


Figure 4.11-11. Percent species composition for night 333 μm zooplankton samples at the intake, November 1970 to November 1971. See key for species designations.

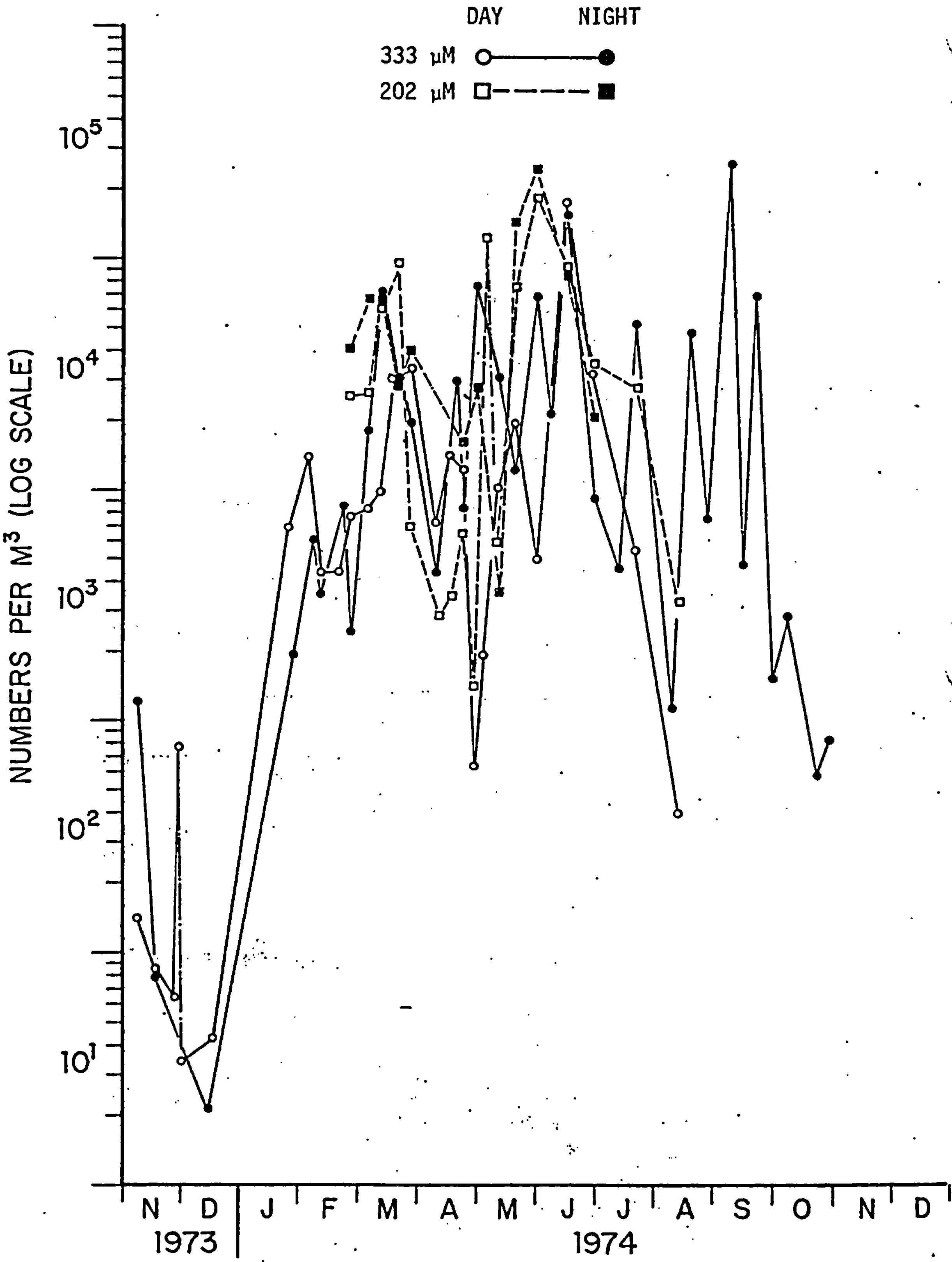


Figure 4.11-12. Day and night abundance per m^3 of total zooplankton in 1974 taken by 333 μm or by 202 μm nets at the intake.

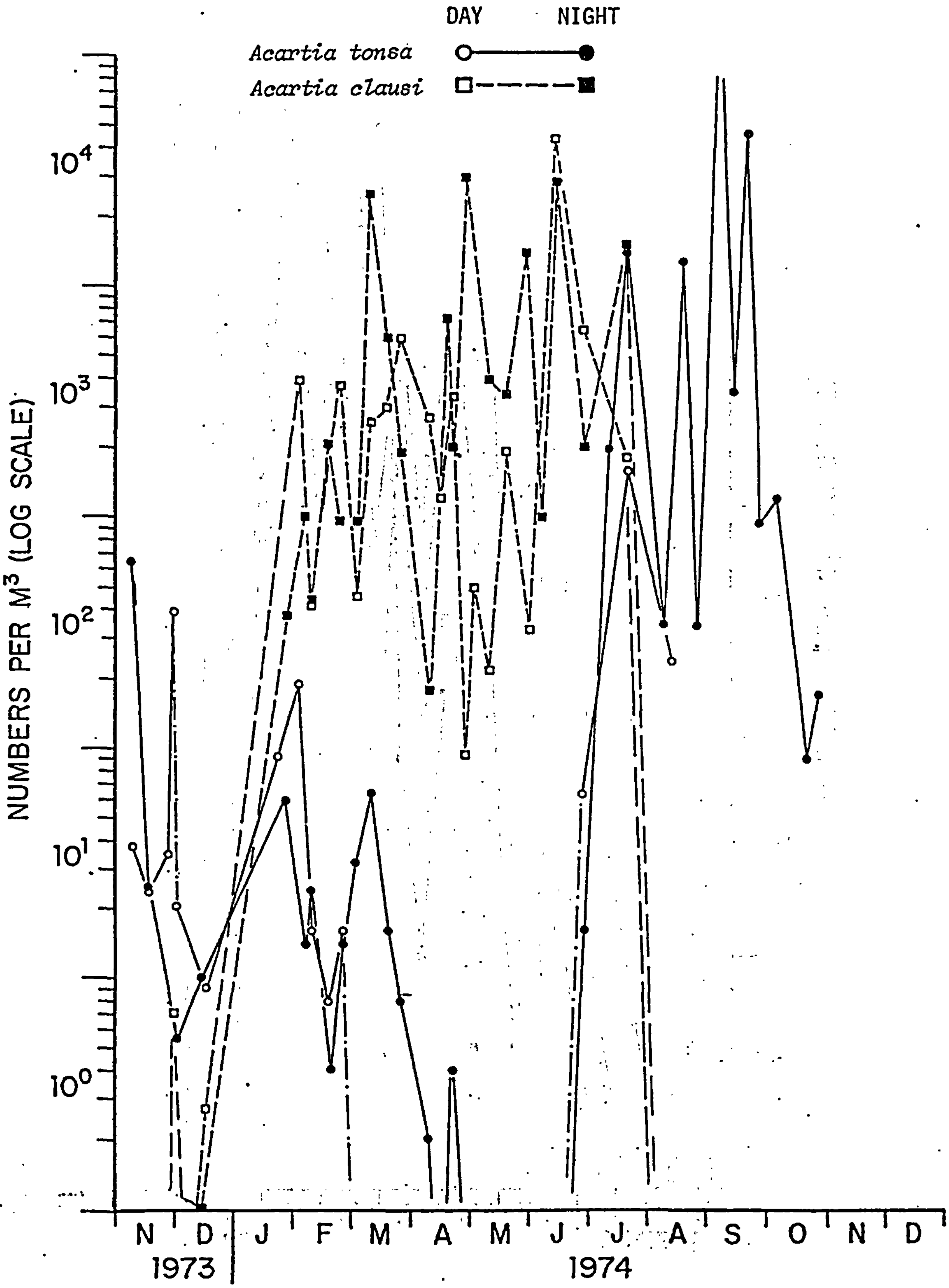


Figure 4.11-13. Day and night abundance per m^3 of *Acartia tonsa* and *A. clausi* at the intake in 1974.

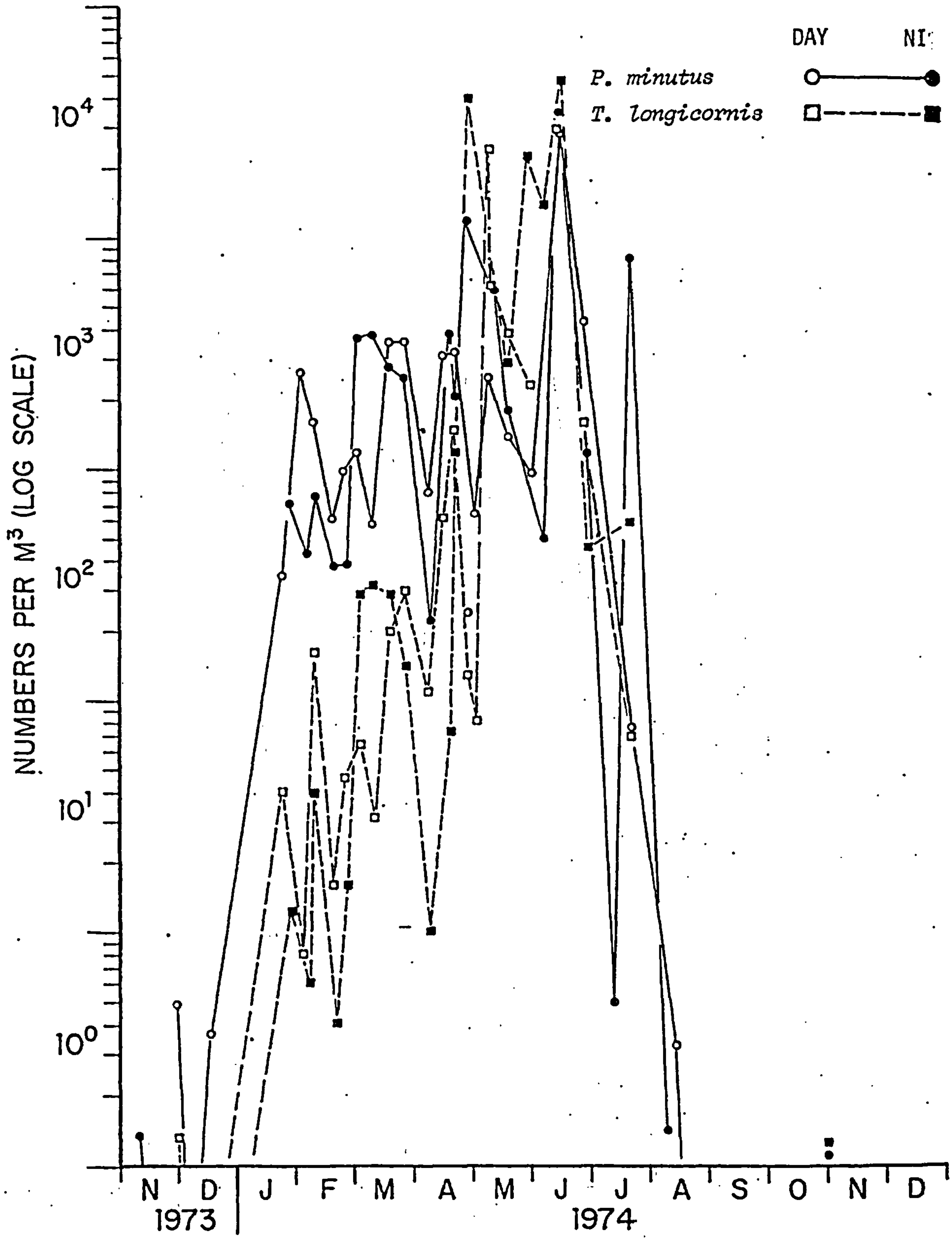


Figure 4.11-14. Day and night abundance per m^3 of *Pseudocalanus minutus* and *Temora longicornis* at the intake in 1974.

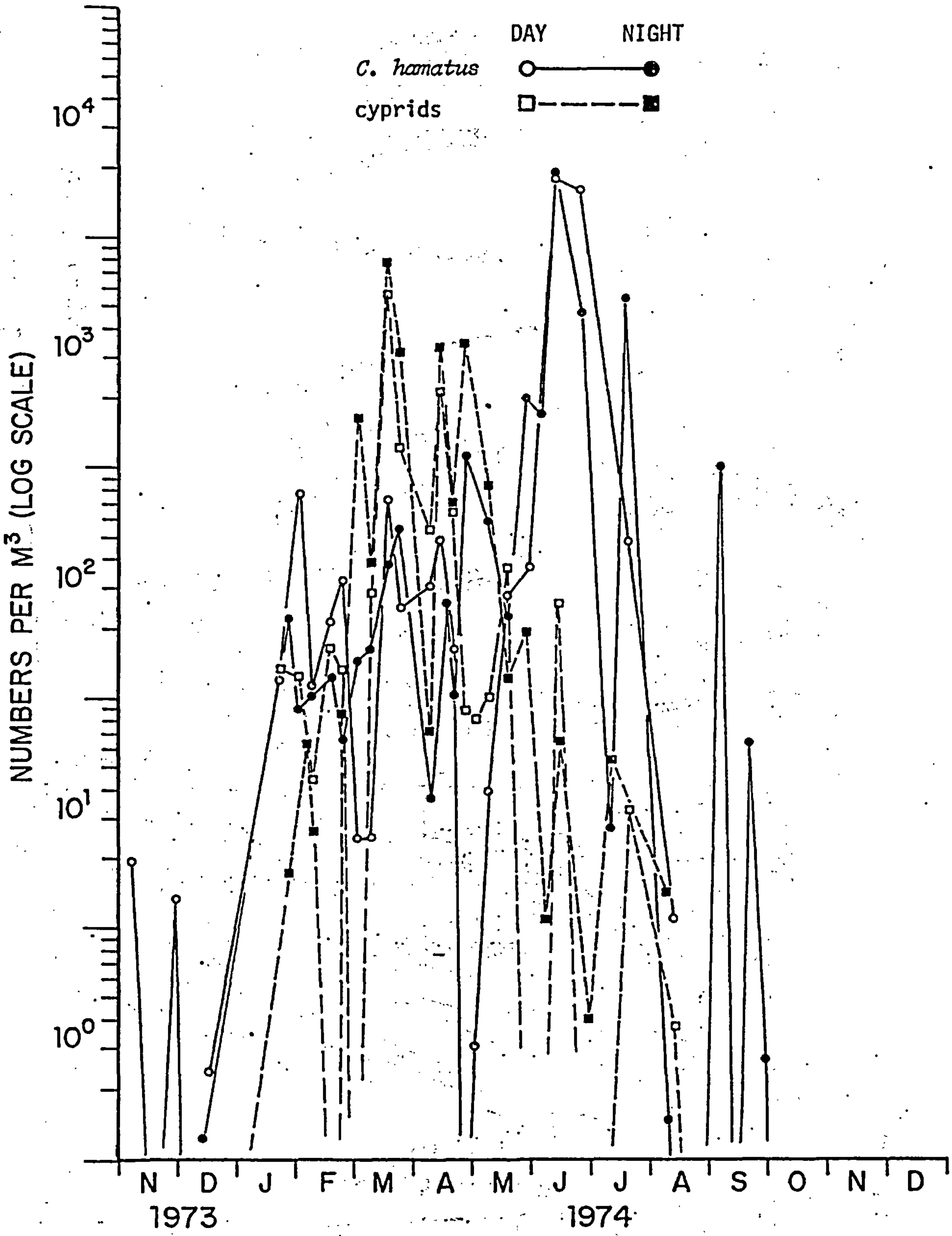


Figure 4.11-15. Day and night abundance per m^3 of *Centropages hamatus* and cirripede cyprids at the intake in 1974.

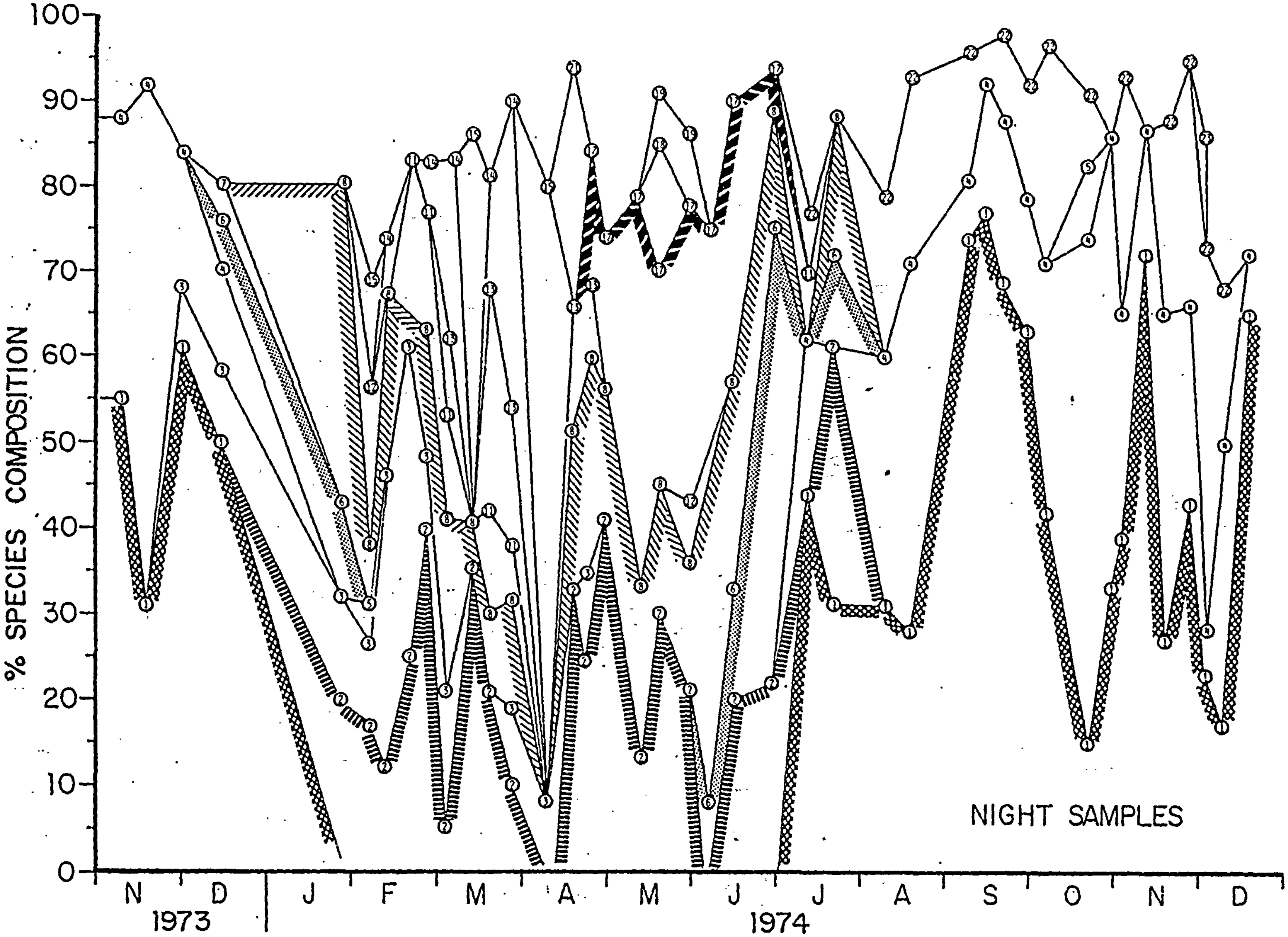


Figure 4.11-16. Percent species composition fo ight 333 µm zooplankton samples at the intake, November 1973 to November 1974. key for disignated species.

NUMBER CONVENTION FOR ZOOPLANKTON GRAPH,
PERCENT COMPOSITION FOR

NOVEMBER 1970 - NOVEMBER 1971
NOVEMBER 1973 - DECEMBER 1974
JANUARY - DECEMBER 1975

1 *Acartia tonsa*
2 *Acartia clausi*
3 *Littorina littorea* eggs
4 *Pseudodiaptomus coronatus*
5 Harpacticoida
6 *Centropages hamatus*
7 *Paracalanus parvus*
8 *Pseudocalanus minutus*
9 Copepod nauplii
10 Void number
11 Polychaete larvae
12 Veliger larvae
13 Cirripedia cypris
14 Cirripedia nauplii
15 *Eurytemora americana*
16 *Rathkea octopunctata*
17 *Temora longicornis*
18 *Evadne* spp.
19 *Podon* spp.
20 Polychaeta
21 *Eurytemora affinis*
22 *Acartia* spp. copepodite
23 Gastropod eggs
24 Amphipoda
25 Brachyuran zoea

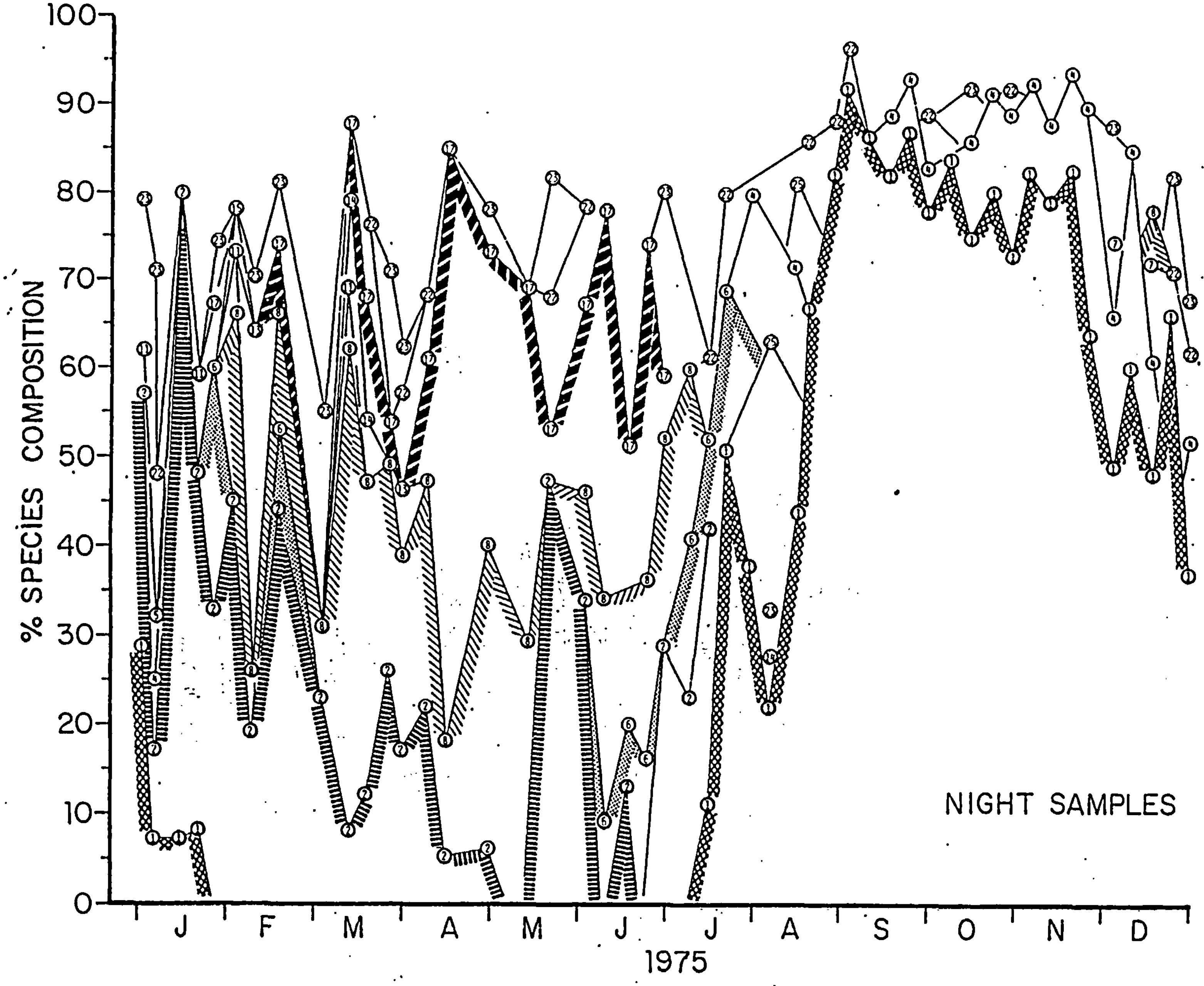


Figure 4.11-17. Percent species composition during 1975 for night 333 µm zooplankton samples at the intake or discharge (after [illegible]ly 1975).

NUMBER CONVENTION FOR ZOOPLANKTON GRAPH,
PERCENT COMPOSITION FOR

NOVEMBER 1970 - NOVEMBER 1971
NOVEMBER 1973 - DECEMBER 1974
JANUARY - DECEMBER 1975

1 *Acartia tonsa*
2 *Acartia clausi*
3 *Littorina littorea* eggs
4 *Pseudodiaptomus coronatus*
5 Harpacticoida
6 *Centropages hamatus*
7 *Paracalanus parvus*
8 *Pseudocalanus minutus*
9 Copepod nauplii
10 Void number
11 Polychaete larvae
12 Veliger larvae
13 Cirripedia cypris
14 Cirripedia nauplii
15 *Eurytemora americana*
16 *Rathkea octopunctata*
17 *Temora longicornis*
18 *Evadne* spp.
19 *Podon* spp.
20 Polychaeta
21 *Eurytemora affinis*
22 *Acartia* spp. copepodite
23 Gastropod eggs
24 Amphipoda
25 Brachyuran zoea

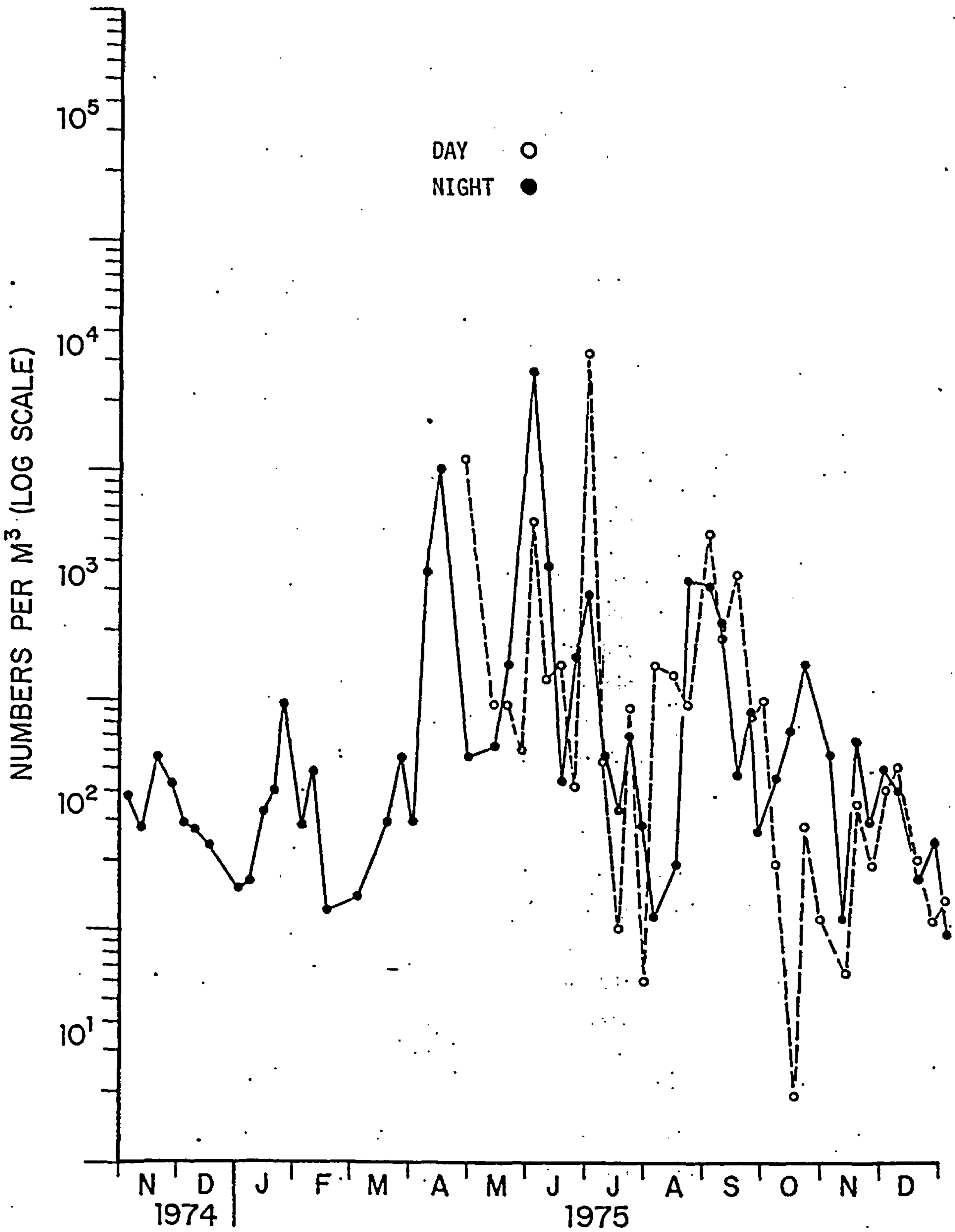


Figure 4.11-18. Total zooplankton per m^3 found in 1975 day or night samples. Samples were collected at intake through June and at the discharge after July.

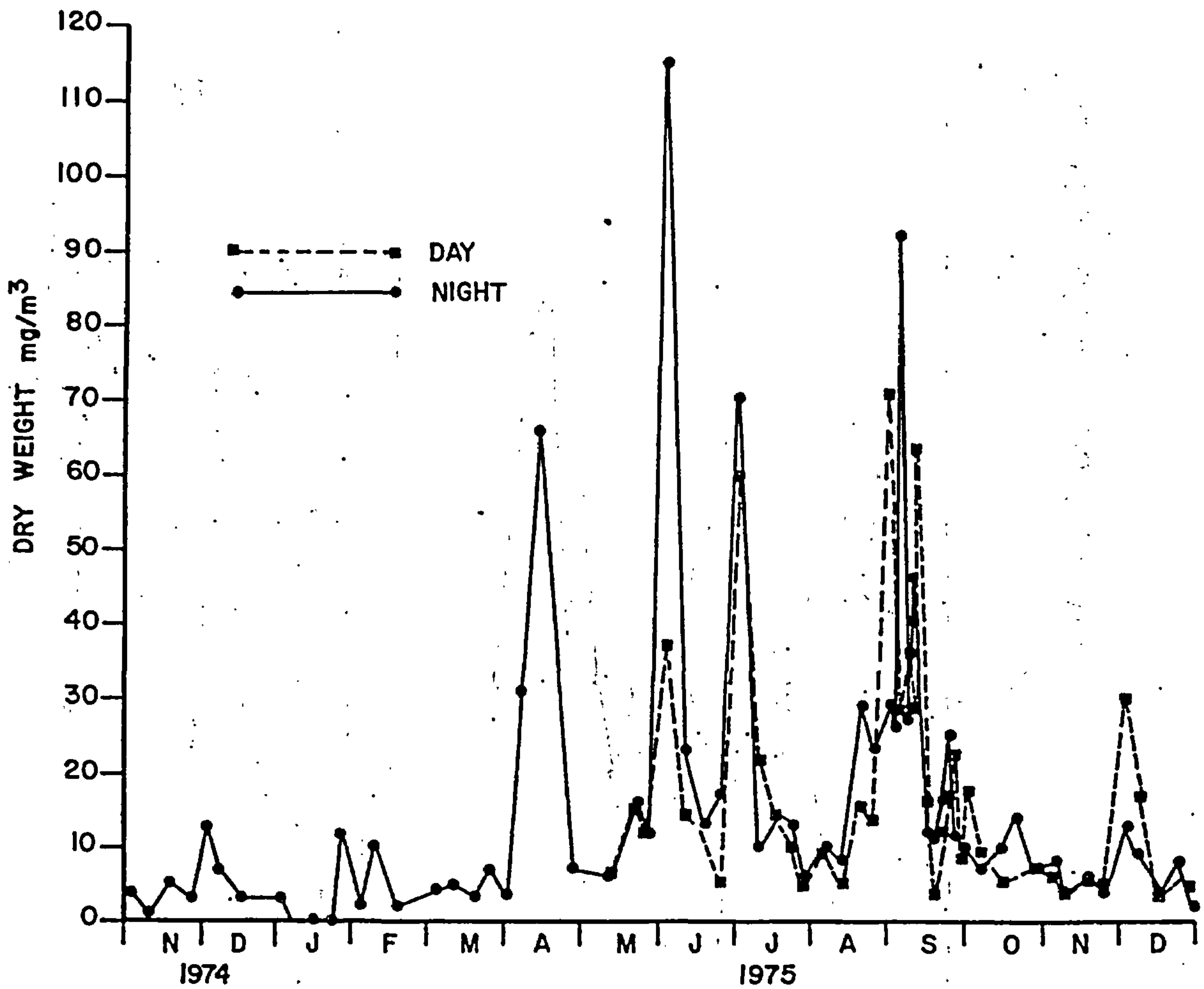


Figure 4.11-19. Dry weight biomass (mg/m^3) of total zooplankton from day and night 333 μm samples.

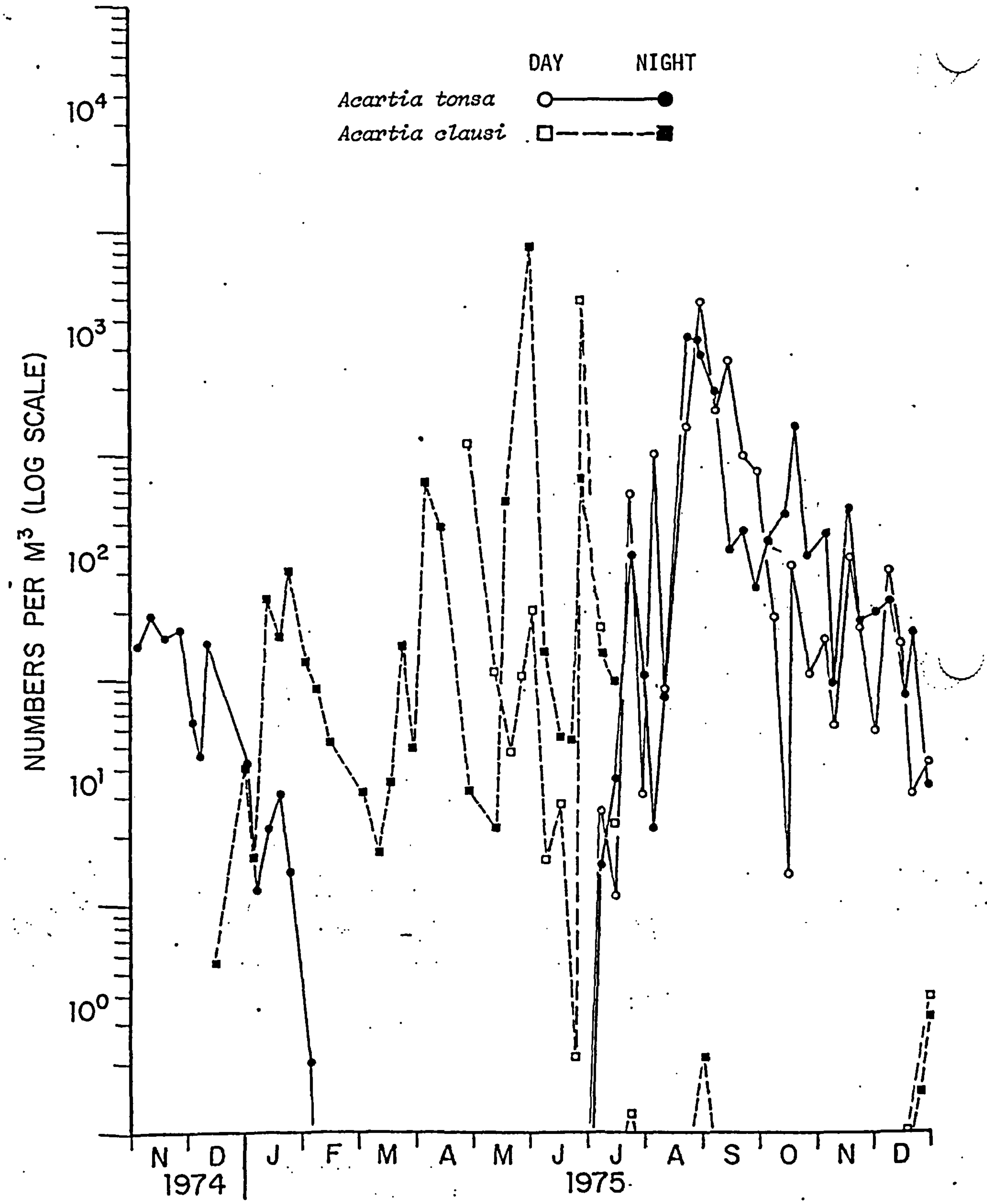


Figure 4.11-20. Day and night abundance per m^3 of *Acartia tonsa* and *A. clausi*.

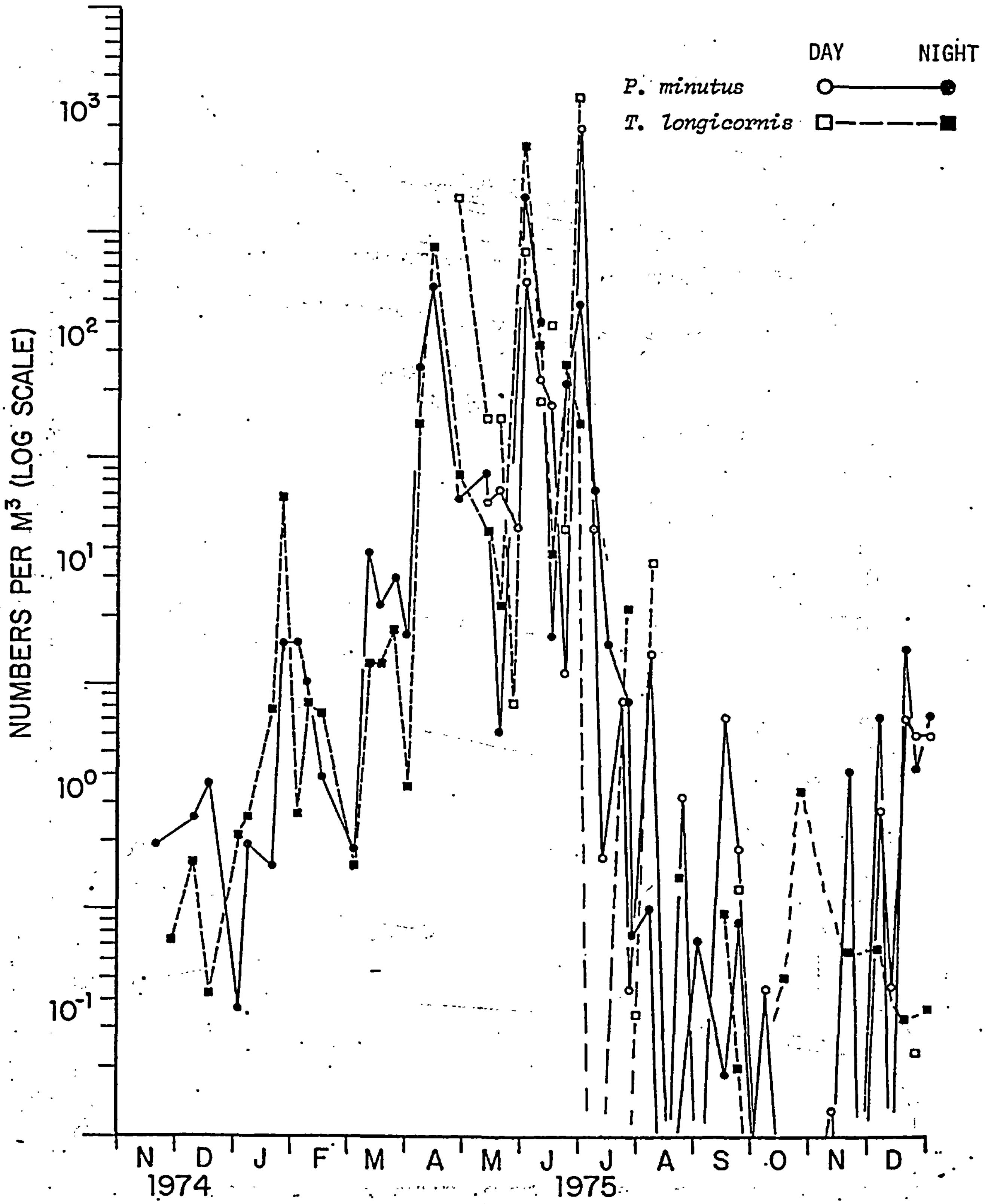


Figure 4.11-21. Abundance per m^3 of *Pseudocalanus minutus* and *Temora longicornis*.

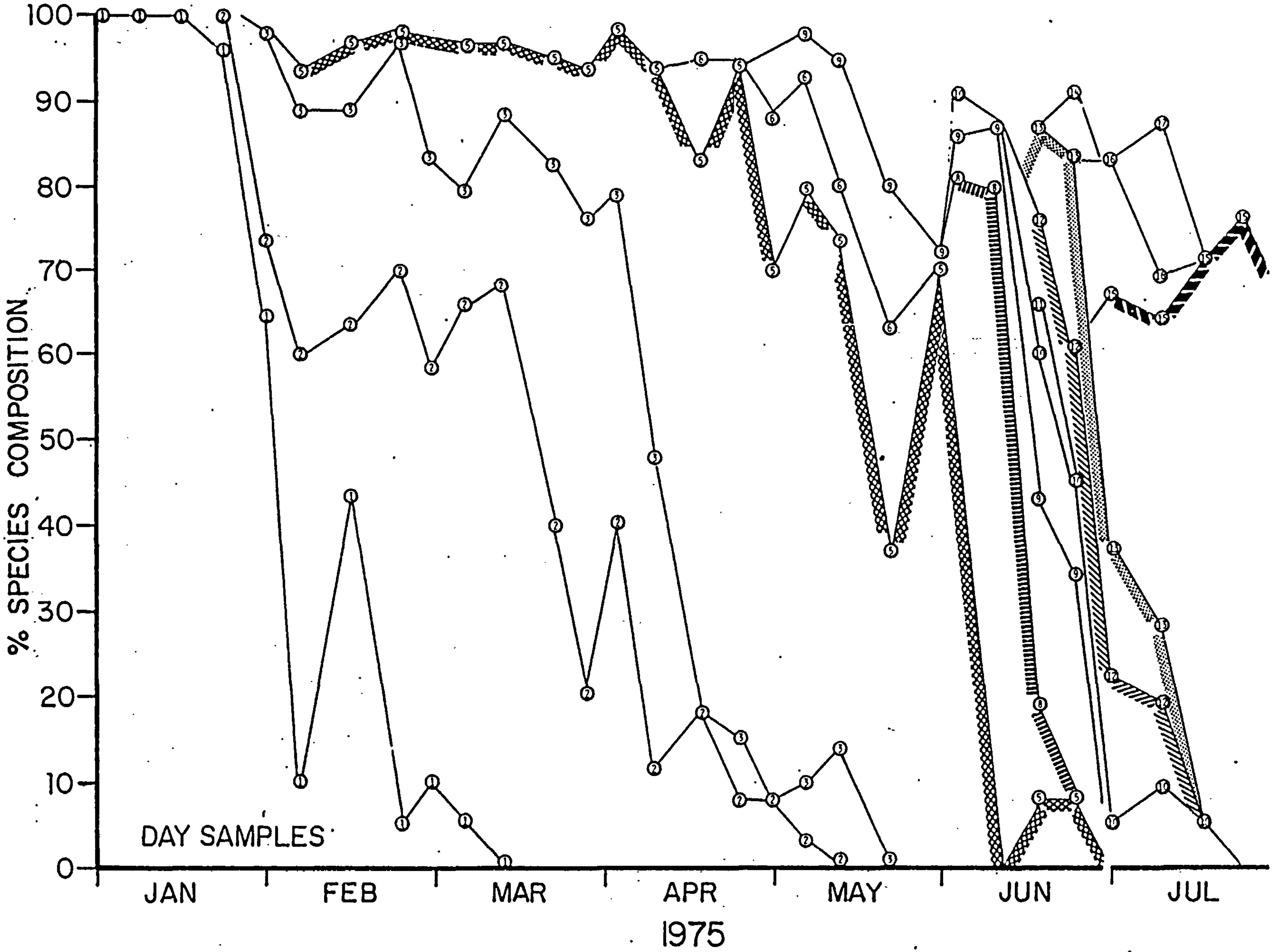


Figure 4.11-22. Percent species composition f[illegible] common fish larvae from day discharge samples in [illegible]'5. See key for numbered species [illegible] ollowing page.

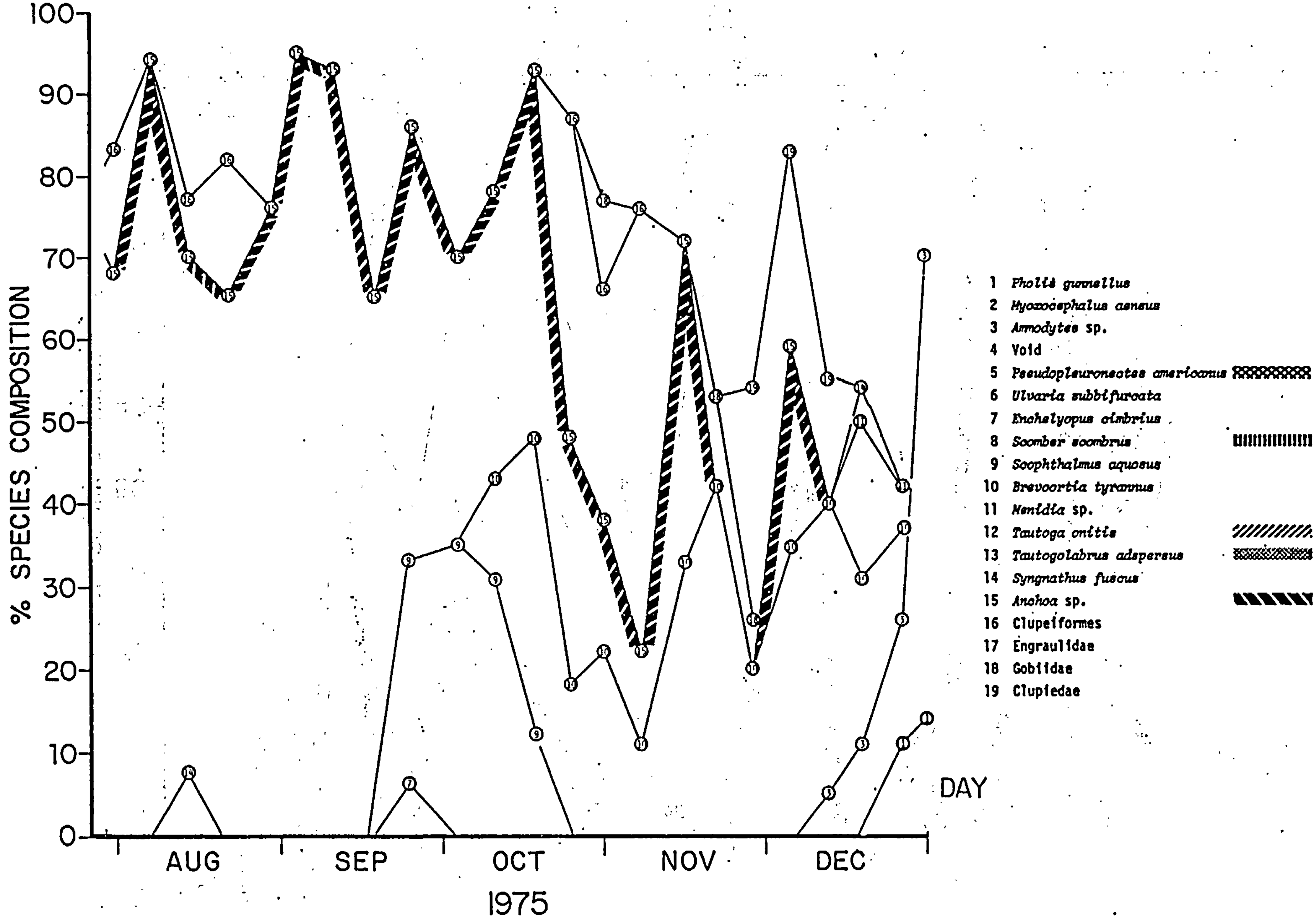


Figure 4.11-22. (Continued).

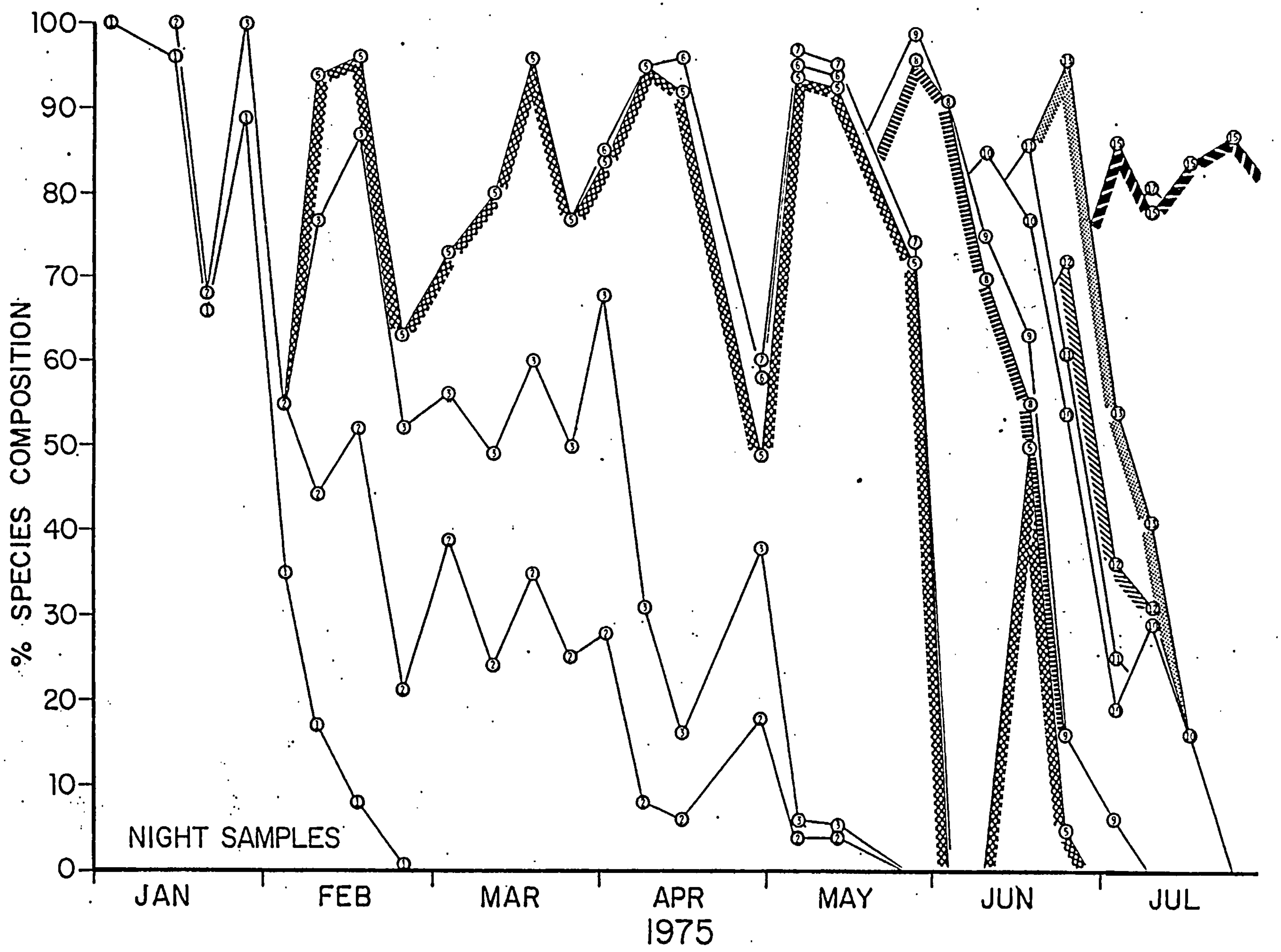


Figure 4.11-23. Percent species composition of mmon fish larvae from night discharge samples in 75. See key for numbered species o llowing page.

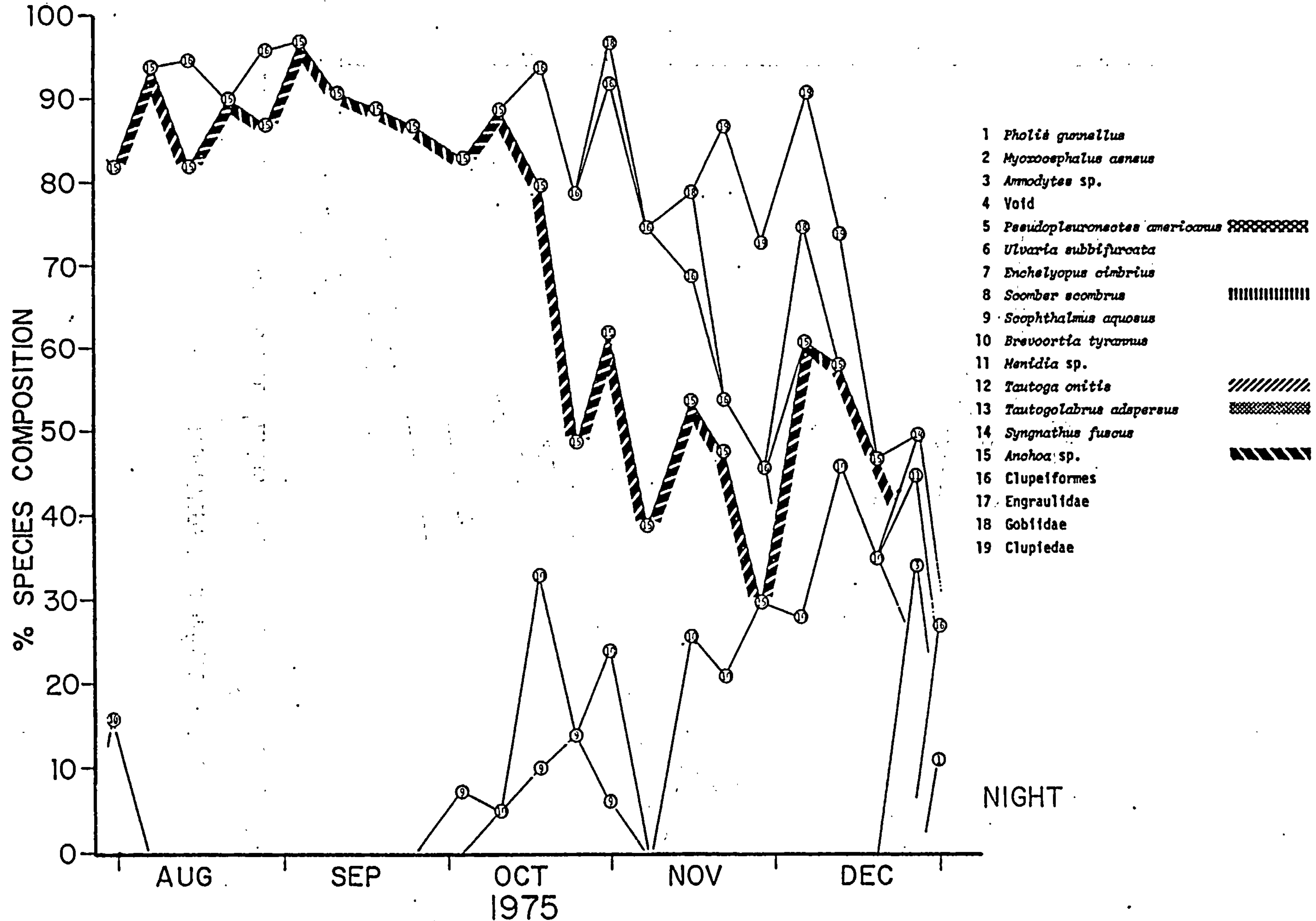


Figure 4.11-23. (Continued).

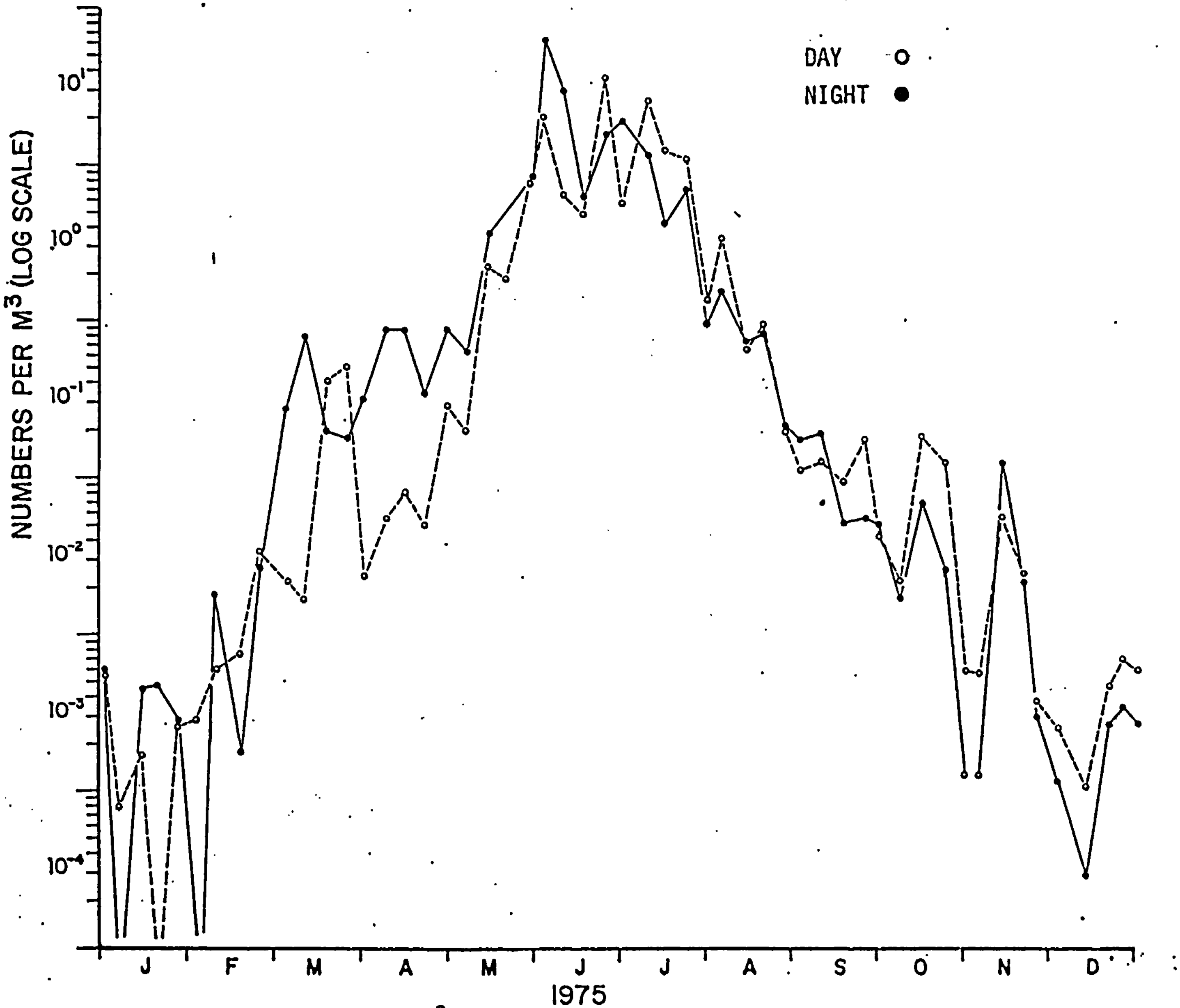


Figure 4.11.24. Total fish eggs per m^3 from 1975 day and night discharge samples. Points are the average of three replicates eac week through June and the weekly averages of ninr samples from July.

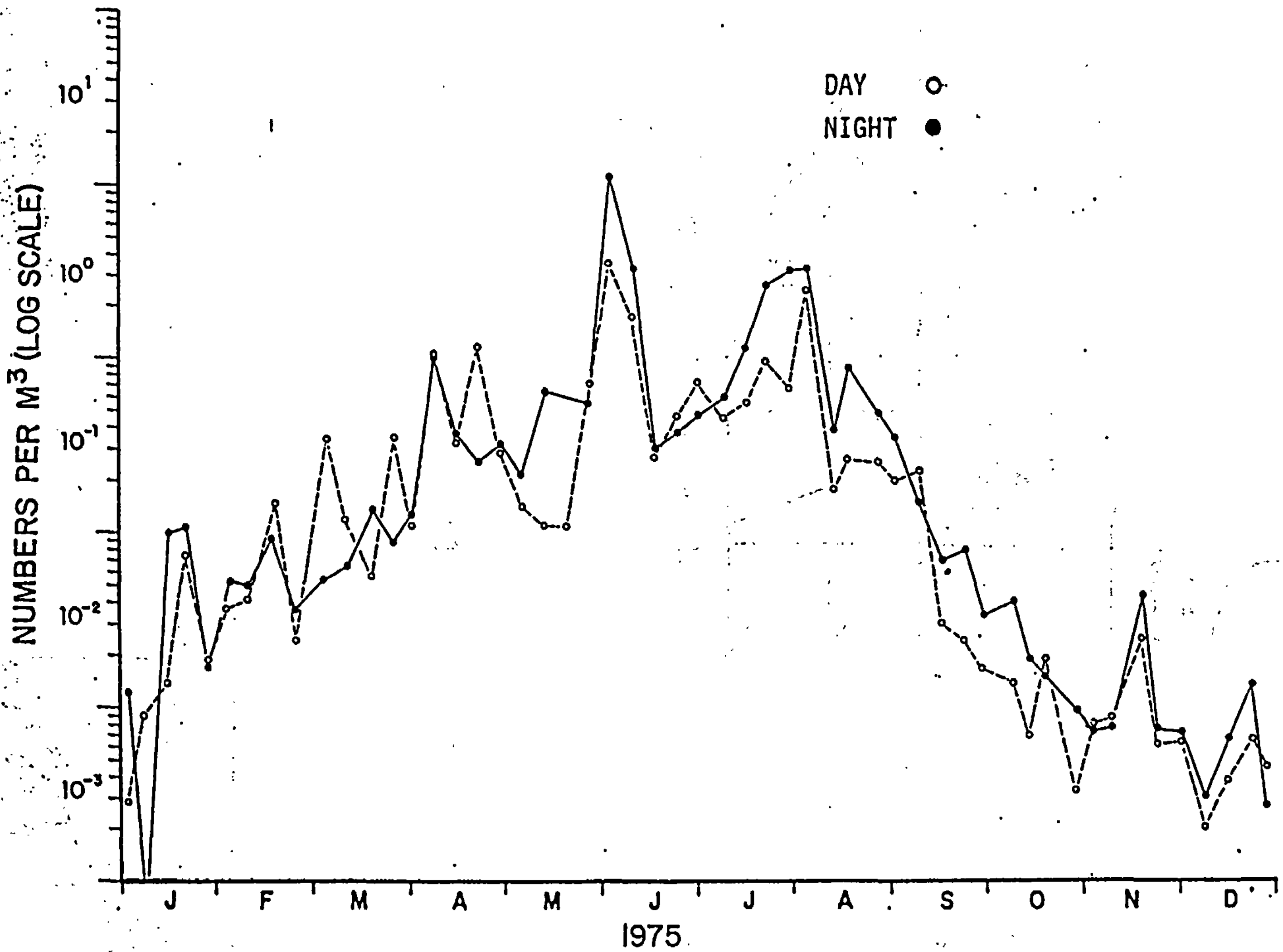


Figure 4.11-25. Total fish larvae per m^3 from 1975 day and night discharge samples. Points are the average of three replicates each week through June and the weekly averages of nine samples from July.

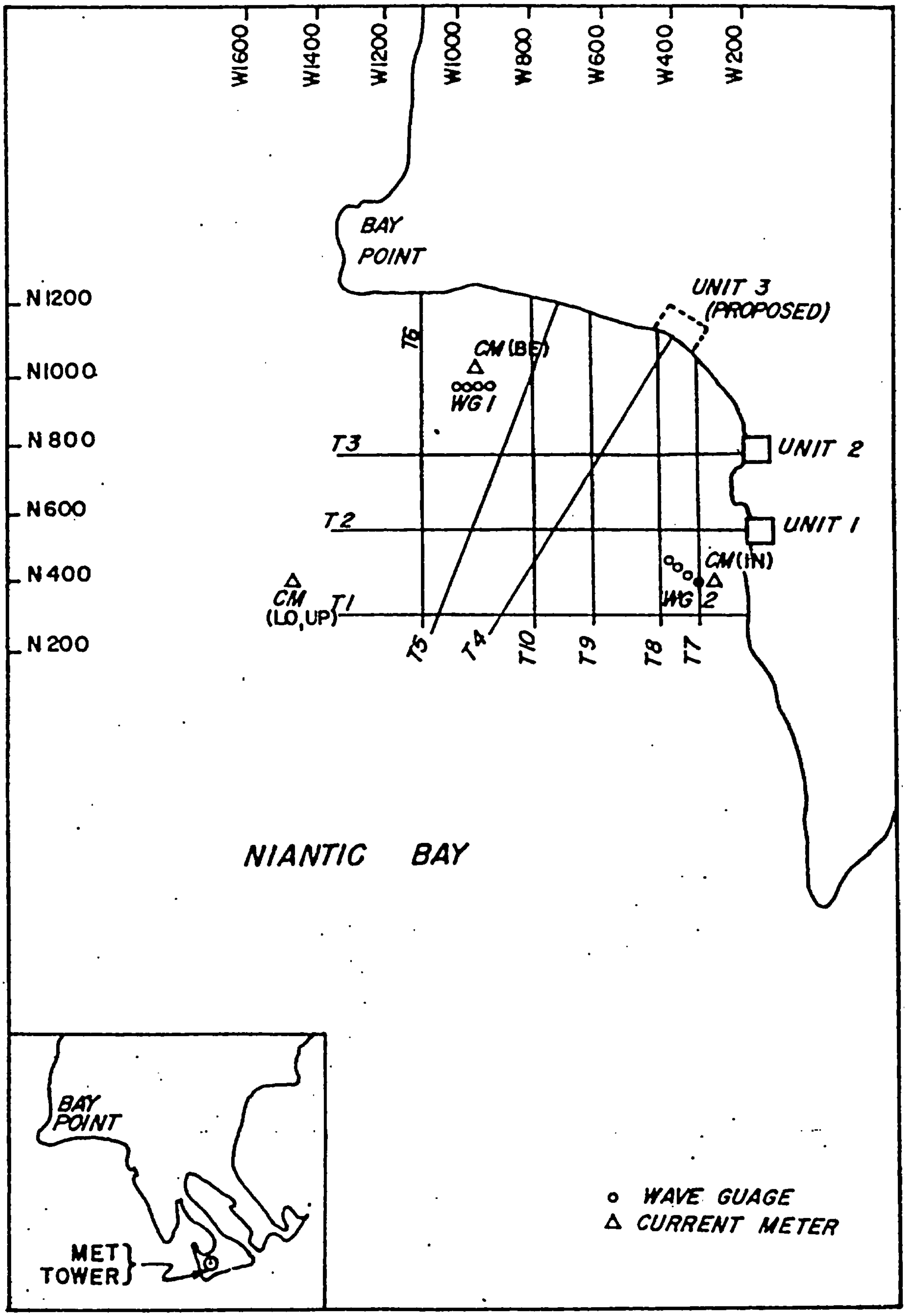
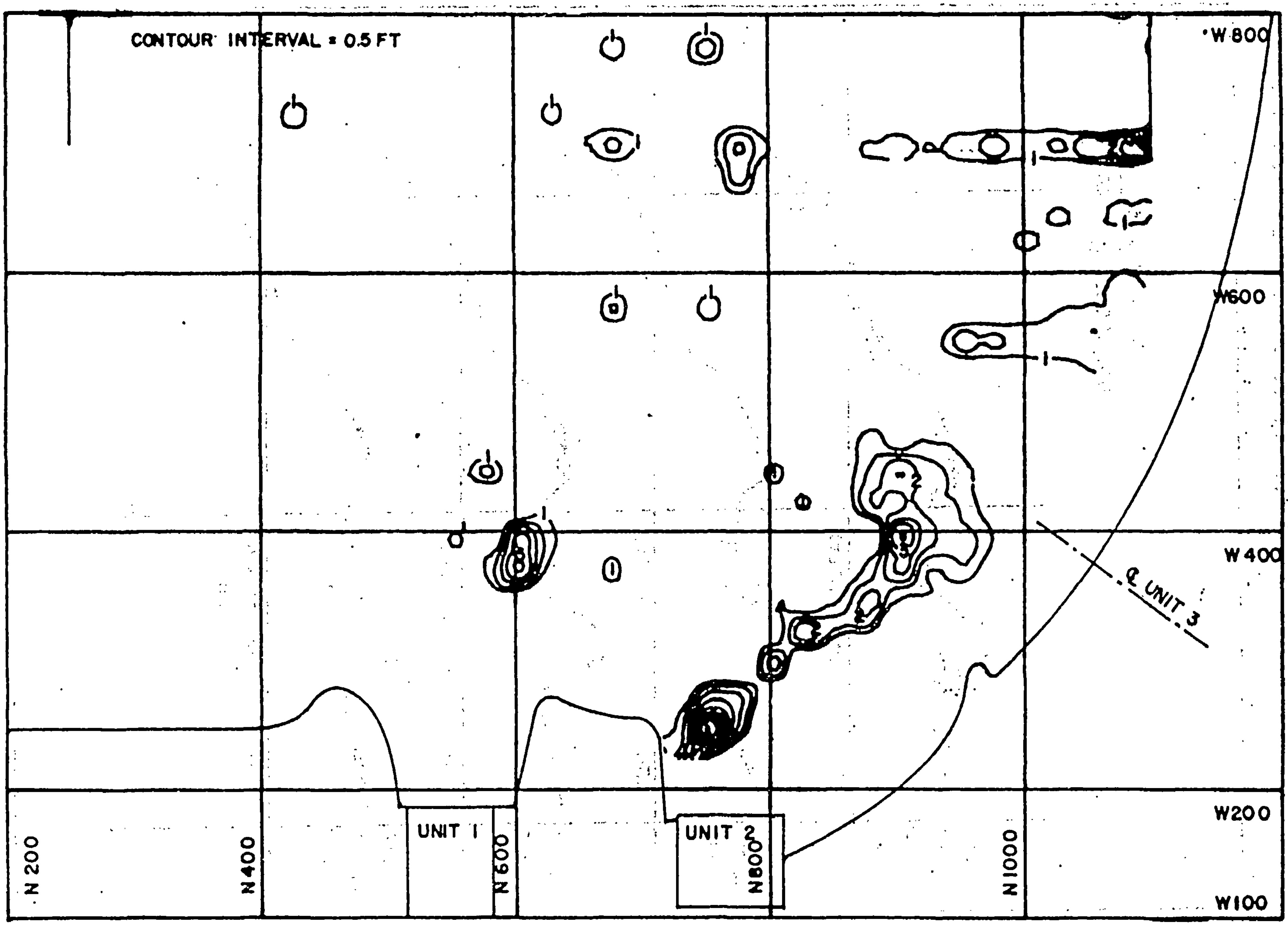


FIG. 4.12-1 LOCATION OF TRANSECTS, CURRENT METERS, WAVE GUAGES & METEOROLOGICAL TOWER

TABLE 4.12-1 Erosion and Deposition Rate (Cu Yd/Month) Computed from Bathymetric Surveys

Difference Between Surveys	Beach Area		Unit 2 Intake Area	
	Erosion	Deposition	Erosion	Deposition
Mar-Apr	67.6	1,322.0	293.4	282.9
Mar-May	12.6	782.2	271.7	298.5
Mar-Jun	4.5	607.7	289.6	67.6
Apr-May	161.1	95.6	297.6	488.7
Apr-Jun	22.0	53.9	224.3	121.8
May-Jun	1.9	123.3	126.9	7.8


CONTOUR INTERVAL = 0.5 FT
W800
W600
W400
W200
W100
N200
N400
N600
N800
N1000
UNIT 1
UNIT 2
℄ UNIT 3

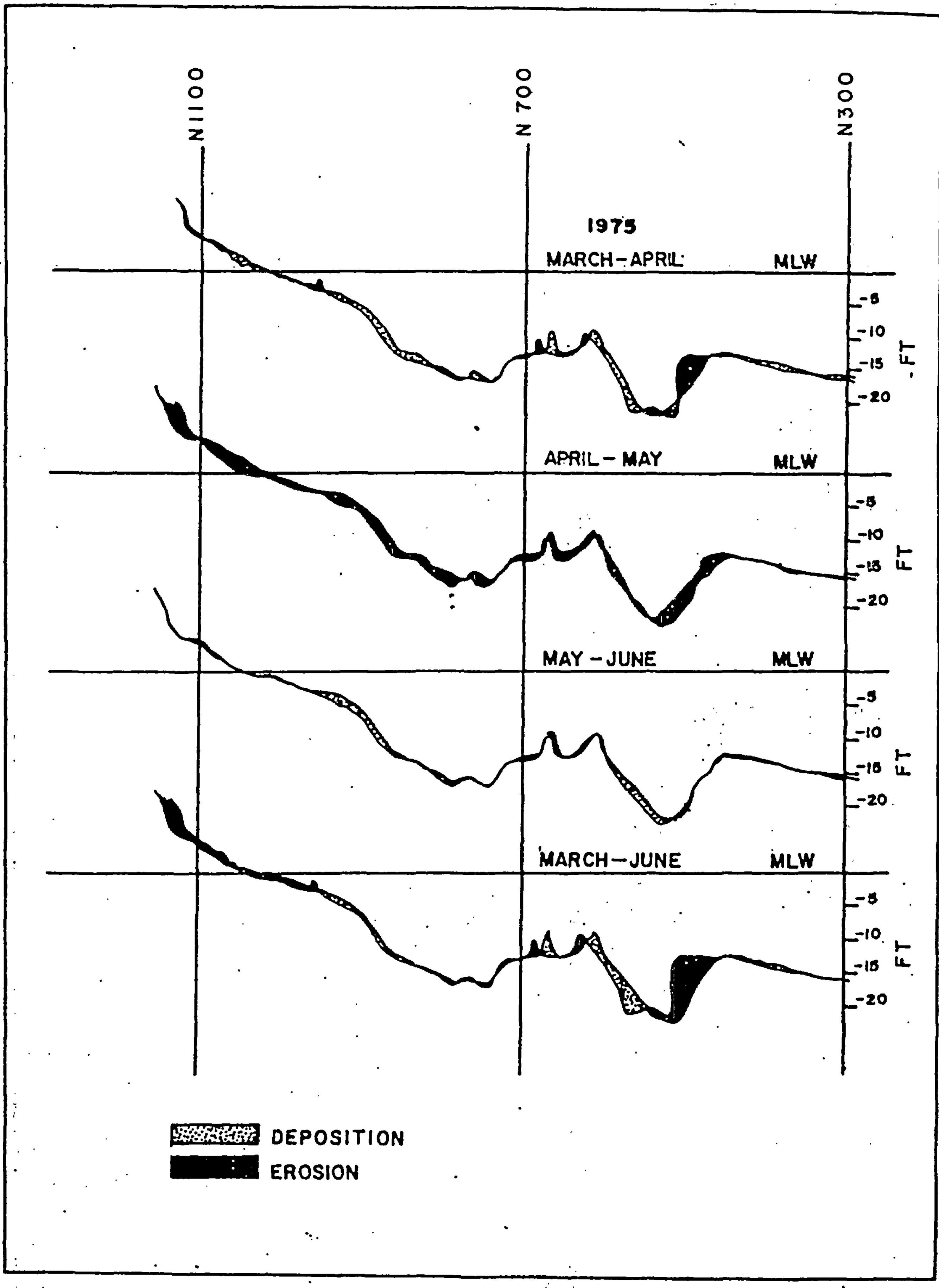


FIG. 4.12-3 COMPARISON OF BEACH PROFILES — TRANSECT T7 (W350)

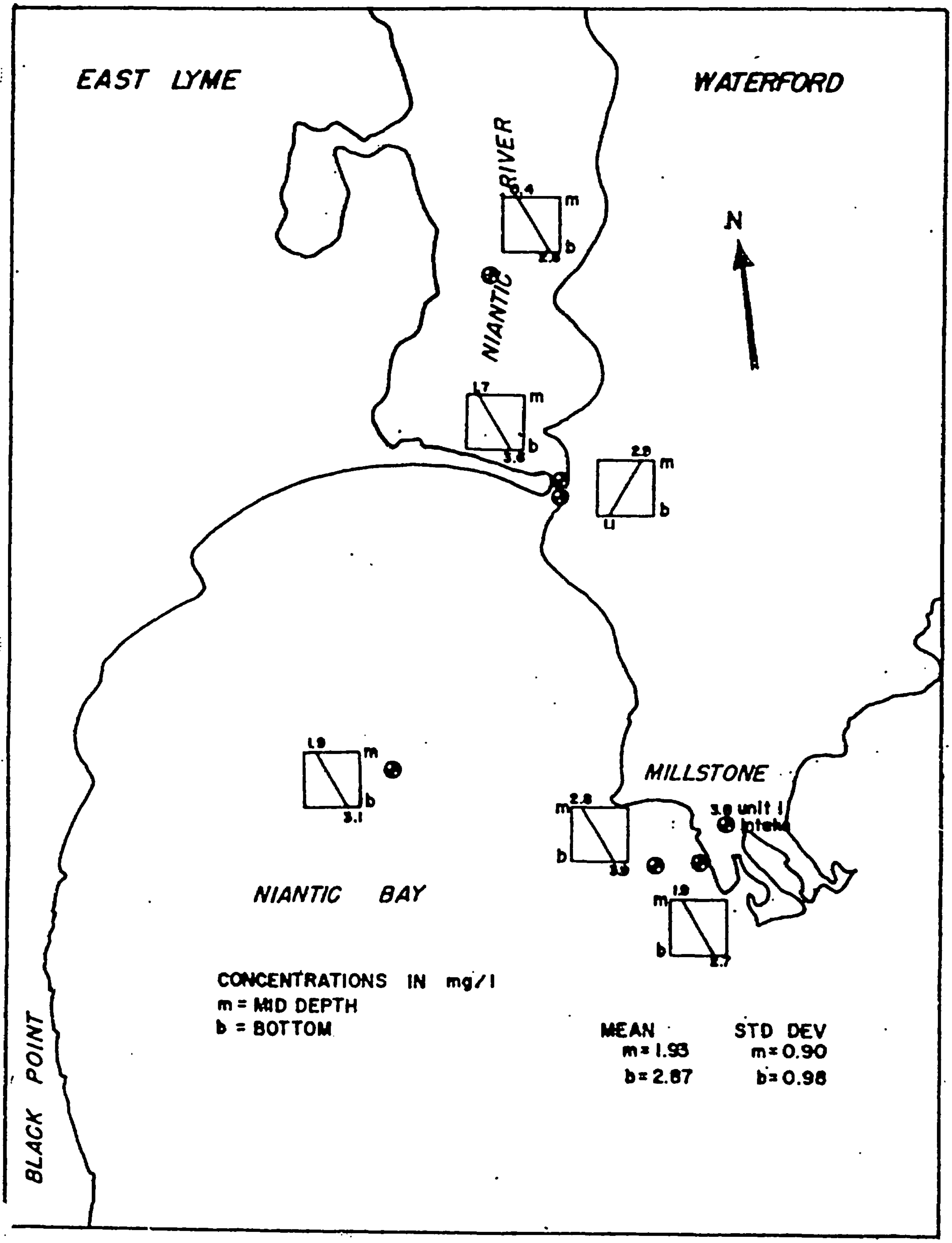


FIG. 4.12-4 WATER SAMPLE LOCATION - SEPT 5, 1978

TABLE 5.2-1. TOP 90 PERCENT OF FISH AND INVERTEBRATE SPECIES IMPINGED FROM JANUARY, 1972, THROUGH DECEMBER, 1975.

Species	Actual Number Impinged	Percent of Total
	FISH	
Pseduopleuronectes americanus	14,712	28
Gasterosteus aculeatus	4,099	8
Myoxocephalus aenaeus	3,858	7
Menidia spp.	3,831	7
Scophthalmus aquosus	2,834	5
Tautogolabrus adspersus	2,608	5
Morone americana	2,573	5
Brevoortia tyrannus	2,518	5
Tautoga onitis	2,332	4
Alosa aestivalis	2,078	4
Merluccius bilinearis	1,762	3
Opsanus tau	1,152	2
Syngnathus fuscus	940	2
Anchoa spp.	921	2
Microgadus tomcod	726	1
Osmerus mordax	658	1
	INVERTEBRATES	
Loligo sp.	13,270	33
Ovalipes ocellatus	10,073	25
Homarus americanus	4,543	11
Callinectes sapidus	4,462	11
Carcinus maenas	2,728	7
Cancer irroratus	2,470	6

Table 5.2-2 WINTER FLOUNDER CATCH/UNIT EFFORT IN TRAWLS AT EACH STATION, 1973-1975

	Stations									
	1	2	4	5	6	7	8	9	10	11
P. americanus	28.8	43.1	17.0	15.4	18.4	7.7	15.6	19.7	21.1	20.0
S. chrysops	1.0	0.8	15.1	52.4	2.9	0.9	2.9	2.9	2.6	6.0
S. aquosus	1.3	2.0	3.8	2.6	2.3	1.2	2.1	7.1	7.5	4.1
Raja spp.	0	0.1	2.7	2.4	1.6	0.6	2.7	6.6	4.3	4.5
T. adspersus	2.2	2.6	0.9	0.6	2.4	6.0	1.5	0.6	2.4	5.8

TABLE 5.2-3 COMPARISON OF TOP 90 PERCENT OF CATCH FROM IMPINGEMENT AND SAMPLING GEAR WITH COMMERCIAL[1] SPECIES

Commercial Species	Impingement	Percent of Total	Otter Trawl	Percent of Total	Gill Net	Percent of Total
Alosa pseudoharengus	Pseudopleuronectes americanus	28	Pseudopleuronectes americanus	43	Clupea harengus	57
Pomatomus saltatrix	Gasterosteus aculeatus	8	Stenotomus chrysops	18	Brevoortia tyrannus	15
Gadus morhua	Myoxocephalus aenaeus	7	Scophthalmus aquosus	9	Prionotus carolinus	4
Pseudopleuronectes americanus	Menidia spp.	7	Raja spp.	7	Tautogolabrus adspersus	3
Limanda ferruginea	Scophthalmus aquosus	5	Tautogolabrus adspersus	5	Pomatomus saltatrix	3
Clupea harengus	Tautogolabrus adspersus	5	Merluccius bilinearis	2	Stenotomus chrysops	3
Brevoortia tyrannus	Morone americana	5	Prionotus spp.	2	Peprilus triananthus	2
Scomber scombrus	Brevoortia tyrannus	5	Menidia menidia	2	Squalus acanthias	2
Paralichthys dentatus	Taitoga onitis	4	Apeltes quadracus	1	Alosa pseudoharengus	2
Cynoscion regalis	Alosa aestivalis	4	Urophycis chuss			
Peprilus triacanthus	Merluccius bilinearis	3				
Menticirrhus saxatilis	Opsanus tau	2				
	Syngnathus fuscus	2				
	Anchoa spp.	2				
	Microgadus tomcod	1				
	Osmerus mordax	1				

[1]From list supplied by Connecticut Department of Environmental Protection.

TABLE 5.2-4 NUMBERS OF SURVIVORS AND PERCENT SURVIVAL OF THE MOST ABUNDANT ARTHROPOD INVERTEBRATE SPECIES IMPINGED ON UNIT NO. 1 INTAKE SCREEN MONTHLY DURING 1975

O. ocellatus			H. americanus			C. sapidus			C. maenas		
No. Impinged	No. Alive	% Alive	No. Impinged	No. Alive	% Alive	No. Impinged	No. Alive	% Alive	No. Impinged	No. Alive	& Alive
0	--	--	40	28	70	0	--	--	67	66	99
0	--	--	3	2	67	0	--	--	3	2	67
0	--	--	25	21	84	0	--	--	23	22	96
0	--	--	67	56	84	0	--	--	13	12	92
53	50	94	78	73	94	7	6	86	62	62	100
190	168	88	272	194	71	89	87	98	59	59	100
241	209	87	176	143	81	76	74	97	50	47	94
354	243	69	30	19	63	133	121	91	178	175	98
444	232	52	18	15	83	130	127	98	93	90	97
93	93	100	29	26	90	75	74	99	77	77	100
278	262	94	83	72	87	124	123	99	77	74	96
47	47	100	46	35	76	8	8	100	65	64	98
1700	1304	77	867	684	79	642	620	97	767	750	98

TABLE 5.2-5 COMPARISON OF NUMBERS OF FISH IMPINGED WITH NUMBERS OF SAME SPECIES COLLECTED IN SAMPLING GEAR

	Total Impinged (1972-1975)	Sample Collections			Total Collected In Samples
		Seine (1969-1975)	Otter Trawls (1973-1975)	Gill Net (1971-1975)	
Pseudopleuronectes americanus	14,712	35	13,176	37	13,248
Gasterosteus aculeatus	4,099	256	208		464
Myoxocephalus aeneus	3,858	13	186	1	200
Menidia spp	3,831	62,941	566		63,507
Scophthalmus aguosus	2,834	1	2,906	4	2,911
Tautogolabrus adspersus	2,608	3	1,656	126	1,785
Morone americana	2,573	10	117	10	137
Brevoortia tyrannus	2,578	4,314	6	572	4,892
Tautog onitis	2,332	3	356	19	378
Alosa aestivalis	2,078	84	7	70	161
Merluccius bilinearis	1,762		720	18	738
Opsanus tau	1,152		30		30
Syngnathus fuscus	940	103	103		206
Anchoa spp	921				
Microgadus tomcod	726	50	25	1	76
Osmerus modax	658	22	30	2	54
Raja spp	586		2,231	8	2239
Prionotus carolinus	470			141	141
Pollachius virens	452		10	3	13
Peprilus triancanthus	433		50	79	129
Sphaeroides maculatus	315	14	9		23
Paralichthys dentatus	309		174		174
Anguilla rostrata	281	186	48		234
Cyclopterus lumpus	233		2		2
Alosa pseudoharengus	213	455	23	71	549
Pomatomus saltatrix	207	37		119	156
Prionotus spp	150		595		595
Gasterosteus spp	139				
Clupea harengus	114	155	2	2,172	2,329
Stenotomus chrysops	108		5,493	111	5,604
Ammodytes spp	97				
Urophycis tenuis	77	3	24	10	37
Pholis gunnellus	59		34		34
Bairdiella chrysura	58				
Cynoscion regalis	57		12	6	18

TABLE 5.2-5 (Cont'd)

	Total Impinged (1972-1975)	Sample Collections: Seine (1969-1975)	Otter Trawls (1973-1975)	Gill Net (1971-1975)	Total Collected In Samples
Merluccius spp	54				
Conger oceanicus	48				
Liparis attanticus	46		5		5
Hemitripterus americanus	44		72		72
Pronotus evolans	43				
Raja ocellata	35				
Fundulus majalis	35	5,946			5,946
Monacanthus spp	35				
Mugil cephalus	31	294		1	295
Enchelyopus cimbrius	31				
Cyprinodon variegatus	30	571			571
Brosme brosme	29				
Fundulus heteroclitus	28	5,701			5,701
Trinectes maculatus	22		3		3
Caranx hippos	15				
Aluterus sp	14				
Morone saxatilis	14			6	6
Centropristes striata	13		39		39
Myoxocephalus scorpius	12		2		2
Rissola marginata	10				
Vomer setapinnis	10		1		1
Selene vomor	10				
Scomber scombrus	8			13	13
Menticirrhus saxatilis	8	31	4	1	36
Sphyraena borealis	7				
Anguilla spp	7				
Aulostomus maculatus	6				
Selar crumenophthalmus	6				
Paralichthys oblongus	6		18		18
Lophius americanus	5		5		5
Mustelus canis	5			48	48
Pungitius pungitius	5	746			746
Etrumeus teres	4			2	2
Chilomycterus schoepfi	4				
Alectis crinitis	3				

TABLE 5.2-5 (Cont'd)

	Total Impinged (1972-1975)	Sample Collections: Seine (1969-1975)	Otter Trawls (1973-1975)	Gill Net (1971-1975)	Total Collected In Samples
Fundulus diaphanus	3				
Squalus acanthias	2		1	78	79
Macrozoarces americanus	2		5		5
Dactylopterus volitans	2		3		3
Hippocampus sp	2				
Pristigenys alta	2				
Aluterus schoepfi	2				
Myoxocephalus spp	2				
Petromyzon marinus	1			1	1
Ammodytes americanus	1	3,371			3,371
Gasterosteidae	1		2		2
Raja laevis	1				
Myoxocephalus octodecemspinosus	1		91	1	92
Lumpenus medius	1				
Chondrichthyes	1				
TOTALS	52,667				118,126

TABLE 5.3-1. SIMPLE VOLUMETRIC ESTIMATES OF NUMBERS OF PHYTOPLANKTON CELLS ENTRAINED FOR THREE UNIT OPERATION ($1.066 \times 10^7 m^3$/DAY).

SAMPLE DATE	DAYS/ INTERVAL	CELLS/L $\times 10^4$	CELLS ENTRAINED PER INTERVAL $\times 10^{13}$	CELLS ENTRAINED PER MONTH $\times 10^{13}$
4-30-75	13	2.71	376	376
5-13-75	14	1.40	209	3,298
5-27-75	14	20.70	3,089	
6-10-75	14	3.48	520	1,453
6-24-75	14	6.25	933	
7-8-75	15	185.00	29,584	61,373
7-23-75	14	213.00	31,789	
8-6-75	14	249.00	37,162	40,999
8-20-75	14	25.70	3,837	
9-3-75	14	18.50	2,760	16,083
9-17-75	35	35.70	13,323	
10-22-75	21	2.49	556	556
11-12-75	14	7.34	1,096	2,042
11-26-75	14	6.34	946	
12-10-75	14	3.30	491	1,496
12-24-75	14	6.74	1,005	
1-7-76	14	14.40	2,149	6,946
1-22-76	15	30.00	4,797	
2-4-76	13	13.00	1,790	6,217
2-18-76	14	27.00	4,029	
2-25-76	7	5.33	398	
3-12-76	15	19.40	3,103	5,496
3-24-76	12	18.70	2,393	
4-7-76	14	31.00	4,627	5,118
4-28-76	21	2.20	491	
TOTAL				151,077 or 1.51×10^{18} phytoplankton cells

TABLE 5.3-2. AMOUNT OF CHLOROPHYLL *a*, CARBON, DRY WEIGHT AND CALORIES ENTRAINED BY THREE UNIT OPERATION IN 1975. THESE FIGURES ARE ALL EXTRAPOLATIONS FROM THE NUMBERS OF CELLS ENTRAINED AND THE FOLLOWING CONVERSION FACTORS:

a assumes average chlorophyll *a* per cell = 3×10^{-12}g

b assumes c/chl *a* ratio of 50 (Strickland, 1960)

c assumes chlorophyll is 1% of dry weight (Parsons, et al., 1961)

d assumes 1 mg carbon ≡ 11.40 calories (Platt and Irwin, 1968)

MONTH	PREDICTED CELLS ENTRAINED $\times 10^{13}$	CHLOROPHYLL *a* ENTRAINED g $\times 10^{4}$ a	CARBON g $\times 10^{6}$ b	DRY WEIGHT g $\times 10^{6}$ c	CALORIES $\times 10^{7}$ d
May	3,298	9.89	4.95	9.89	5,637
June	1,453	4.36	2.17	4.36	2,478
July	61,373	184.12	92.05	184.12	104,941
August	40,999	122.99	61.50	123.00	70,108
September	16,083	47.93	23.97	47.93	27,327
October	556	1.67	0.84	1.67	958
November	2,042	6.13	3.07	6.13	3,390
December	1,496	4.49	5.40	4.49	6,153
January	6,946	20.90	10.43	20.84	11,886
February	6,217	18.69	9.35	18.69	10,653
March	5,496	16.49	8.24	16.49	9,396
April	5,118	15.36	7.69	15.36	8,762
ANNUAL TOTAL	151,077	453.02	229.66	452.97	261,689

TABLE 5.3-3. DRY WEIGHT, CARBON AND CALORIES OF ZOOPLANKTON ESTIMATED ENTRAINED EACH MONTH USING NIGHT ZOOPLANKTON SAMPLES FROM 1975.

1975 MONTH	DRY WEIGHT g x 10^6	ZOOPLANKTON CARBON a g x 10^6	ZOOPLANKTON CALORIES b x 10^7	$\frac{\text{PHYTOPLANKTON C}}{\text{ZOOPLANKTON C}}$
January	1.64	0.65	860	16.02
February	1.24	0.49	651	18.94
March	1.45	0.58	761	14.27
April	13.49	5.40	7,083	1.42
May	3.59	1.44	1,886	3.44
June	12.59	5.04	6,613	0.43
July	9.32	3.73	4,895	24.70
August	5.00	2.00	2,624	30.82
September	9.80	3.92	5,143	6.12
October	3.59	1.44	1,886	0.58
November	1.65	0.66	865	4.63
December	2.49	0.99	1,306	5.41
TOTAL	65.85	26.34	34,573	$\bar{x}$ = 8.72

a = 40% of dry weight (Beers, 1966)

b = 5250 cal/g dry weight (Laurence, 1976)

TABLE 5.3-4. MILLIONS OF FISH LARVAE OR EGGS PREDICTED TO BE ENTRAINED FROM EITHER DAY OR NIGHT SAMPLES BY MONTH FOR 1975. THE AVERAGE ABUNDANCE PER M^3 FOR EGGS AND LARVAE IN DISCHARGE SAMPLES WAS MULTIPLIED BY THE NUMBER OF FULL DAYS PRECEDING IT AND BY THE DAILY COOLING WATER VOLUME WITH THREE UNIT OPERATION (1.066×10^7 m^3/DAY).

1975	DAY LARVAE ENTRAINED $\times 10^6$	NIGHT LARVAE ENTRAINED $\times 10^6$	DAY EGGS ENTRAINED $\times 10^6$	NIGHT EGGS ENTRAINED $\times 10^6$
January	0.91	1.60	0.06	0.11
February	1.87	1.72	0.39	0.33
March	6.61	2.56	7.09	11.16
April	21.65	13.36	3.63	19.90
May	7.79	16.64	90.51	150.58
June	444.15	1,105.65	4,453.90	8,317.05
July	198.45	495.60	3,811.50	2,849.70
August	252.00	486.15	385.35	267.75
September	55.65	63.00	37.80	29.40
October	4.27	7.75	29.53	11.31
November	4.54	4.33	7.67	18.51
December	1.82	2.63	0.78	0.72
ANNUAL TOTAL $\times 10^6$	999.26	2,200.99	9,328.21	11,676.53

TABLE 5.3-5. NUMBERS OF TOTAL ZOOPLANKTON ENTRAINED PER MONTH ASSUMING THREE UNIT OPERATION (1.066×10^7 m^3/DAY) AND THE ABUNDANCES FROM DAY AND NIGHT SAMPLES FROM NOVEMBER 1970 TO NOVEMBER 1971.

1970-1971	TOTAL ZOOPLANKTON ENTRAINED ESTIMATED FROM DAY SAMPLES $\times 10^6$	TOTAL ZOOPLANKTON ENTRAINED ESTIMATED FROM NIGHT SAMPLES $\times 10^6$
November	7,521	48,237
December	108,341	111,969
January	95,964	59,426
February	193,635	387,942
March	241,352	141,211
April	574,755	383,049
May	194,898	442,650
June	348,751	602,136
July	147,132	231,220
August	233,420	190,095
September	174,061	380,330
October	77,313	226,291
November	117,392	50,370
TOTAL	2,514,535	3,259,926
	or 2.51×10^{12}	or 3.25×10^{12}

TABLE 5.3-6. NUMBERS OF TOTAL ZOOPLANKTON ENTRAINED PER MONTH ASSUMING THREE UNIT OPERATION (1.066×10^7 m^3/DAY) AND THE ABUNDANCES FROM DAY AND NIGHT FROM NOVEMBER 1973 TO NOVEMBER 1974. *DAY SAMPLES IN SEPTEMBER AND OCTOBER WERE NOT ANALYZED LEAVING THIS FIGURE AN UNDERESTIMATE OF ENTRAINMENT.

1973-1974	TOTAL ZOOPLANKTON ENTRAINED ESTIMATED FROM DAY SAMPLES x 10^6	TOTAL ZOOPLANKTON ENTRAINED ESTIMATED FROM NIGHT SAMPLES x 10^6
November	39,649	126,478
December	8,680	11,102
January	811,941	203,721
February	2,467,400	1,287,896
March	8,930,224	12,707,733
April	2,175,718	11,224,688
May	3,656,626	9,079,362
June	10,480,015	25,063,721
July	1,294,234	11,032,529
August	62,271	5,069,120
September	* ---	22,252,330
October	* ---	617,836
TOTAL	29,922,559	98,676,514
	or *2.99×10^{13}	or 9.87×10^{13}

TABLE 5.3-7. NUMBERS OF TOTAL ZOOPLANKTON ENTRAINED PER MONTH ASSUMING THREE UNIT OPERATION (1.066×10^7 m^3/DAY) AND ABUNDANCES FROM NIGHT SAMPLES COLLECTED DURING 1975.

1975	TOTAL ZOOPLANKTON ENTRAINED ESTIMATED FROM NIGHT SAMPLES $\times 10^6$
January	163,645
February	75,913
March	90,600
April	1,611,373
May	248,584
June	2,344,424
July	726,522
August	392,646
September	480,200
October	354,860
November	122,095
December	96,033
TOTAL	$6,706,896 \times 10^6$ or 6.71×10^{12}

TABLE 5.3-8. NUMBERS OF TOTAL FISH LARVAE OR EGGS AND SOME IMPORTANT SPECIES ENTRAINED FOR THREE YEARS USING DAY AND NIGHT REPLICATES TO MAKE INDEPENDENT ESTIMATES. *ASTERISK DENOTES A PARTIAL YEAR (APRIL 3, 1973 TO DECEMBER 31, 1973).

SPECIES	YEAR	NUMBER ENTRAINED USING DAY REPLICATES x 10^6	NUMBER ENTRAINED USING NIGHT REPLICATES x 10^6
Total fish larvae	1973*	243.36	251.29
	1974	243.36	281.12
	1975	999.26	2,200.98
Total fish eggs	1973*	9,034.02	4,584.14
	1974	2,055.47	3,477.85
	1975	9,328.26	11,666.03
P. americanus larvae	1973*	13.40	16.32
	1974	77.39	53.59
	1975	209.59	273.88
T. adspersus eggs	1973	7,139.39	3,062.94
	1974	795.81	1,875.52
T. adspersus larvae	1973*	28.91	20.04
	1974	0.46	6.99
	1975	12.38	30.71
T. onitis larvae	1973	22.38	5.60
	1974	6.99	9.32
	1975	30.93	22.44

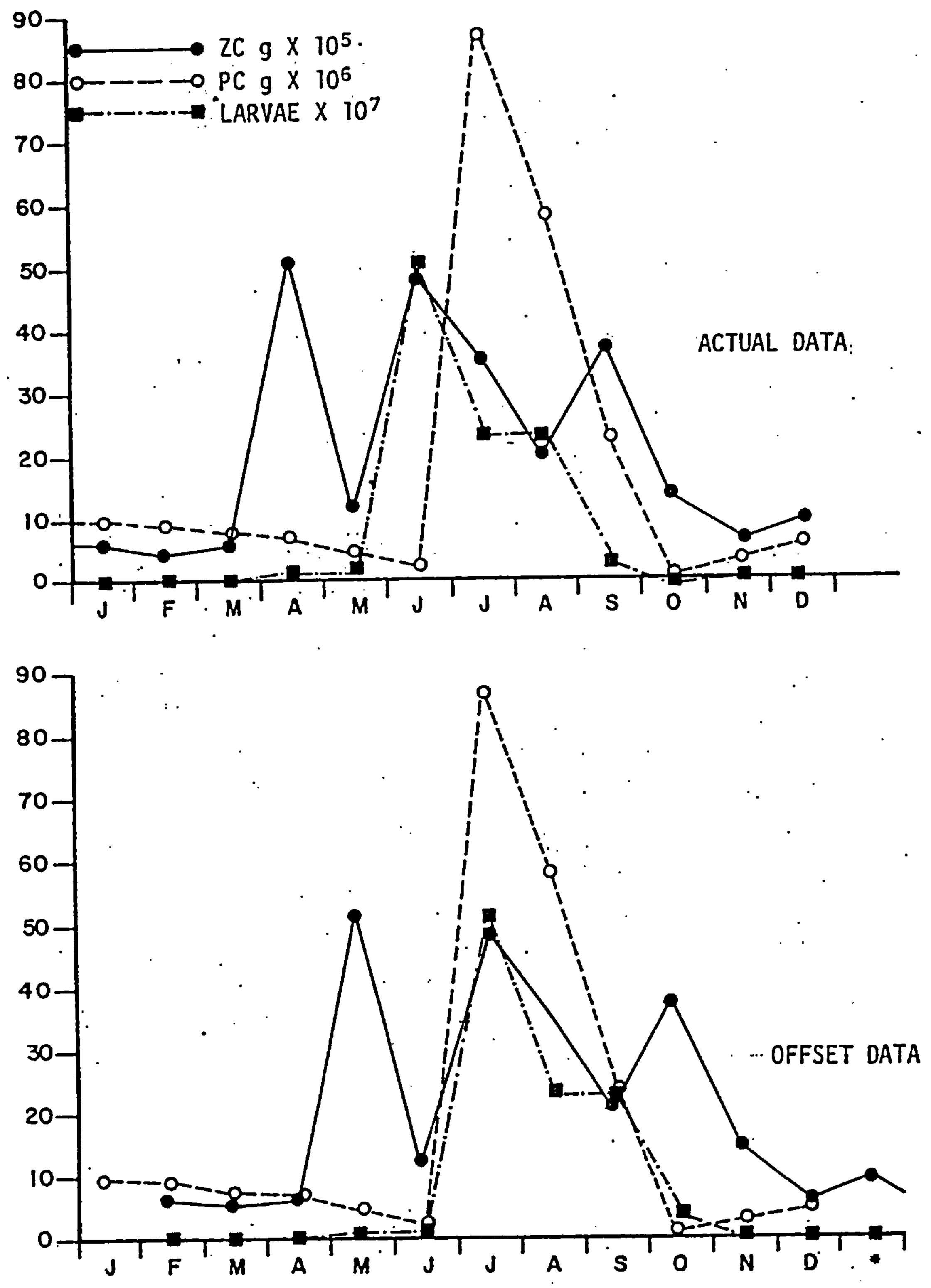


Figure 5.3-1. Biomass of zooplankton carbon (ZC g x 10^5), phytoplankton carbon (PC g x 10^6) and numbers of fish larvae using monthly data from 1975. Zooplankton and fish larvae figures have been offset (advanced) one month in the lower panel.

TABLE 5.4-1. TOTAL RELATIVE NUMBERS OF LARVAE REMAINING IN THE BIGHT WITH AND WITHOUT POWER PLANT OPERATION

Tidal Cycle	Without Plant	With Plant	% Difference
0	1.000	1.000	-
1	.997	.993	-
2	.959	.948	-
3	.894	.880	-
4	.822	.809	-
5	.755	.743	-
6	.695	.684	-
7	.642	.632	-
8	.595	.587	-
9	.554	.547	-
10	.518	.512	-
11	.482	.447	1.180
12	.455	.450	1.076
13	.430	.426	.998
14	.408	.404	.957
15	.389	.383	.903
16	.368	.365	.848
17	.350	.347	.800
18	.334	.332	.748
19	.319	.317	.721
20	.305	.303	.688

TABLE 5.4-2 LENGTH, WEIGHT AND FECUNDITY OF WINTER FLOUNDER BY AGE AND SEX
L IS IN MM AND W IS IN GRAMS

Age (Years)	Males L	Males W	Females L	Females W	Females FEC (x 1,000)	Average W
1	125	21.9	135	27.9	-	25.7
2	188	78.9	215	120.3	-	105.2
3	236	160.0	274	257.4	260	227.3
4	275	260.4	318	410.8	443	356.1
5	304	356.7	352	565.0	637	489.2
6	326	444.1	377	700.7	813	607.3
7	342	516.1	396	817.7	970	707.9
8	354	575.1	401	918.8	1107	793.7
9	363	622.3	422	998.2	1217	861.4
10	370	660.7	430	1058.8	1301	913.9
11	375	689.1	436	1105.9	1367	954.2
12	379	712.5	441	1146.2	1424	988.3

TABLE 5.4-3 INITIAL AGE-CLASS STRUCTURE FOR THE NIANTIC RIVER WINTER FLOUNDER POPULATION

Age	Number
1	83,724
2	12,172
3	4,017
4	1,326
5	437
6	144
7	48
8	16
9	5
10	2
11	1
12	---
Total	101,892

TABLE 5.4-4. AGE-STRUCTURE BASED ON THE POPULATION ESTIMATE OF WINTER FLOUNDER (*PSEUDOPLEURONECTES AMERICANUS*) GREATER THAN 150 MM IN LENGTH IN NIANTIC BAY, USING JOLLY'S METHOD

Age	Number of Fish
1	738,375
2	107,319
3	35,368
4	11,656
5	3,841
6	1,266
7	417
8	137
9	45
10	15
11	5
12+	2

TABLE 5.4-5. PROJECTIONS OF TOTAL NUMBER OF FISH FOR VARIOUS PLANT INDUCED MORTALITY RATES BASED ON JOLLY'S METHOD (CALCULATED) N = 160,073)

	Plant Mortality Rate						
Years	0.0	0.01	0.03	0.05	0.08	0.12	0.20
0	899	899	899	899	899	899	899
5	899	885	856	828	786	732	629
10	899	876	830	786	723	643	500
15	899	868	807	750	668	569	401
20	899	861	788	719	623	509	326
25	899	855	771	693	585	460	269
30	899	850	757	670	553	419	223
35	899	846	745	651	525	384	187
40	899	854	767	684	567	429	222
45	899	860	783	706	596	461	246
50	899	865	797	728	625	494	273
55	898	870	710	748	653	526	301
60	898	873	821	766	678	558	331
65	898	877	831	782	702	589	363
70	898	880	840	796	724	618	395
75	898	882	848	809	744	646	428
80	898	885	854	820	763	672	461
85	898	886	860	830	779	697	494
90	898	888	865	839	794	719	526
95	898	889	870	847	807	740	558
100	898	891	874	854	818	758	589

NOTE: Multiply above 10^3 to get actual total population size of winter flounder. Plant mortality ends after 35 years.

TABLE 5.4-6 MEAN RANGE AND TIME LAG FOR TIDE GAUGE STATIONS

SUMMER SURVEY

Station	Mean Range (cm)	Time Lag (min)
F	71.1	0
A	78.5	2.0
C	77.7	12.0

WINTER SURVEY

Station	Mean Range (cm)	Time Lag (min)
2	75.2	0.0
3	73.1	-4.5
4	77.3	-2.6
5	76.4	11.3
6	64.5	16.8
7	86.3	23.2

TABLE 5.4-7 BACKGROUND DATA FOR DYE RELEASES

Study Number	1	2	3	4	5
Date	19 June	26 June	9 July	23 July	11 March
Time of Dye Release (EDT)	0800-2030	0730-2000	0730-2000	0730-2000	0800-200
Tide*	0627/2.3	0612/-0.1	0422/-0.4	0420/-0.1	0453/2.0
	1236/0.1	1207/2.4	1007/2.6	1017/2.4	1147/-0.1
	1850/3.2	1826/0.3	1625/0.0	1628/0.1	1730/2.0
	0130/-0.1	0016/2.8	2219/3.4	2230/2.9	2358/0.0
Wind (m/s/octant) during injection	0.7/NE	3.4/E	2.0/S		

*Time/Elevation (EDT/feet), New London predictions

TABLE 5.4-8 ENTRAINMENT COMPARISON

Study Number	1	2	3	4	5
Observed	7.4-8.9	4.2	1.9	4.2	6.8
Predicted	7.6	7.3	1.5	1.14	7.9
Predicted/Observed	1	1.7	0.8	0.27	1.16

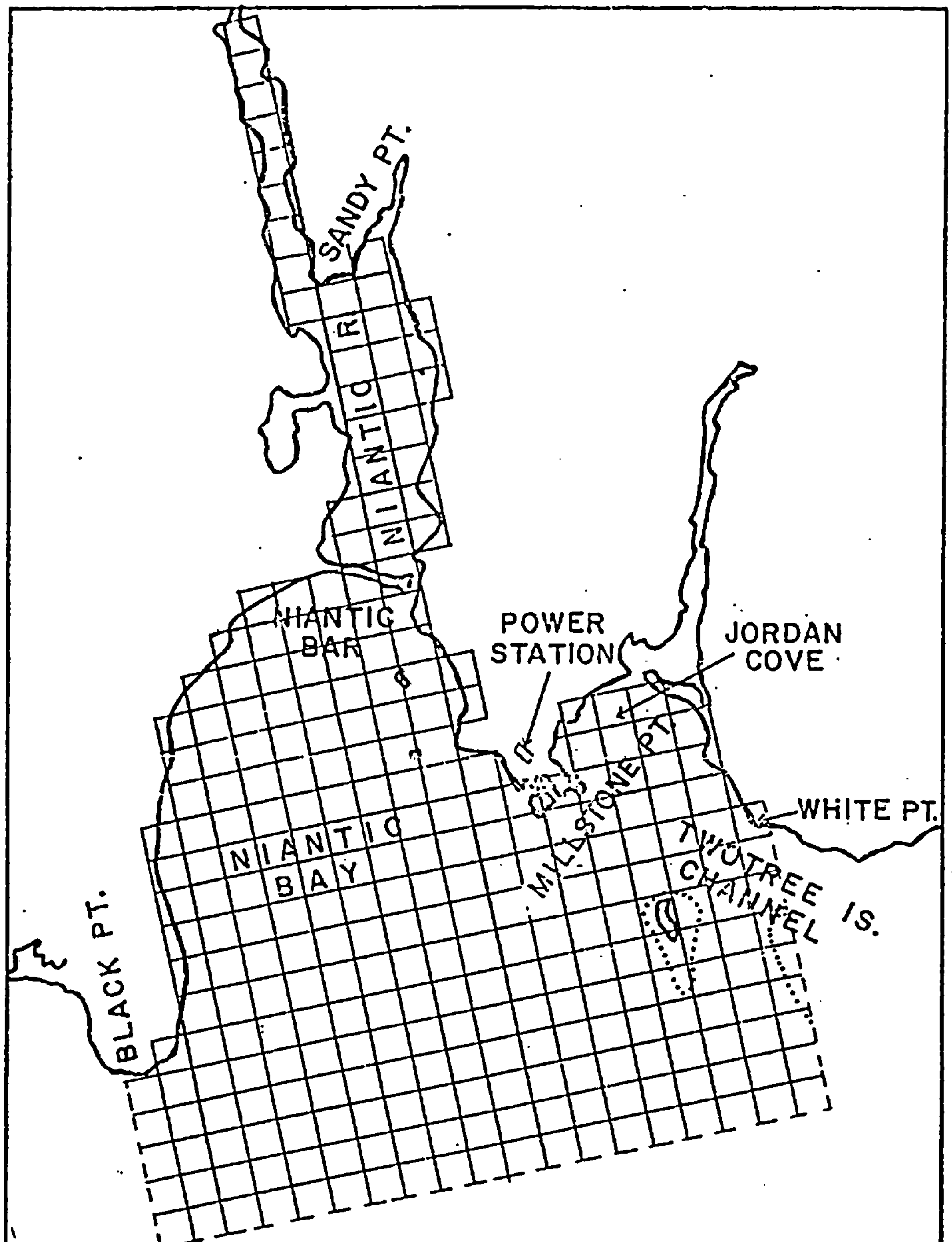


FIGURE 5.4-1

MILLSTONE BIGHT CIRCULATION AND DISPERSION MODELS GRID NETWORK

MILLSTONE NUCLEAR POWER STATION

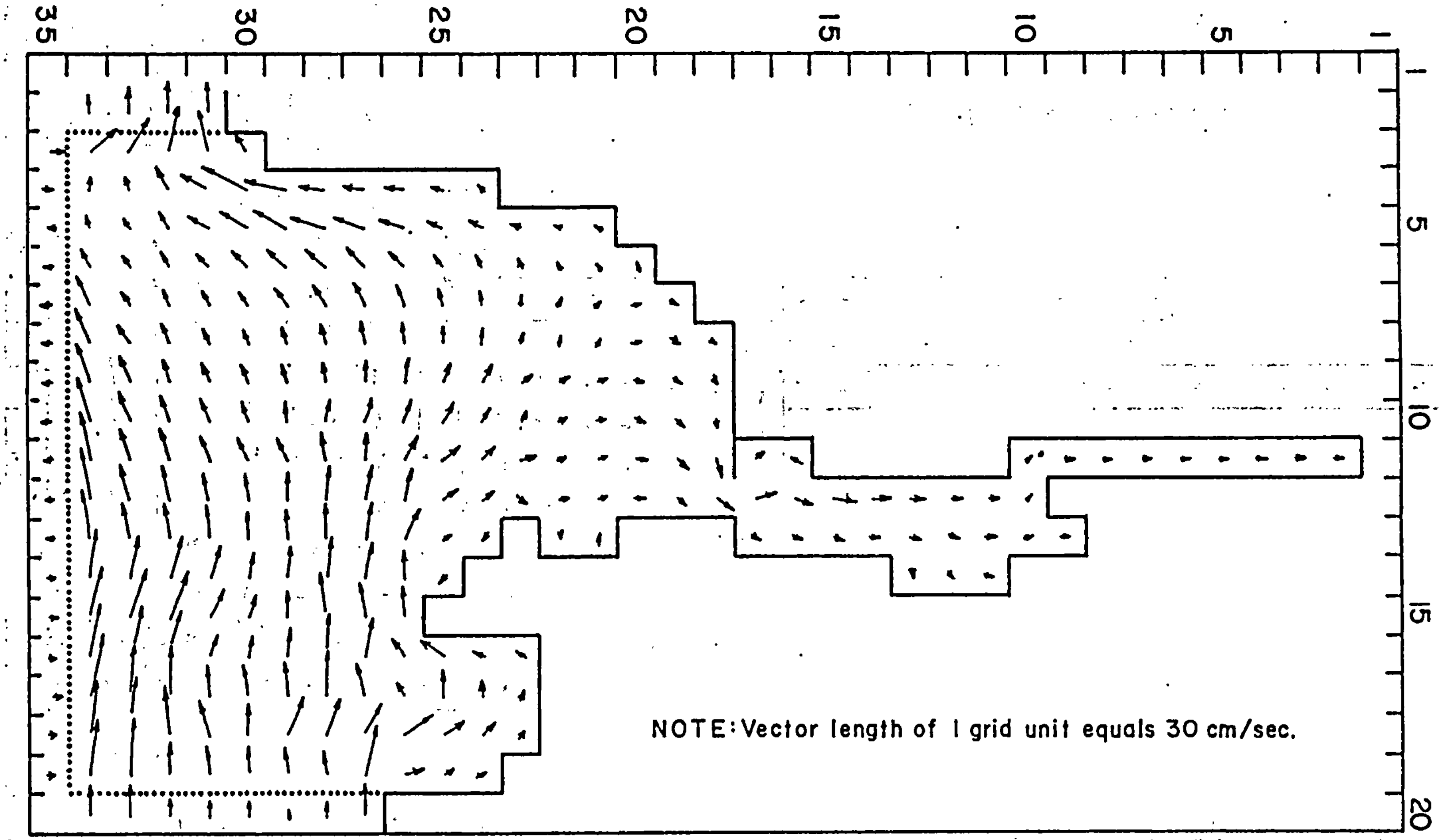


FIGURE 5.4-2

PREDICTED CURRENTS DURING FLOOD

MILLSTONE NUCLEAR POWER STATION

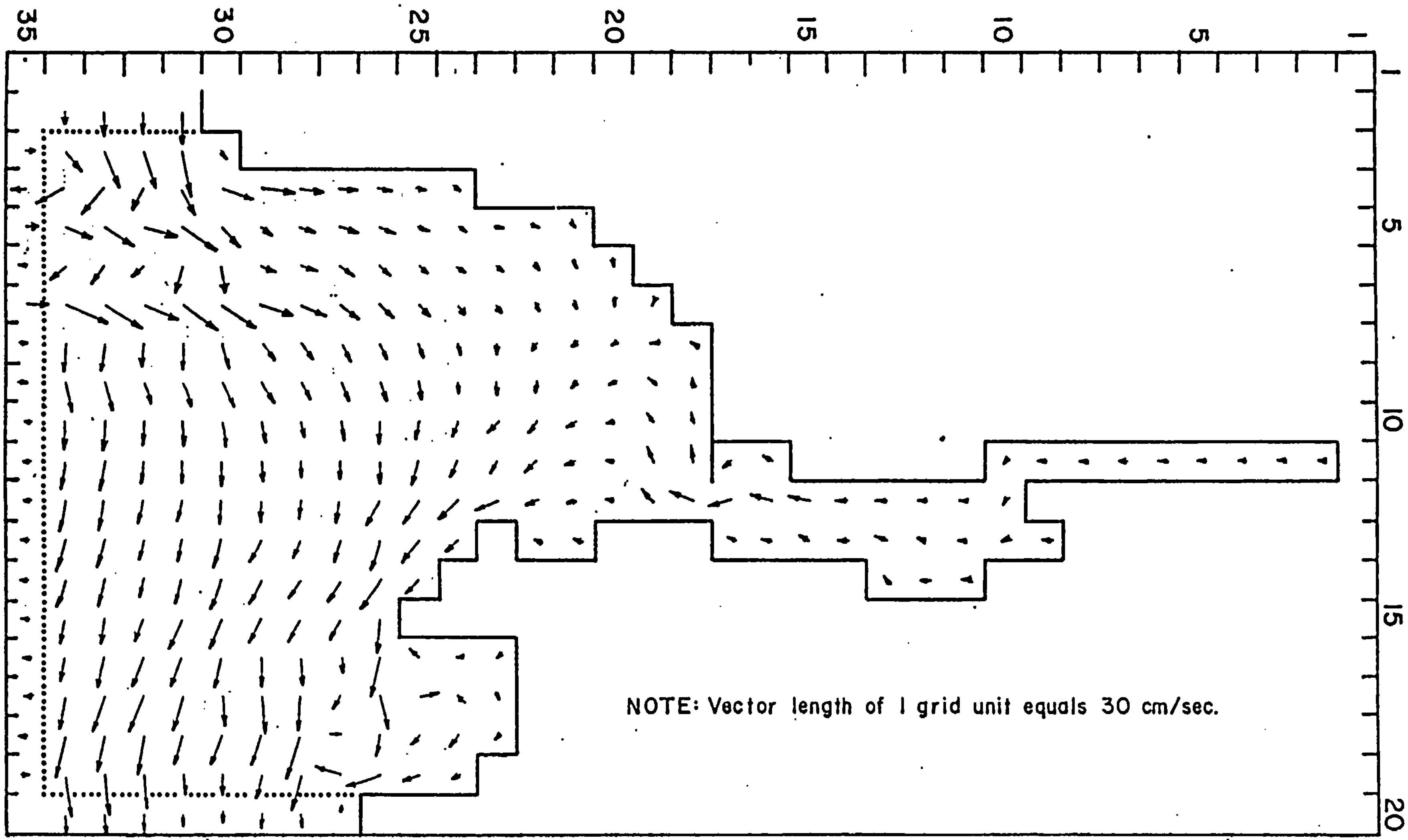
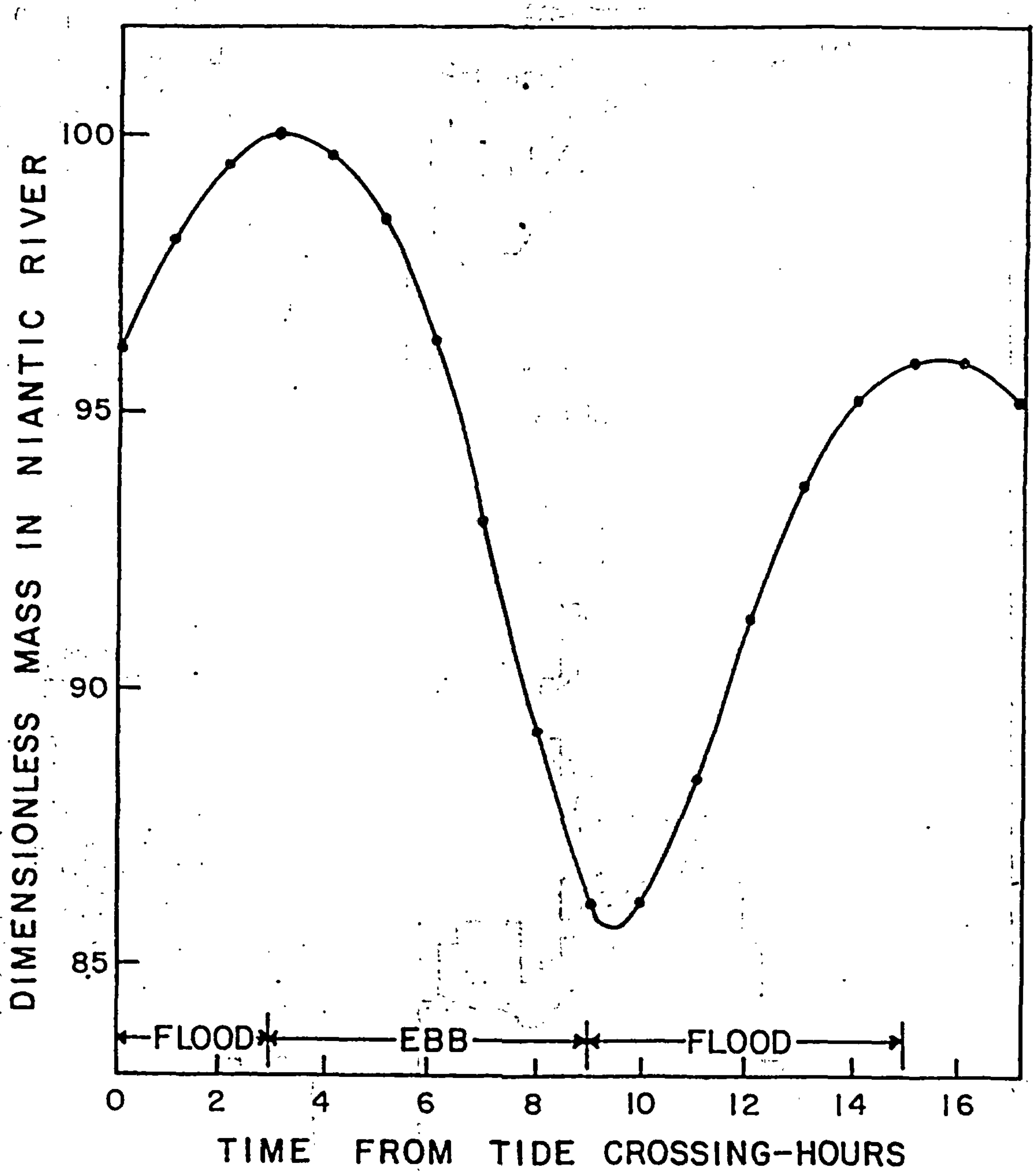


FIGURE 5.4-3

PREDICTED CURRENTS DURING EBB

MILLSTONE NUCLEAR POWER STATION



NOTE: Simulation indicates that 72% of mass leaving the river on ebb, returns on flood.

FIGURE 5.4-4

SIMULATED MASS IN NIANTIC RIVER
MILLSTONE NUCLEAR POWER STATION

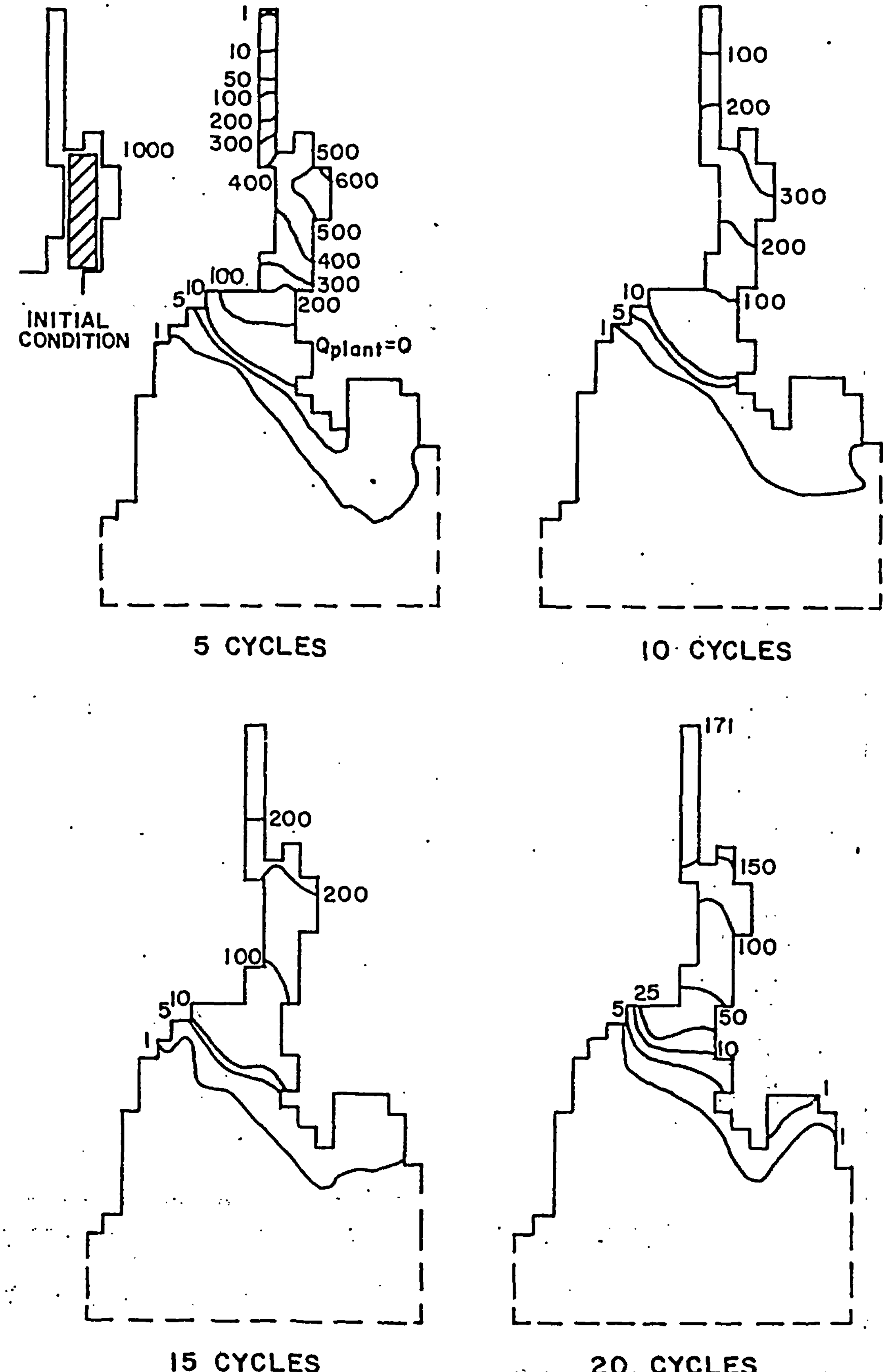
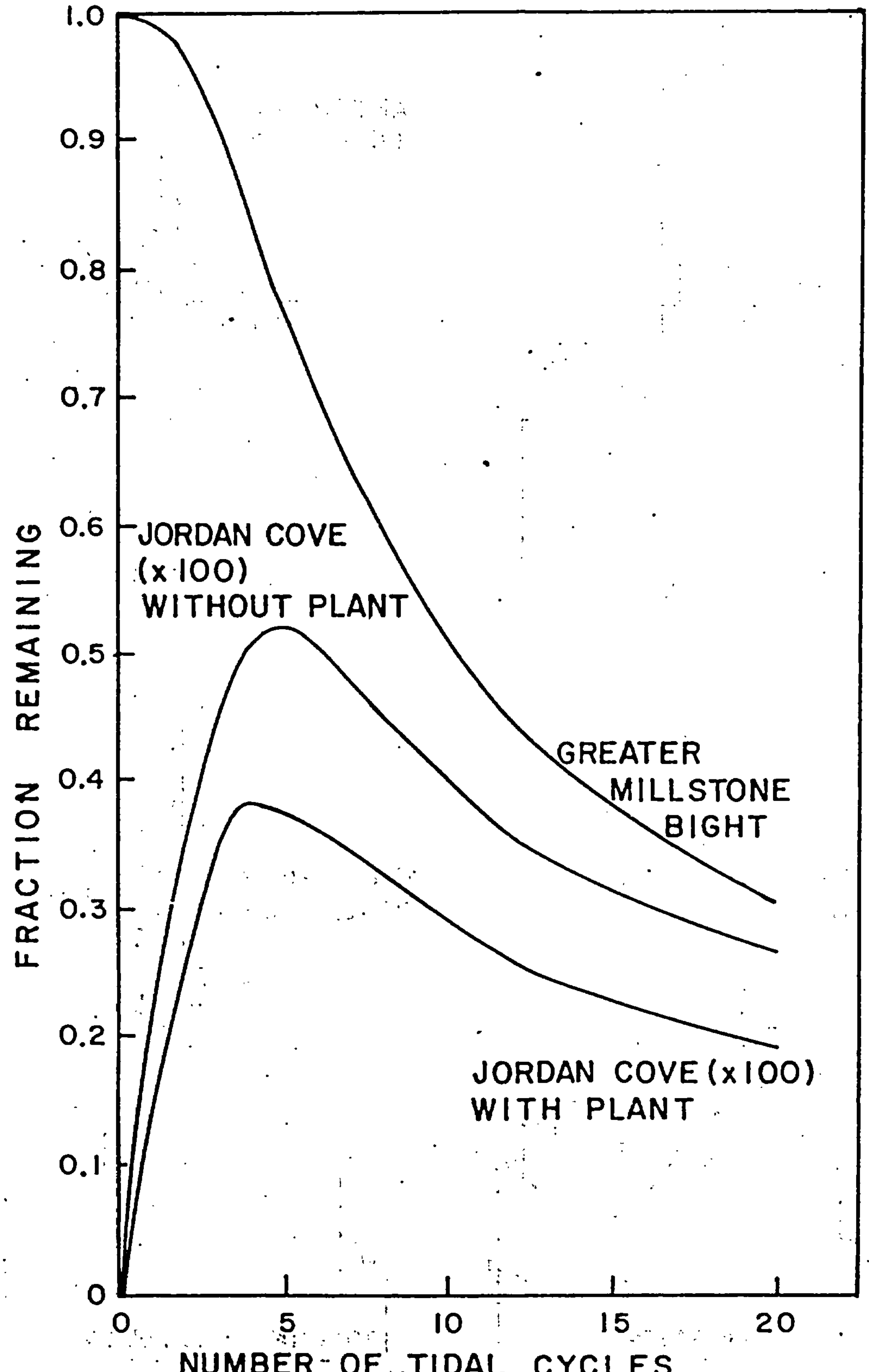


FIGURE 5.4-5

SIMULATED CONCENTRATION DISTRIBUTION OF LARVAE AT 5,10,15 & 20 CYCLES AFTER HATCHING IN NIANTIC RIV.

MILLSTONE NUCLEAR POWER STATION



NOTE: The fraction remaining in the bight with and without the plant differs only slightly, see Table 4.2-1

FIGURE 5.4-6

FRACTION OF ORGANISMS REMAINING IN THE GREATER MILLSTONE BIGHT AND JORDAN COVE

MILLSTONE NUCLEAR POWER STATION

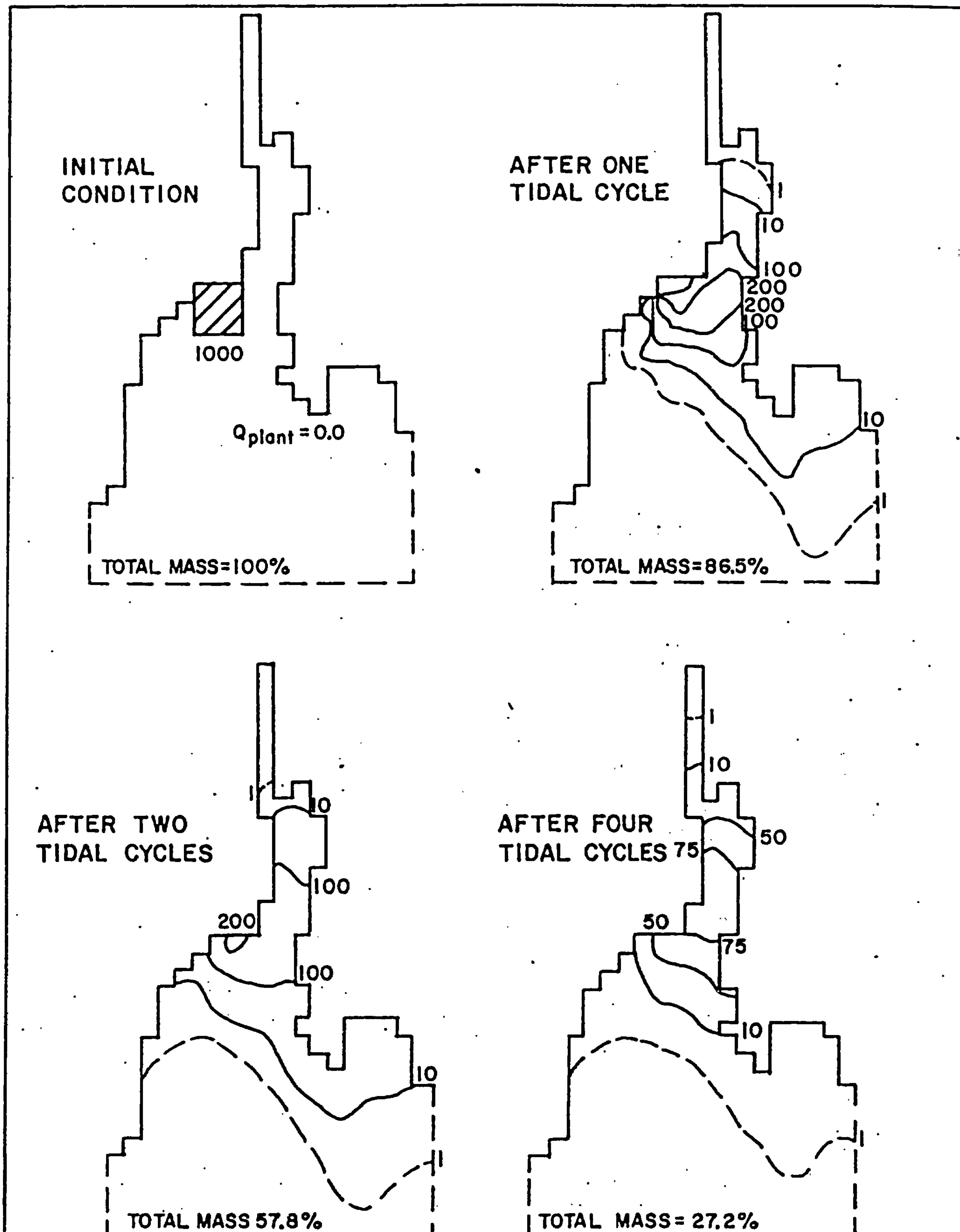


FIGURE 5.4-7

SIMULATED CONCENTRATION DISTRIBUTION OF LARVAE AT 1,2 & 4 TIDAL CYCLES AFTER HATCHING NEAR NIANTIC BAR
MILLSTONE NUCLEAR POWER STATION

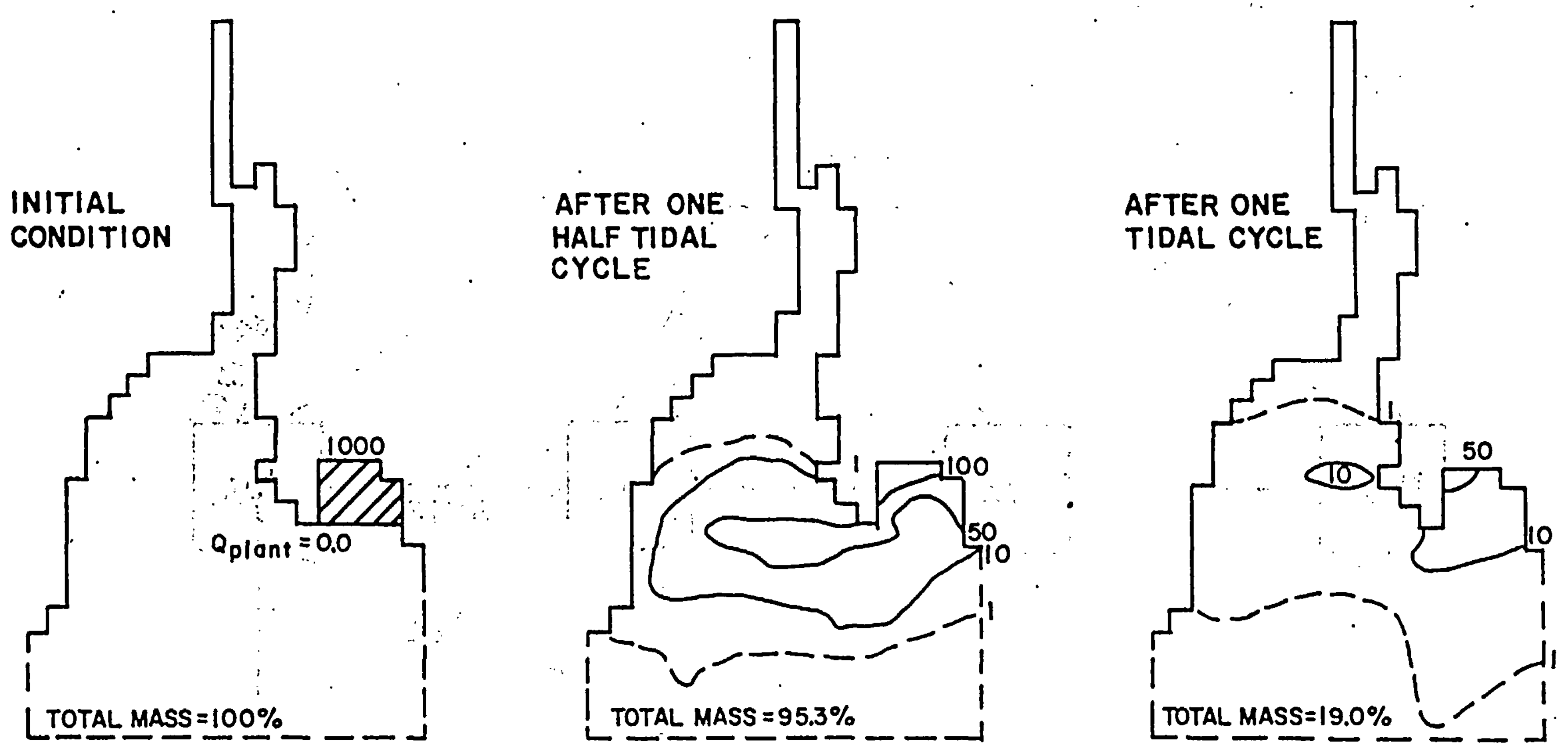


FIGURE 5.4-8
SIMULATED CONCENTRATION
DISTRIBUTION OF LARVAE AT
1 AND 2 TIDAL CYCLES AFTER
HATCHING IN JORDAN COVE
MILLSTONE NUCLEAR POWER STATION

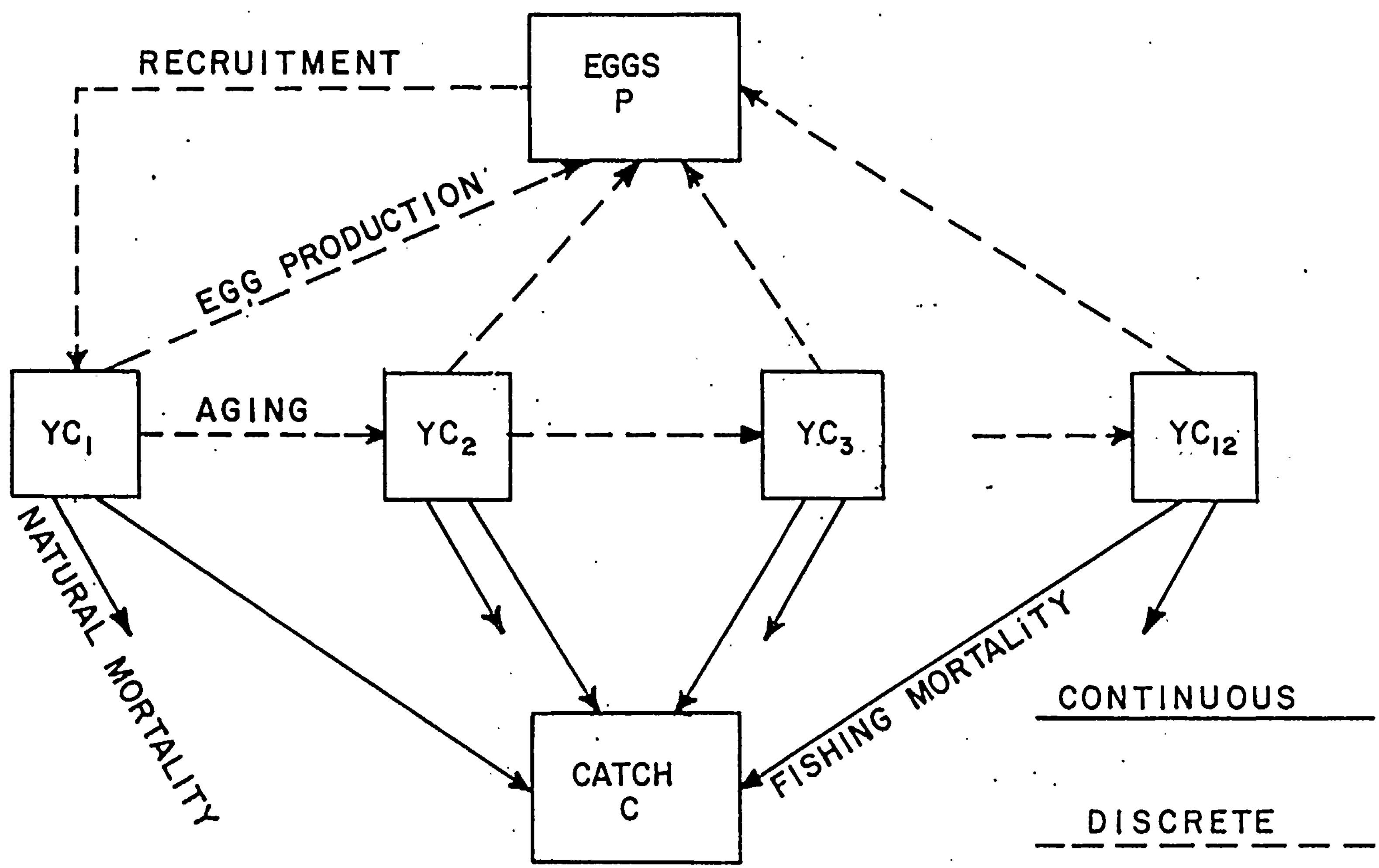


FIGURE 5.4-9
WINTER FLOUNDER POPULATION COMPARTMENT MODEL
MILLSTONE NUCLEAR POWER STATION

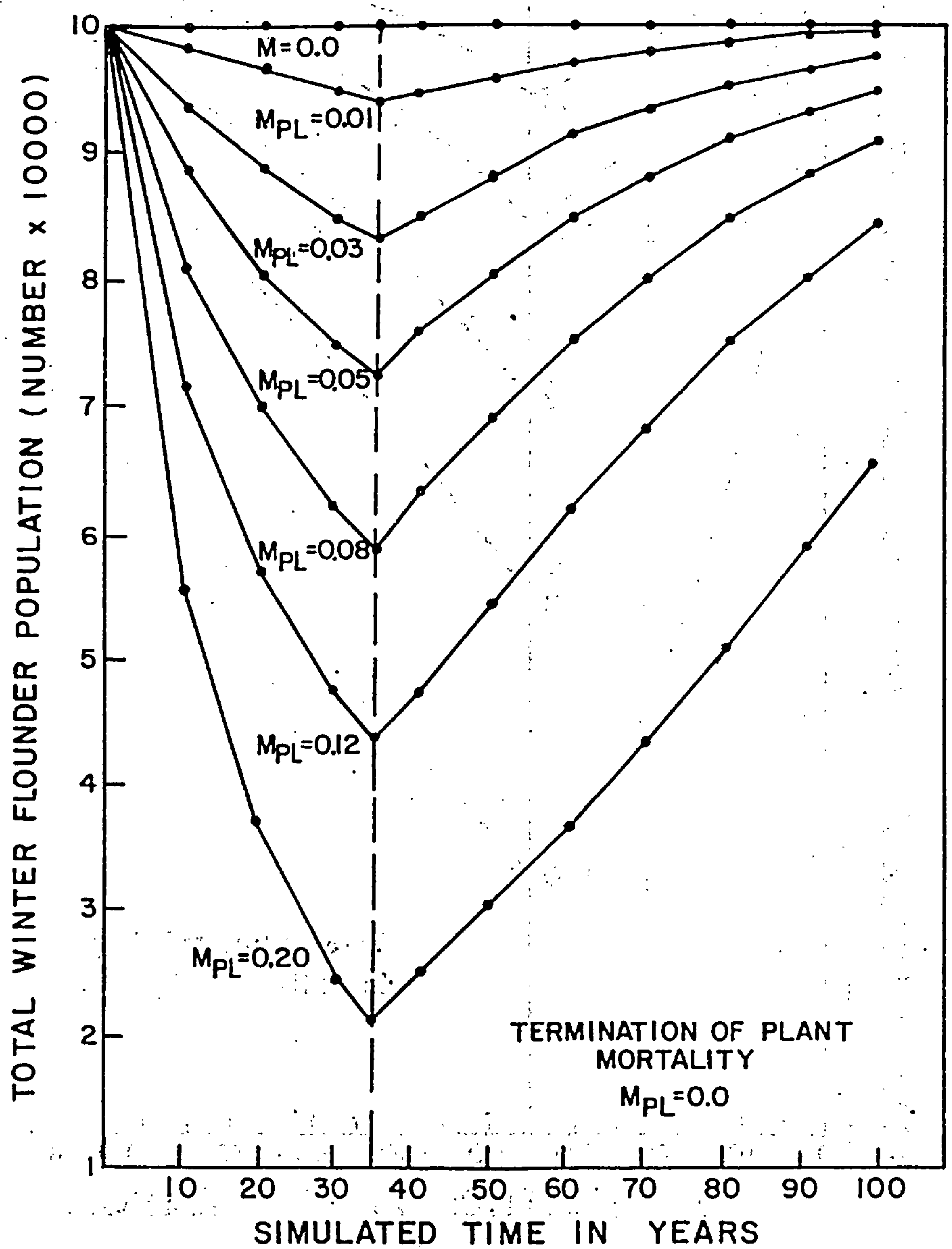


FIGURE 5.4-10
SIMULATED TOTAL POPULATION OF WINTER FLOUNDER BREEDING IN NIANTIC RIVER WITH VARIOUS LEVELS OF ENTRAINMENT MORTALITY, M_{PL}
MILLSTONE NUCLEAR POWER STATION

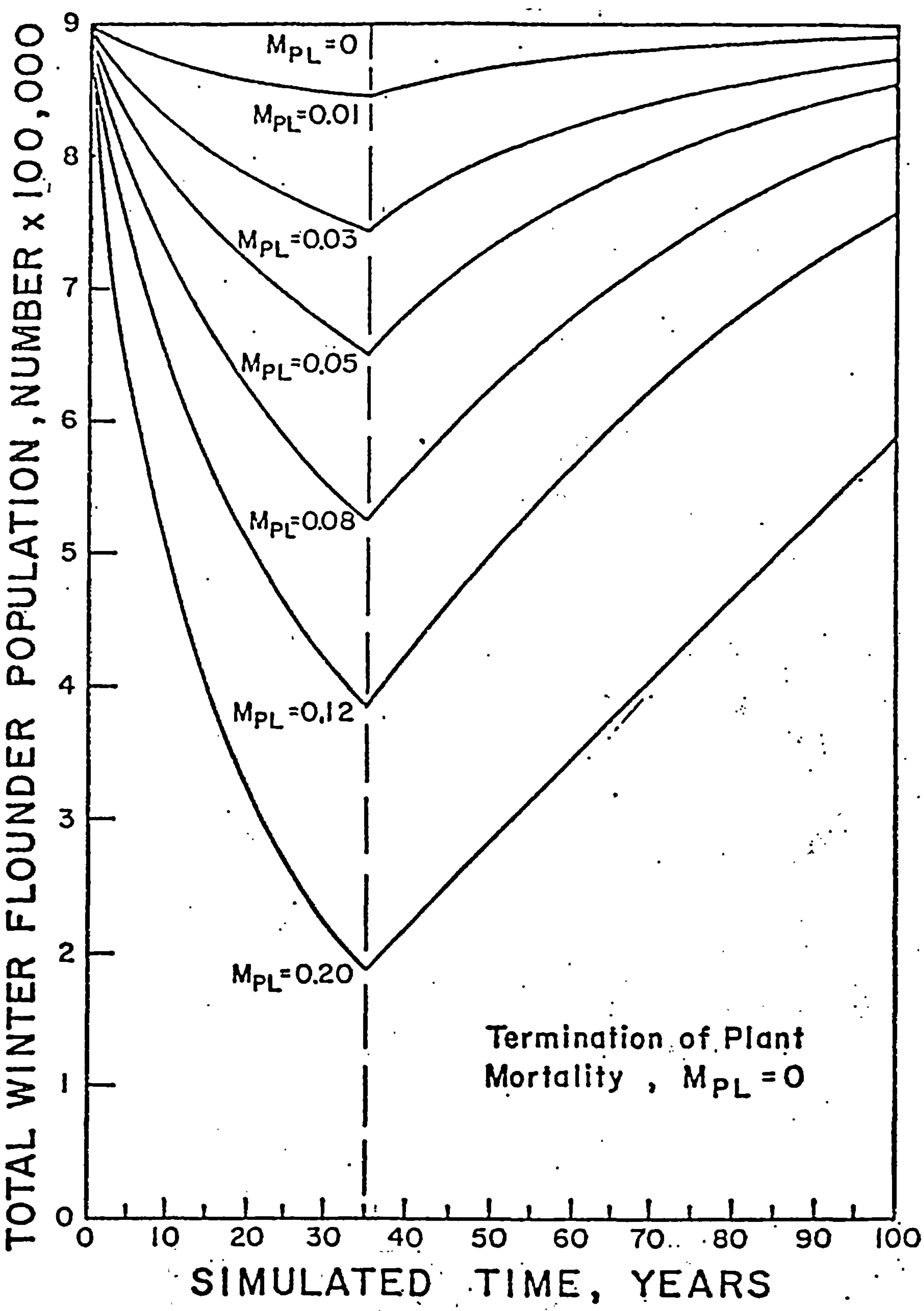


FIGURE 5.4-11 Simulated total population of winter flounder breeding in Niantic River based on Jolly's method with various levels of entrainment mortality (M_{PL}). $\hat{N}$ = 160,073.

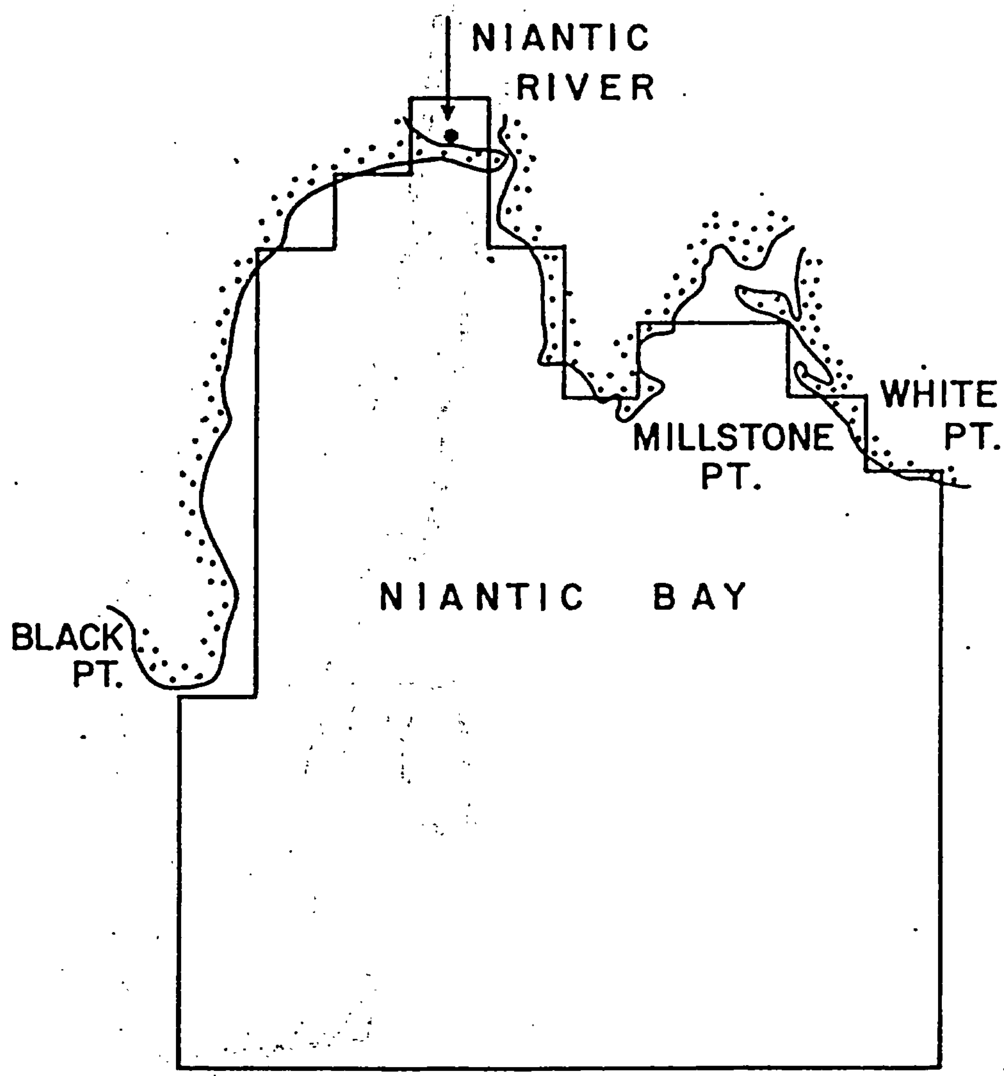


FIGURE 5.4–12
NIANTIC BAY GRIDNET, $\Delta L = 2000'$
MILLSTONE NUCLEAR POWER STATION

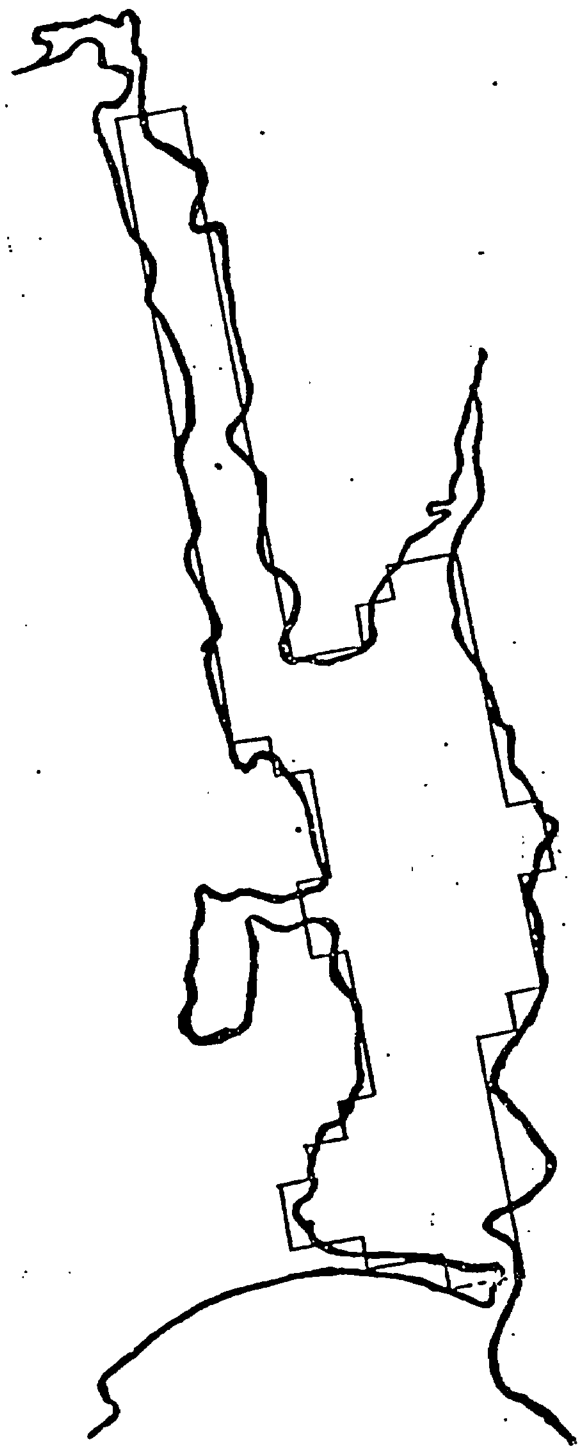


FIGURE 5.4–13

GRID NETWORK FOR THE NIANTIC RIVER, $\Delta L = 500$ FEET

MILLSTONE NUCLEAR POWER STATION

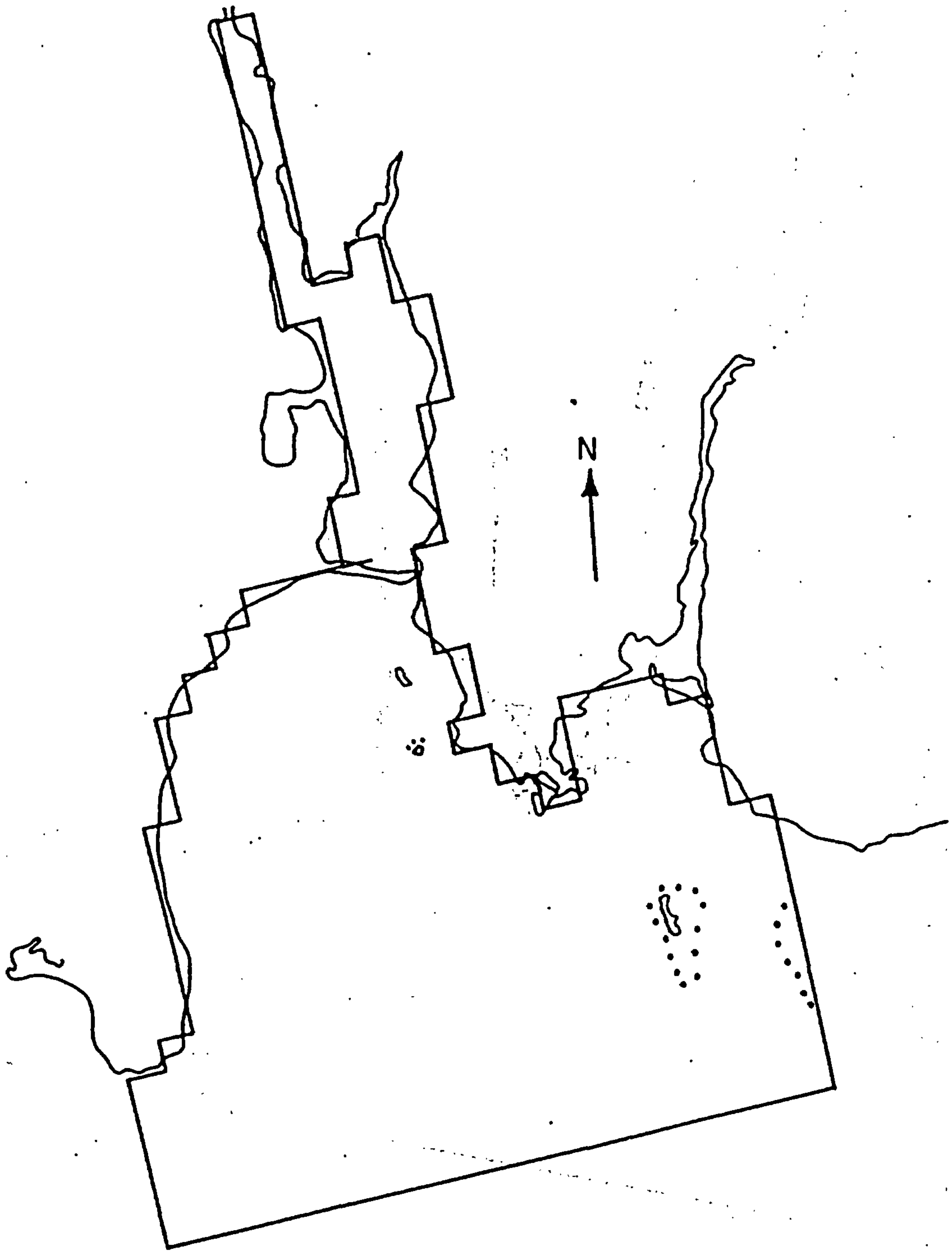


FIGURE 5.4-14
EARLIER GRID NETWORK FOR THE RIVER AND BAY MODEL, $\Delta L=1000'$
MILLSTONE NUCLEAR POWER STATION

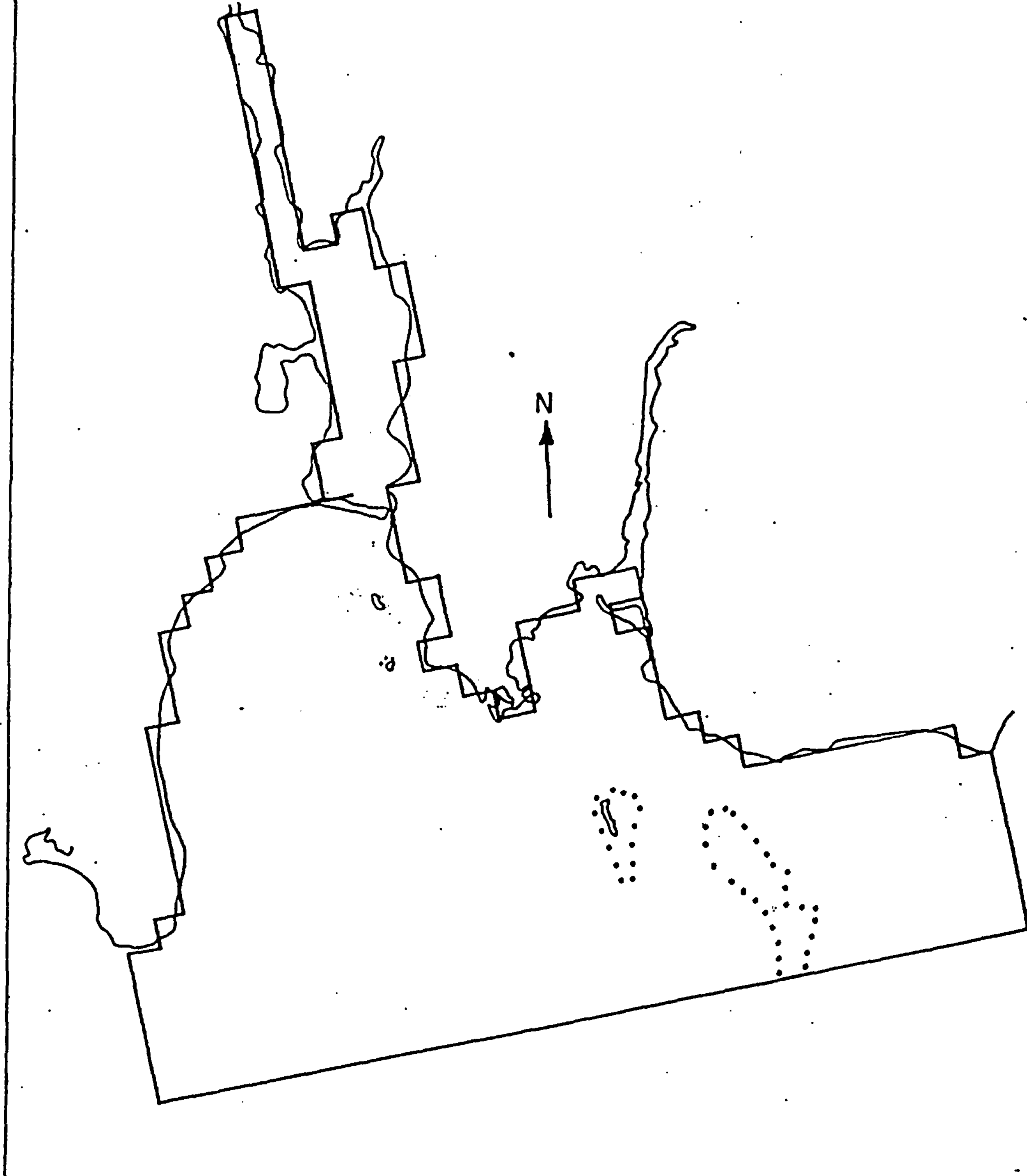
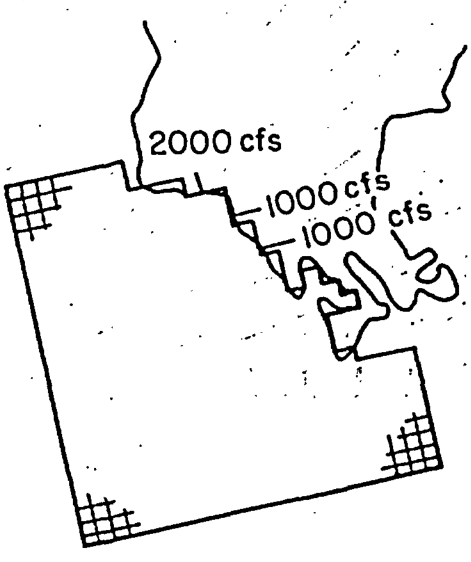


FIGURE 5.4-15
PRESENT GRID NETWORK FOR THE RIVER AND BAY MODEL, $\Delta L = 1000'$
MILLSTONE NUCLEAR POWER STATION

1000 ft GRID



200 ft GRID

FIGURE 5.4-16
GRID PATTERN NEAR MILLSTONE POINT NUCLEAR POWER PLANT
MILLSTONE NUCLEAR POWER STATION

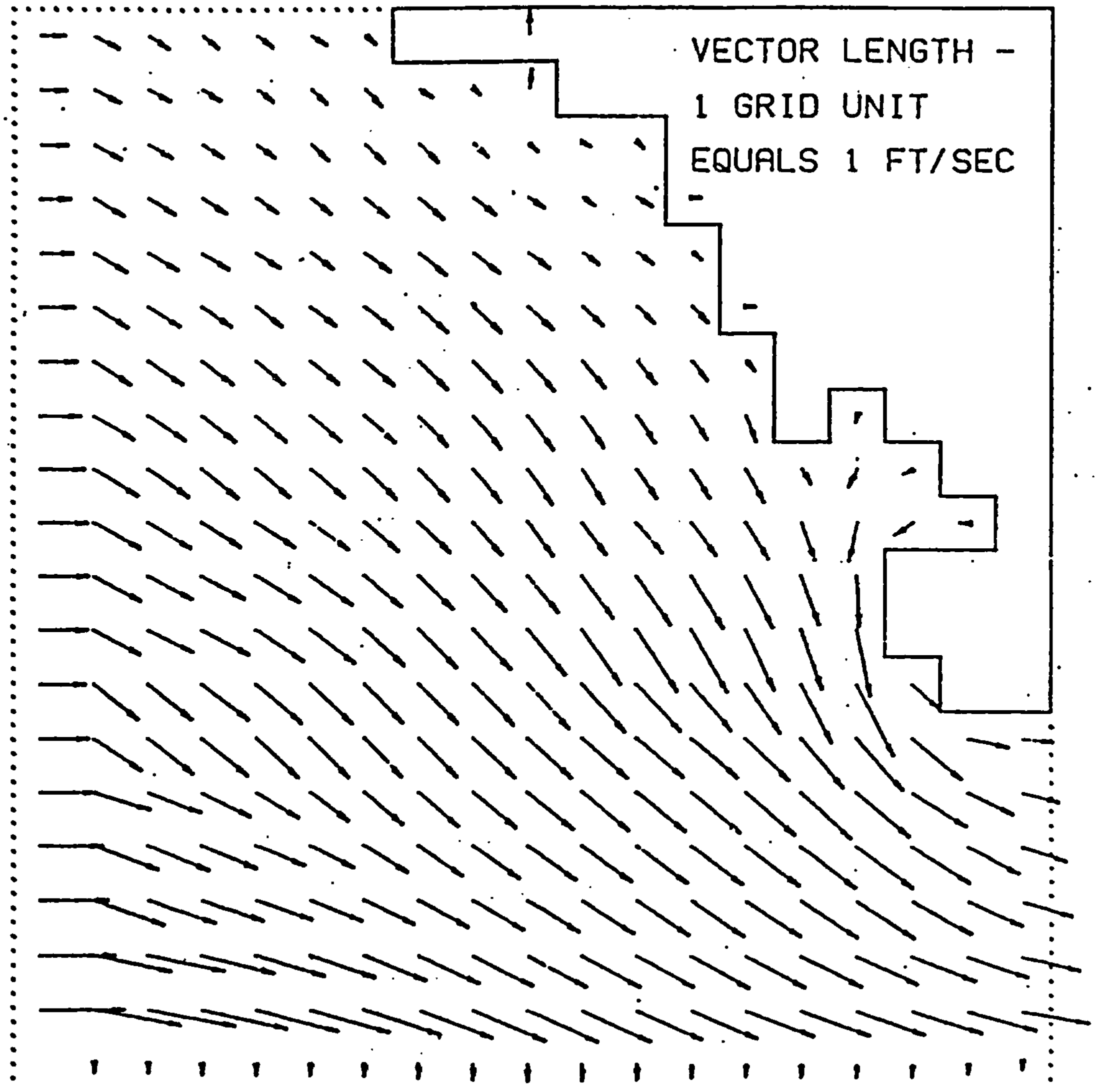


FIGURE 5.4-17

FLOOD CURRENT VELOCITIES NEAR THE PLANT AS PREDICTED BY THE 200FT. GRID SIZE HYDRODYNAMIC MODEL
MILLSTONE NUCLEAR POWER STATION

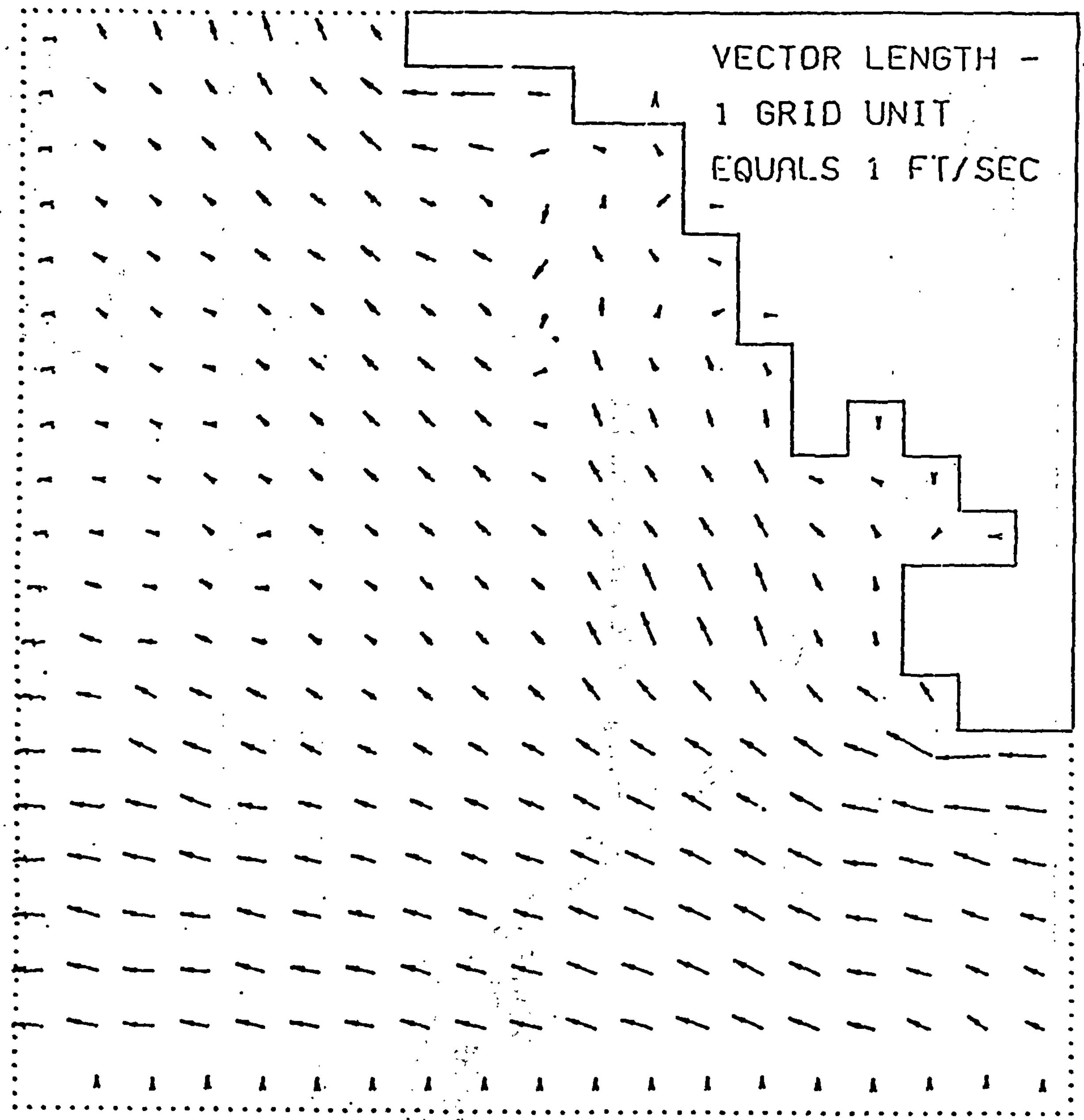


FIGURE 5.4-18

EBB CURRENT VELOCITIES NEAR THE PLANT AS PREDICTED BY THE 200 FT. GRID SIZE HYDRODYNAMIC MODEL

MILLSTONE NUCLEAR POWER STATION

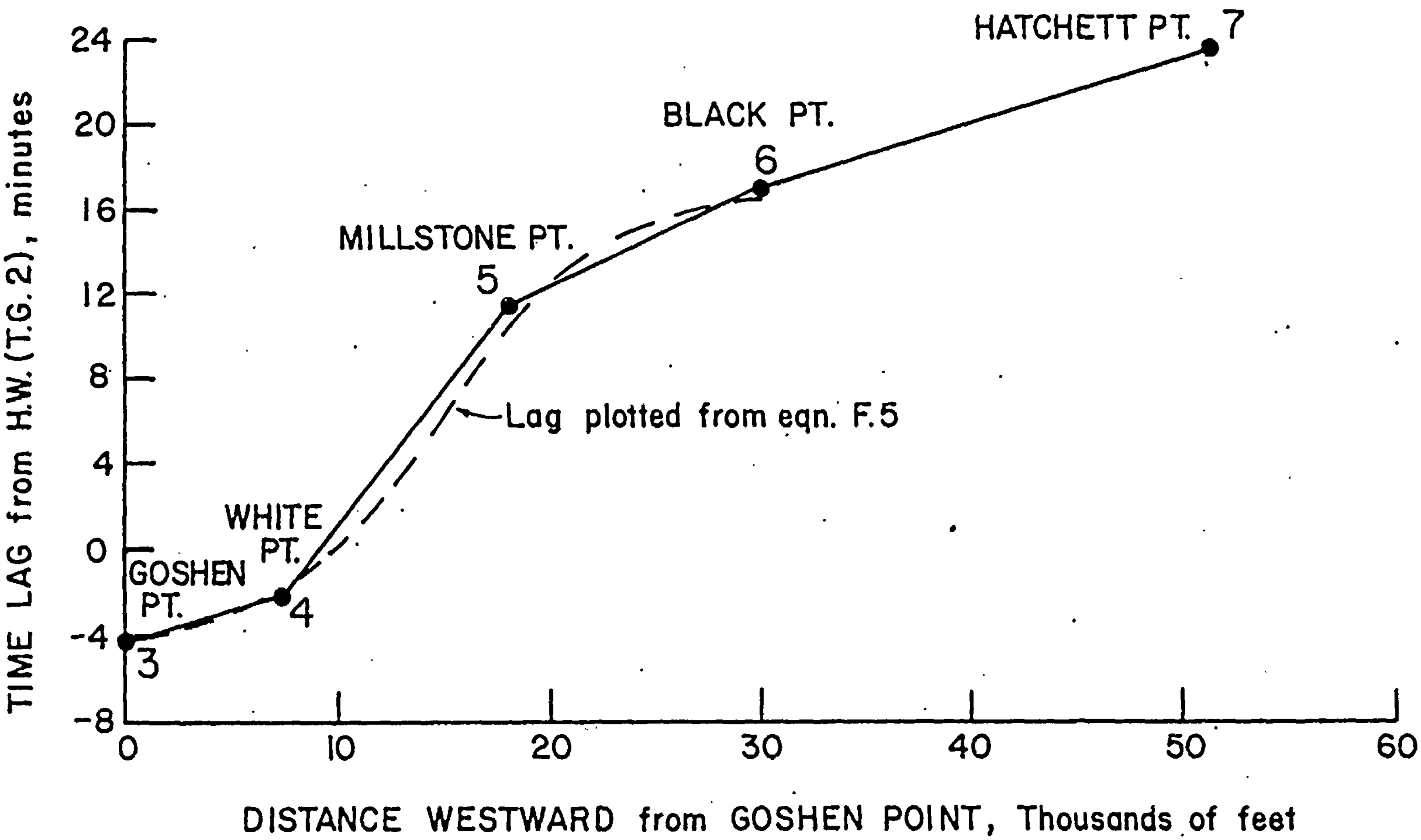


FIGURE 5.4-19
TIME LAG FROM HIGH WATER (H.W.) AT TIDE STATION 2 AS A FUNCTION OF DISTANCE WESTWARD FROM GOSHEN POINT
MILLSTONE NUCLEAR POWER STATION

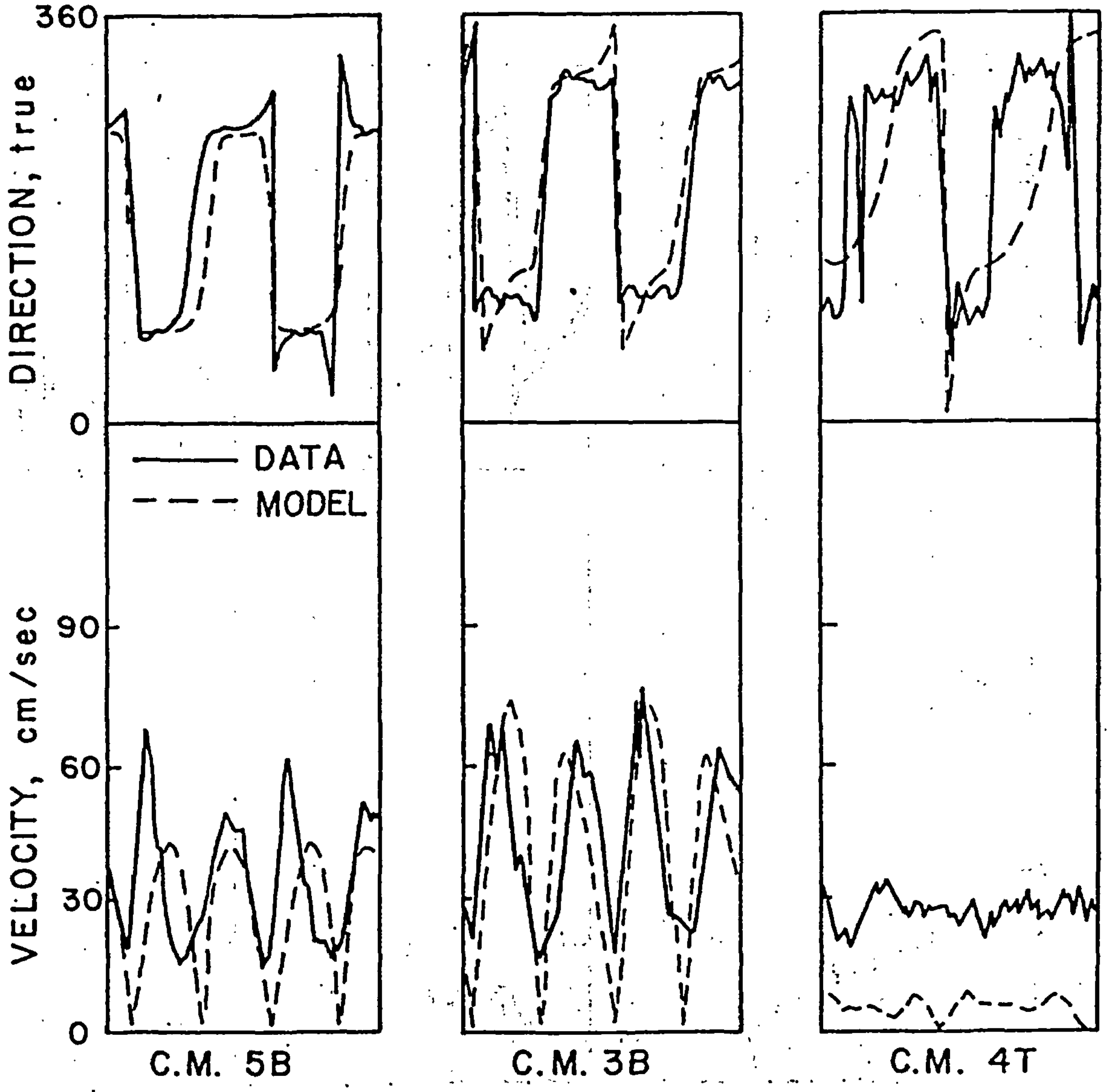


FIGURE 5.4-20
COMPUTED AND OBSERVED
CURRENT SPEED AND DIRECTION
FEB. 11, 1974 - C.M. 5B, 3B & 4T
MILLSTONE NUCLEAR POWER STATION

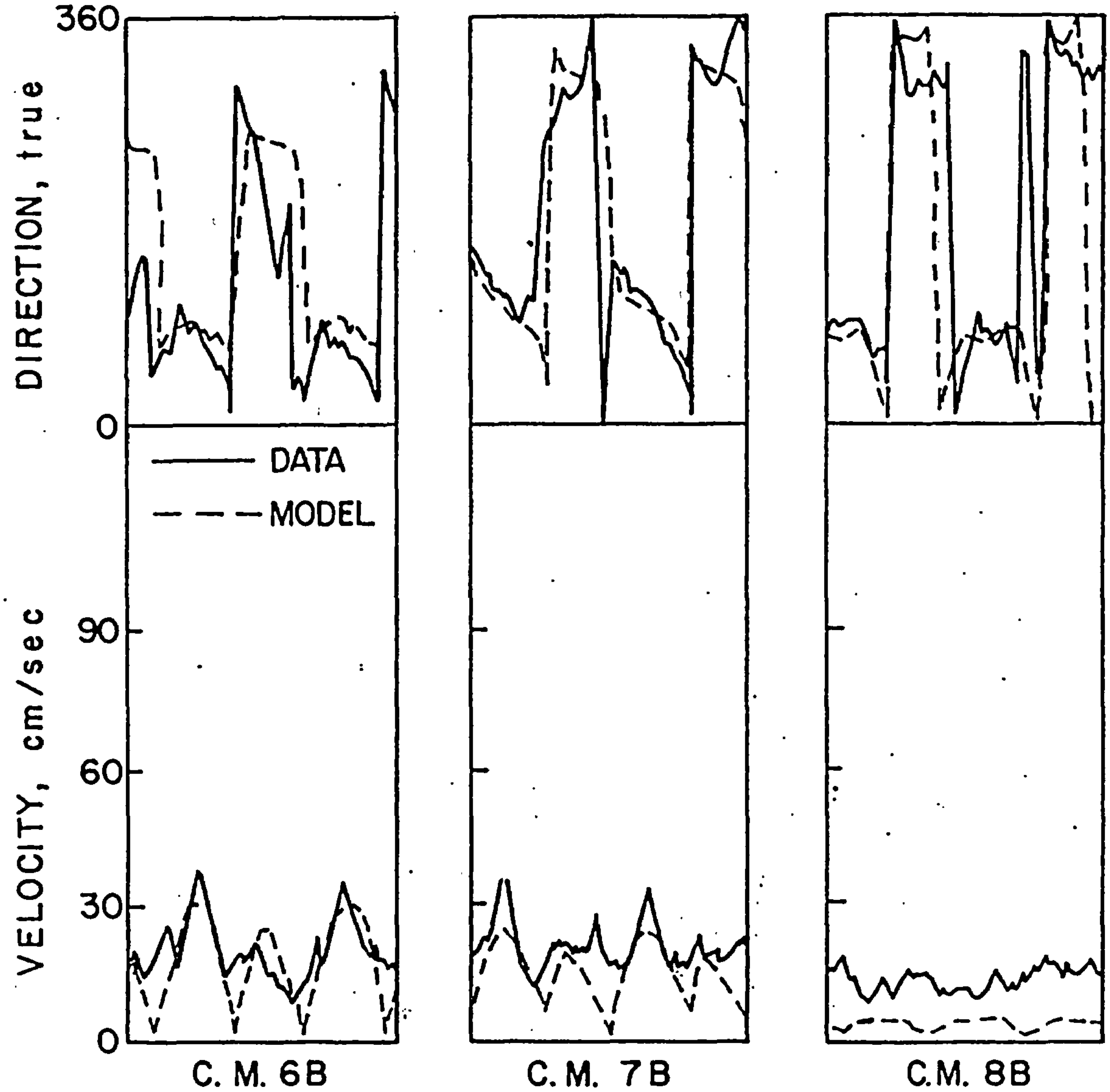


FIGURE 5.4-21
COMPUTED AND OBSERVED CURRENT SPEED AND DIRECTION FOR FEB. 11, 1974; C.M. 6B, 7B & 8B
MILLSTONE NUCLEAR POWER STATION

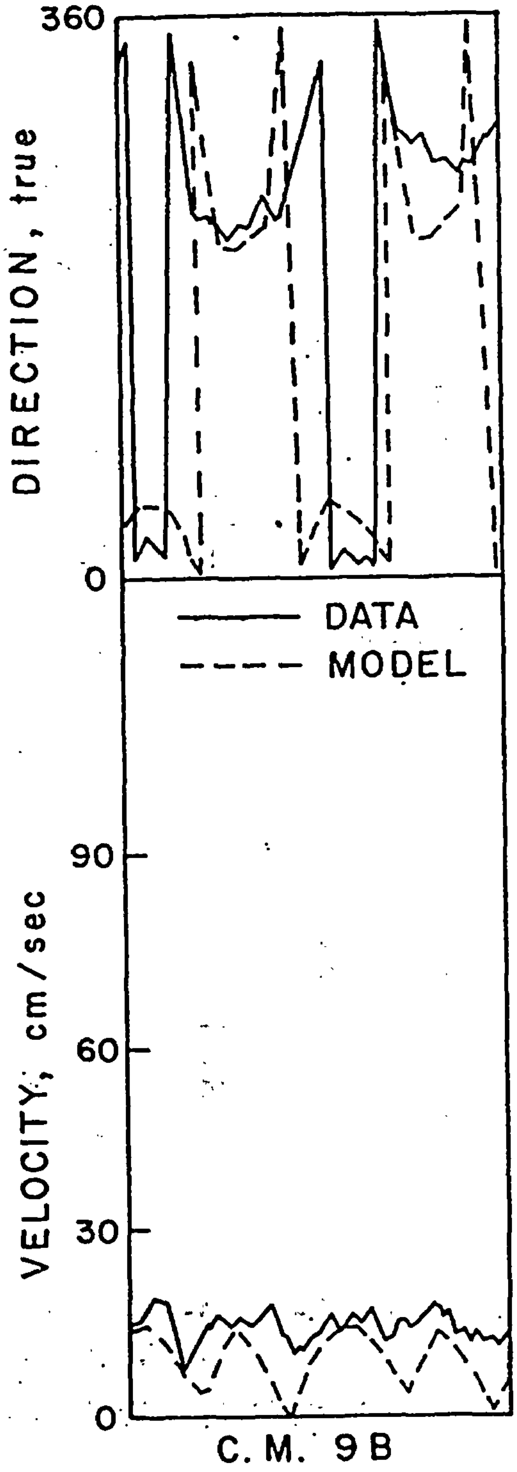


FIGURE 5.4-22
COMPUTED AND OBSERVED CURRENT SPEED AND DIRECTION FOR FEB. 11, 1974; C.M. 9B
MILLSTONE NUCLEAR POWER STATION

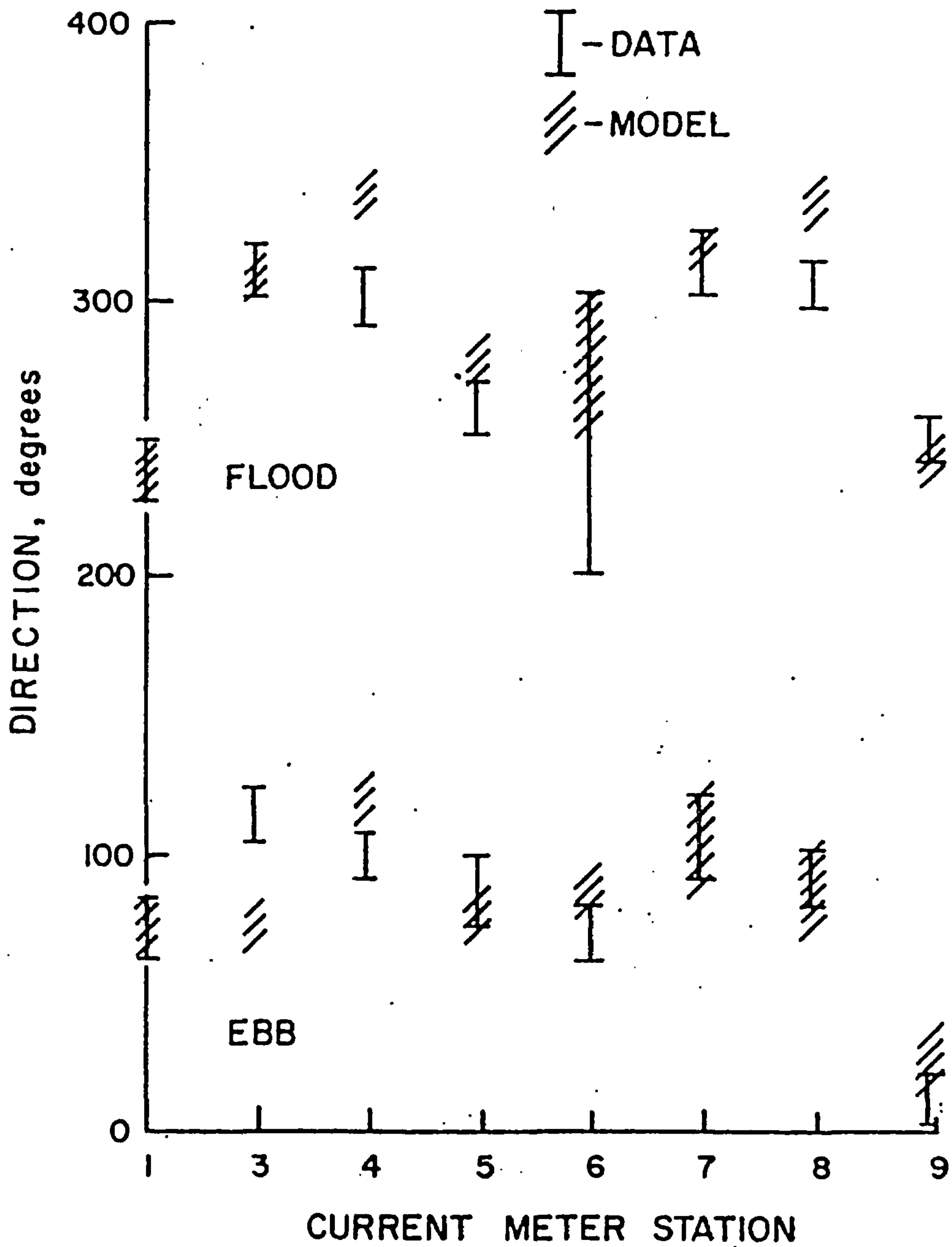


FIGURE 5.4-23
COMPARISON OF MODELED AND OBSERVED CURRENT DIRECTIONS SHOWING THE EXPECTED ACCURACY OF THE PREDICTIONS
MILLSTONE NUCLEAR POWER STATION

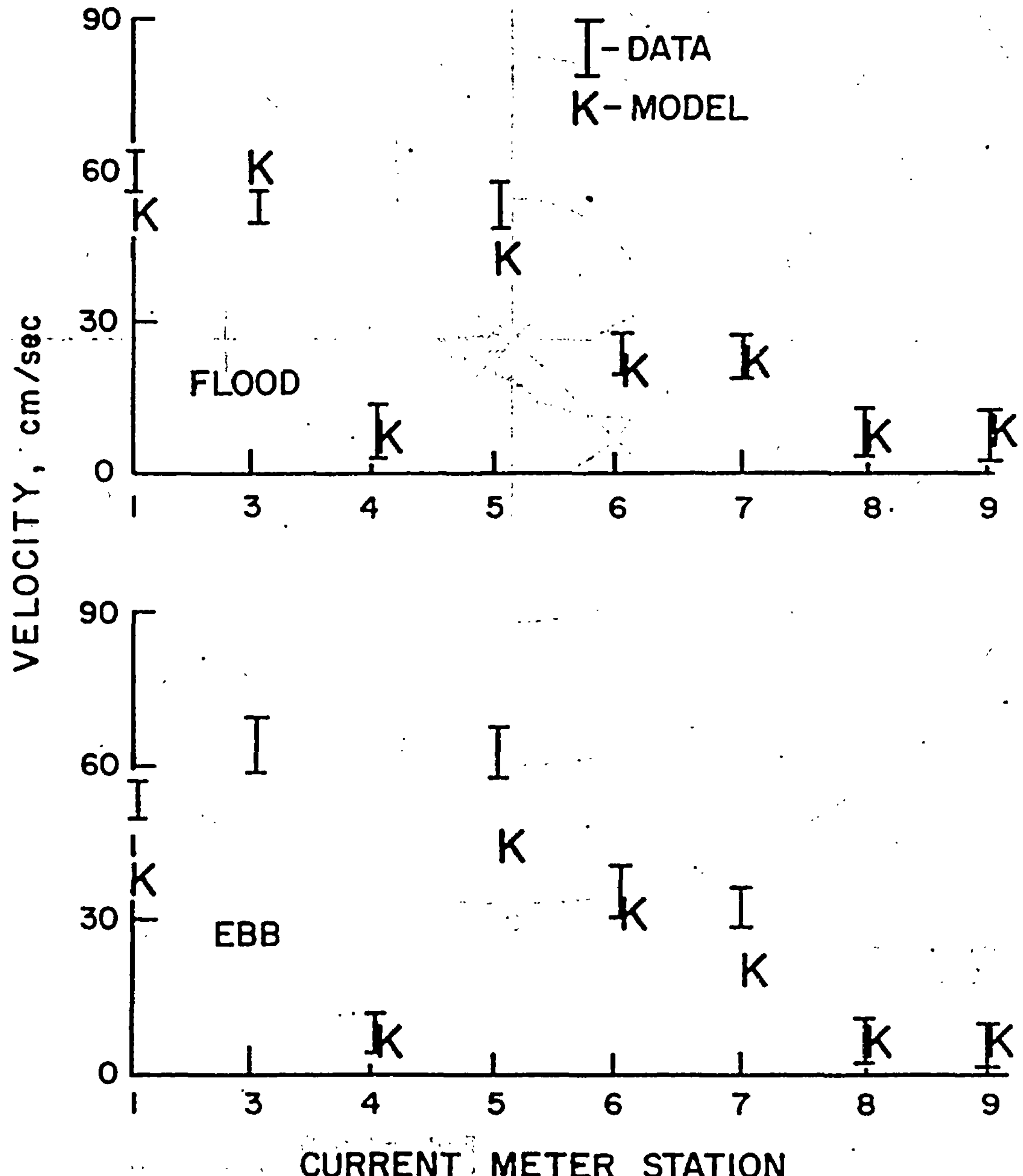


FIGURE 5.4-24
COMPARISON OF MODELED AND OBSERVED CURRENT SPEEDS SHOWING THE EXPECTED ACCURACY OF THE PREDICTIONS
MILLSTONE NUCLEAR POWER STATION

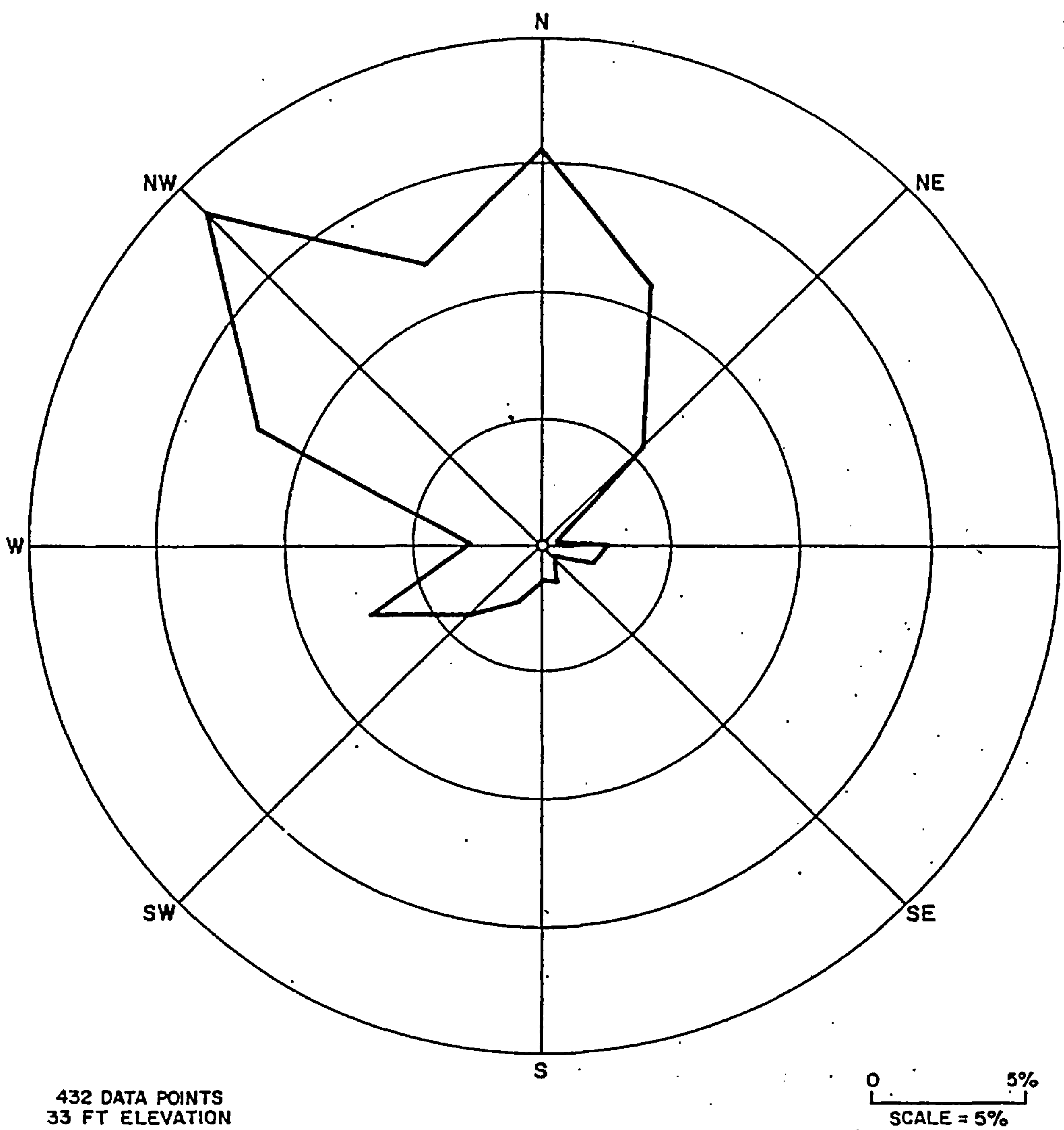


FIGURE 5.4-25
WIND DIRECTION FREQUENCY
AT MILLSTONE POINT,
FEBRUARY 1 TO 20, 1974
MILLSTONE NUCLEAR POWER STATION

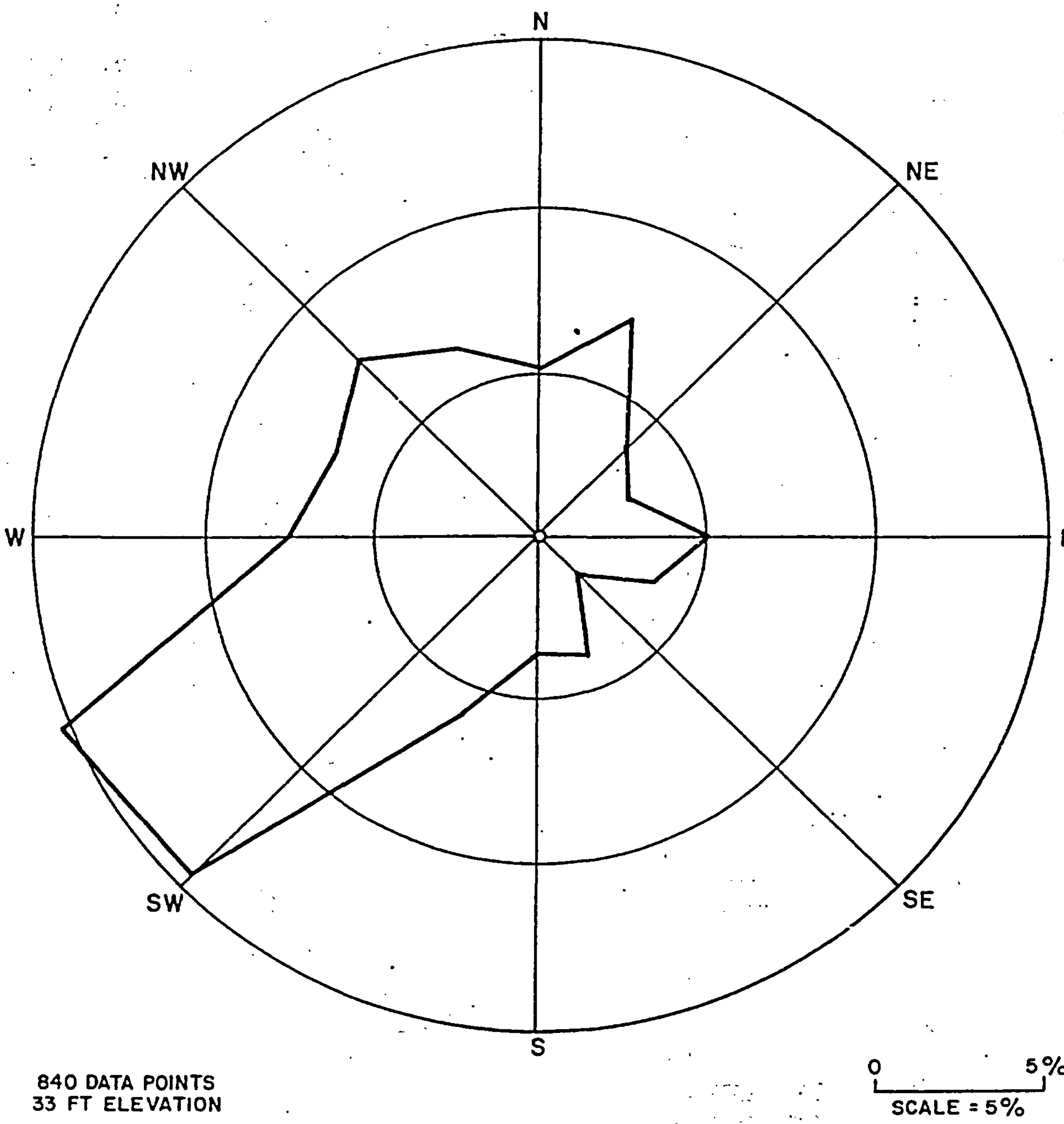


FIGURE 5.4-26
WIND DIRECTION FREQUENCY
AT MILLSTONE POINT,
8 AUG. TO 10 SEPT. 1973
MILLSTONE NUCLEAR POWER STATION

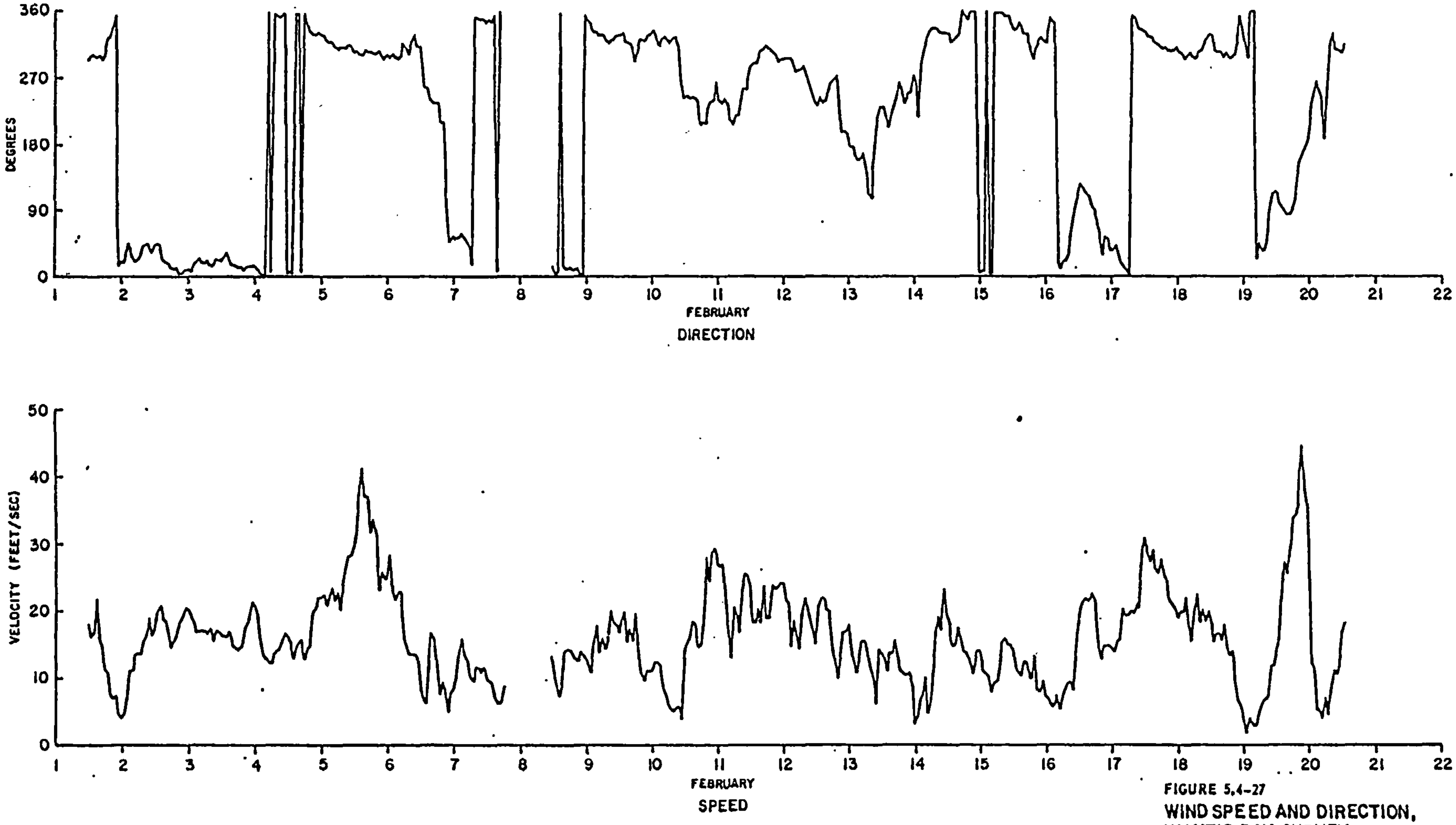


FIGURE 5.4-27
WIND SPEED AND DIRECTION,
NIANTIC BAY SURVEY,
MILLSTONE POINT, 33-FT. ELEV.,
1 FEB. TO 20 FEB. 1974
MILLSTONE NUCLEAR POWER STATION

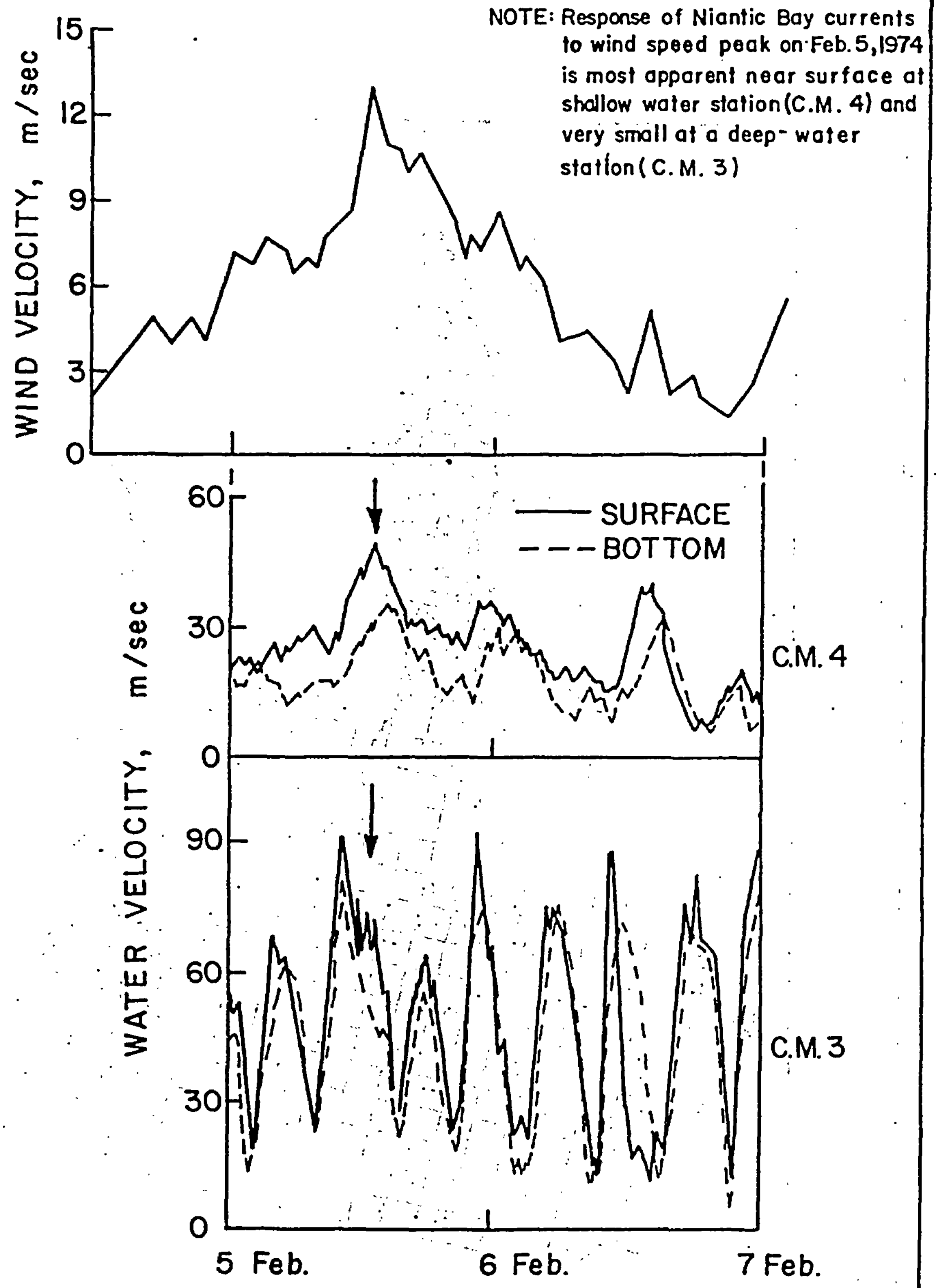


FIGURE 5.4-28
RESPONSE OF NIANTIC BAY CURRENTS TO WIND, FEB. 5-7, 1974
MILLSTONE NUCLEAR POWER STATION

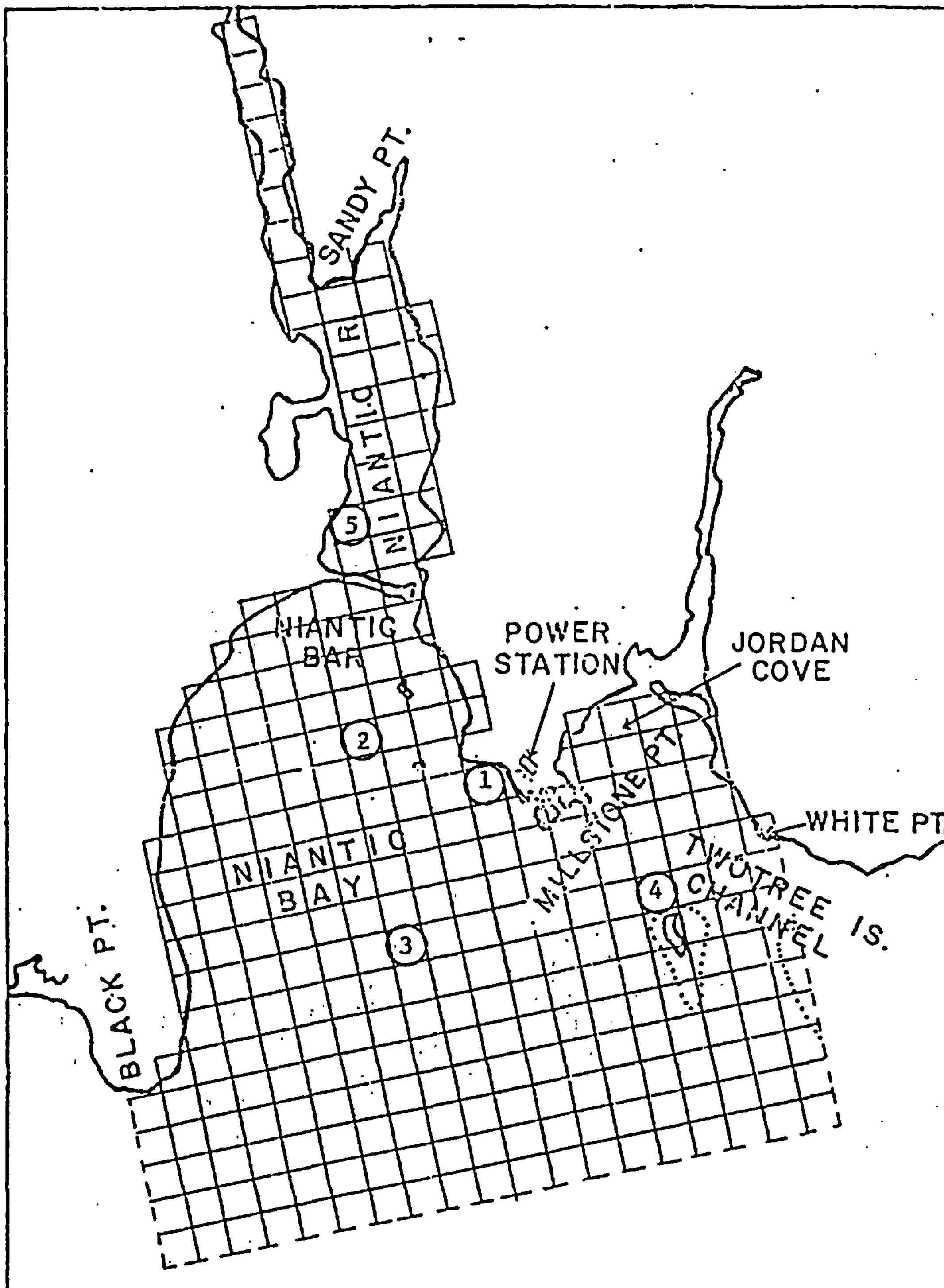


FIGURE 5.4-29 LOCATIONS OF DYE RELEASES.

(#)--STUDY NUMBER

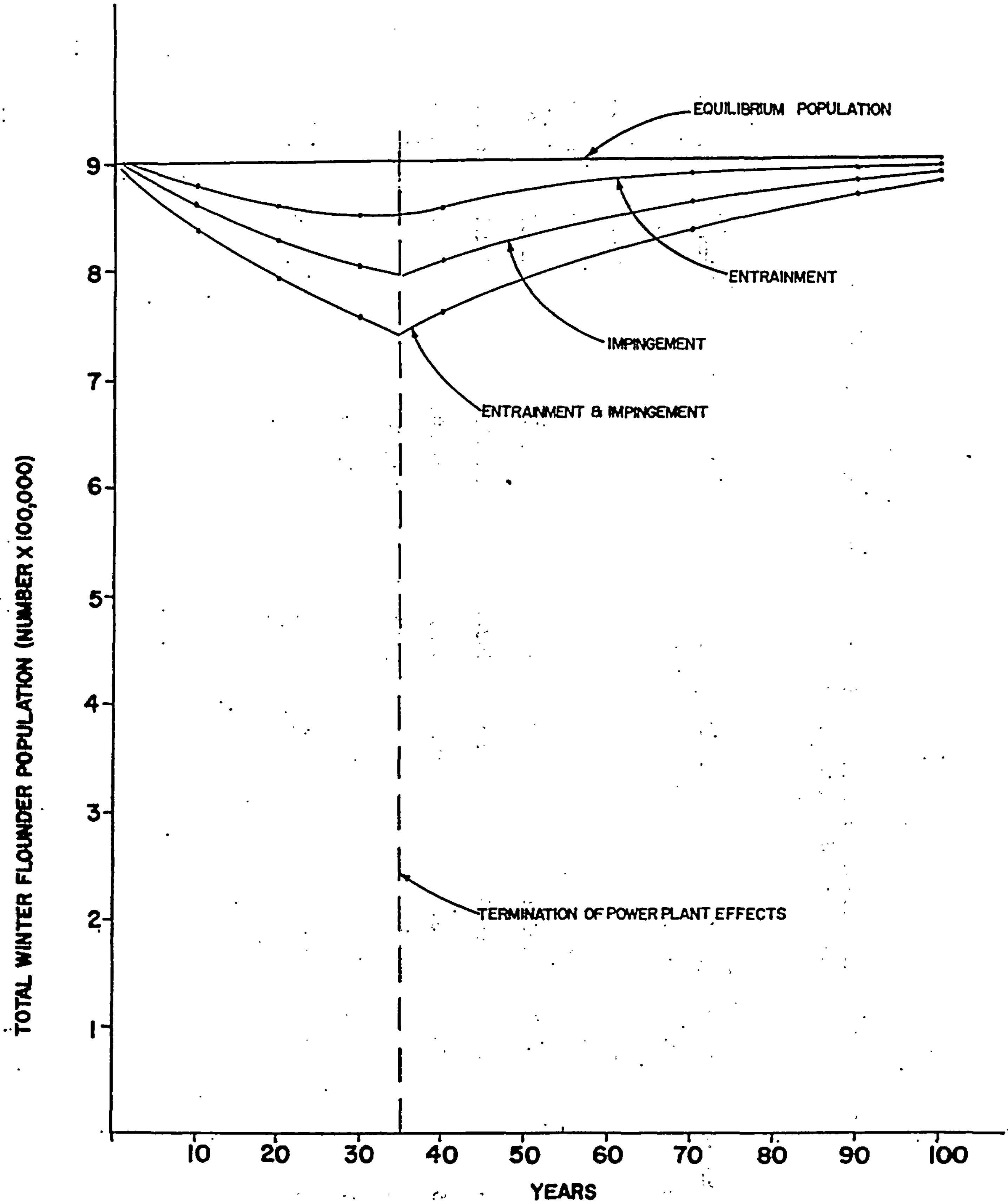


FIGURE 5.4-30 ESTIMATES OF THE EFFECT OF 3-UNIT OPERATION ON THE TOTAL WINTER FLOUNDER POPULATION

Table 5.5-1 **Basic Population Parameters for Atlantic Menhaden from Vaughan et.al. (1976) Length in Millimeters, Weight in Grams**

Year Class	Males Length	Males Weight	Females Length	Females Weight	Fecundity	Average Weight	Sex Ratio (M:F)
0	74.9	6.8	75.5	7.9	0	7.3	1:0.98
1	174.3	95.8	175.5	109.5	0	102.8	1:1.03
2	235.6	243.1	238.4	277.0	37,300	259.9	1:0.99
3	273.4	385.2	278.0	437.9	97,500	412.6	1:1.08
4	296.6	496.8	302.9	563.7	147,100	532.7	1:1.16
5	311.0	576.1	318.5	652.6	187,300	617.6	1:1.19
6	319.8	629.4	328.3	712.2	216,600	677.1	1:1.36
7	325.3	664.1	334.5	750.9	236,900	721.0	1:1.90
8	329.8	713.9	339.8	784.3	255,500	758.9	1:1.78

Table 5.5-2 Percent of fish tagged in an area which are found in other areas the next year (Dryfoos et al, 1973)

Tagging Area	Recovery Area Following Year: NY-NJ	Chesapeake	NC-FL
1967-1968			
NY-NJ	0.738	0.254	0.007
Chesapeake	0.269	0.730	0.001
NC-FL	0.132	0.653	0.204
1968-1969			
NY-NJ	0.882	0.112	0.006
Chesapeake	0.143	0.841	0.016
NC-FL	0.029	0.654	0.314
Combined Years			
NY-NJ	0.810	0.183	0.007
Chesapeake	0.206	0.786	0.009
NC-FL	0.081	0.654	0.259

NY-NJ is the New York - New Jersey subpopulation or the area north of the Chesapeake Bay subpopulation.

NC-FL is the North Carolina - Florida subpopulation or the area south of the Chesapeake Bay subpopulation.

Table 5.5-3 Menhaden impinged on Millstone traveling screens in 1975

Unit 1

Fish Size	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
0-2.9"	0	37	13	0	0	0	1	0	0	0	23	2	76
3-6"	0	0	2	0	0	0	0	0	0	0	105	11	118
6" +	3	0	6	9	0	0	1	0	14	1	4	2	40
Total	3	37	21	9	0	0	2	0	14	1	132	15	234
No. Alive	0	0	0	0	-	-	0	-	0	0	3	0	

Unit 2

Fish Size	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
0-2.9"									0	0	23	1	24
3-6"									0	0	34	4	38
6" +									1	2	0	0	3
Total									1	2	57	5	65
No. Alive									0	0	9	0	

TABLE 5.5-4 Change in age distribution (percent) for ages 1 through 4 for a simulation of 5 years of power plant mortality (m = 0.087) in the NY-NJ areas, followed by recovery.

Area	Age	Without Power Plant Mortality	After 5 Years of Power Plant Mortality	Years of Recovery 1	2	3	4	Years to Complete Recovery
NY-NJ	1	0.7828	0.7726	0.7875	0.7831	0.7828	-	3
	2	0.1709	0.1773	0.1656	0.1713	0.1709	-	3
	3	0.0367	0.0393	0.0368	0.0359	0.0367	-	3
	4	0.0077	0.0085	0.0079	0.0077	0.0076	-	3
Chesapeake	1	0.7832	0.7818	0.7818	0.7828	0.7831	0.7832	4
	2	0.1731	0.1736	0.1736	0.1734	0.1731	0.1731	4
	3	0.0350	0.0356	0.0356	0.0349	0.0350	0.0350	4
	4	0.0070	0.0072	0.0072	0.0071	0.0069	0.0070	4
Carolina-Florida	1	0.9135	0.9120	0.9120	0.9133	0.9135	-	3
	2	0.0783	0.0795	0.0795	0.0784	0.0783	-	3
	3	0.0073	0.0075	0.0075	0.0074	0.0073	-	3
	4	0.0008	0.0008	0.0008	0.0008	0.0008	-	3

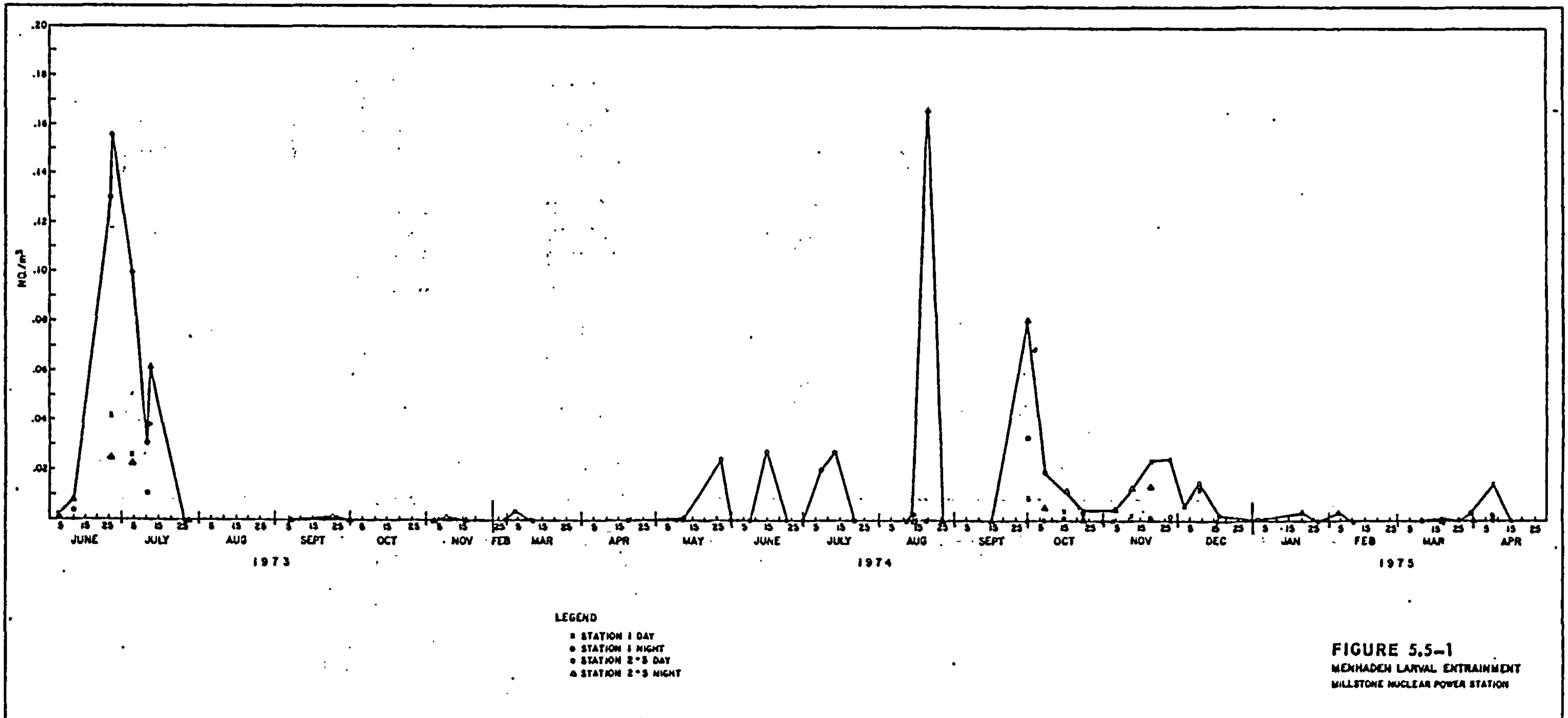


FIGURE 5.5-1
MENHADEN LARVAL ENTRAINMENT
MILLSTONE NUCLEAR POWER STATION

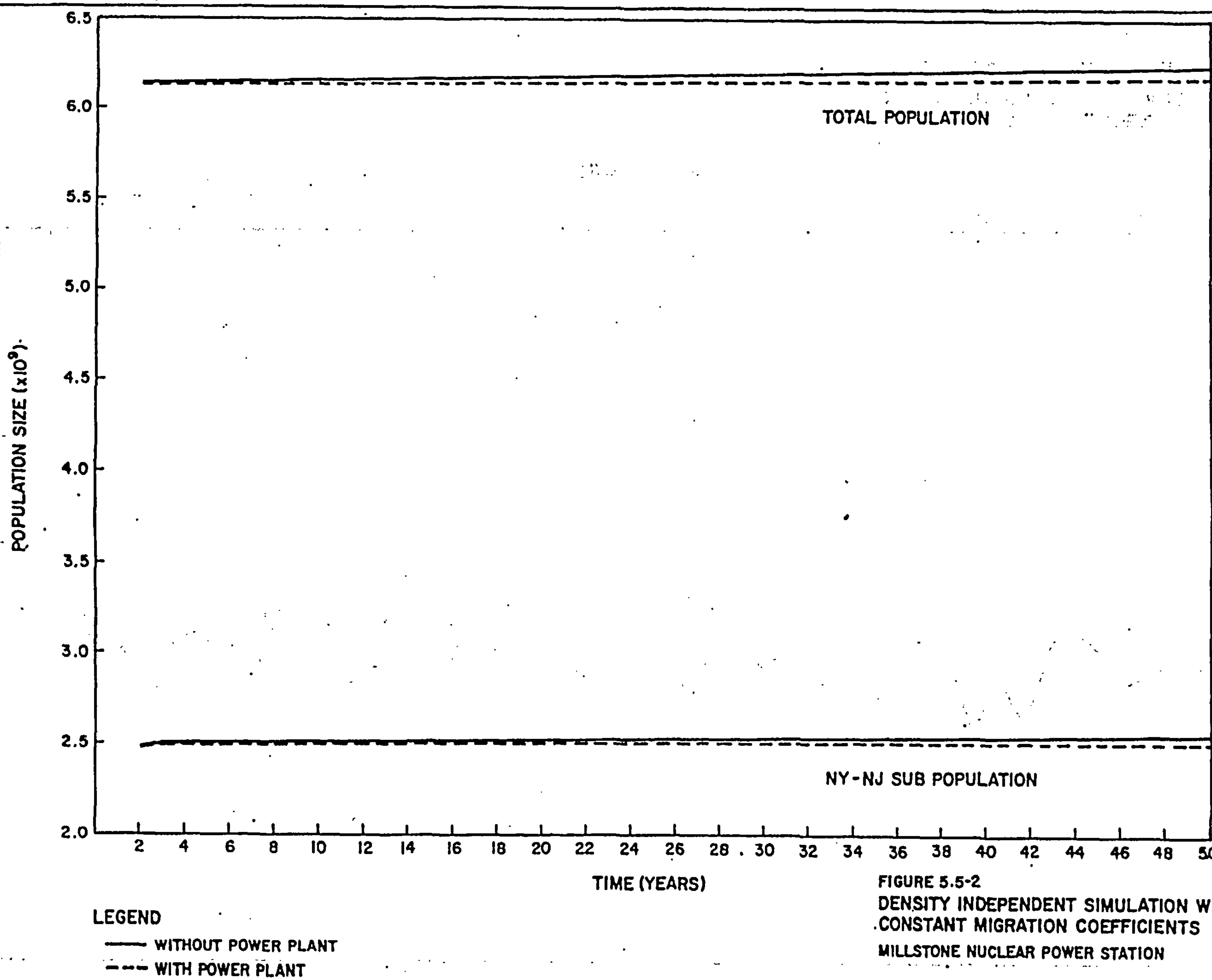


FIGURE 5.5-2
DENSITY INDEPENDENT SIMULATION WITH CONSTANT MIGRATION COEFFICIENTS
MILLSTONE NUCLEAR POWER STATION

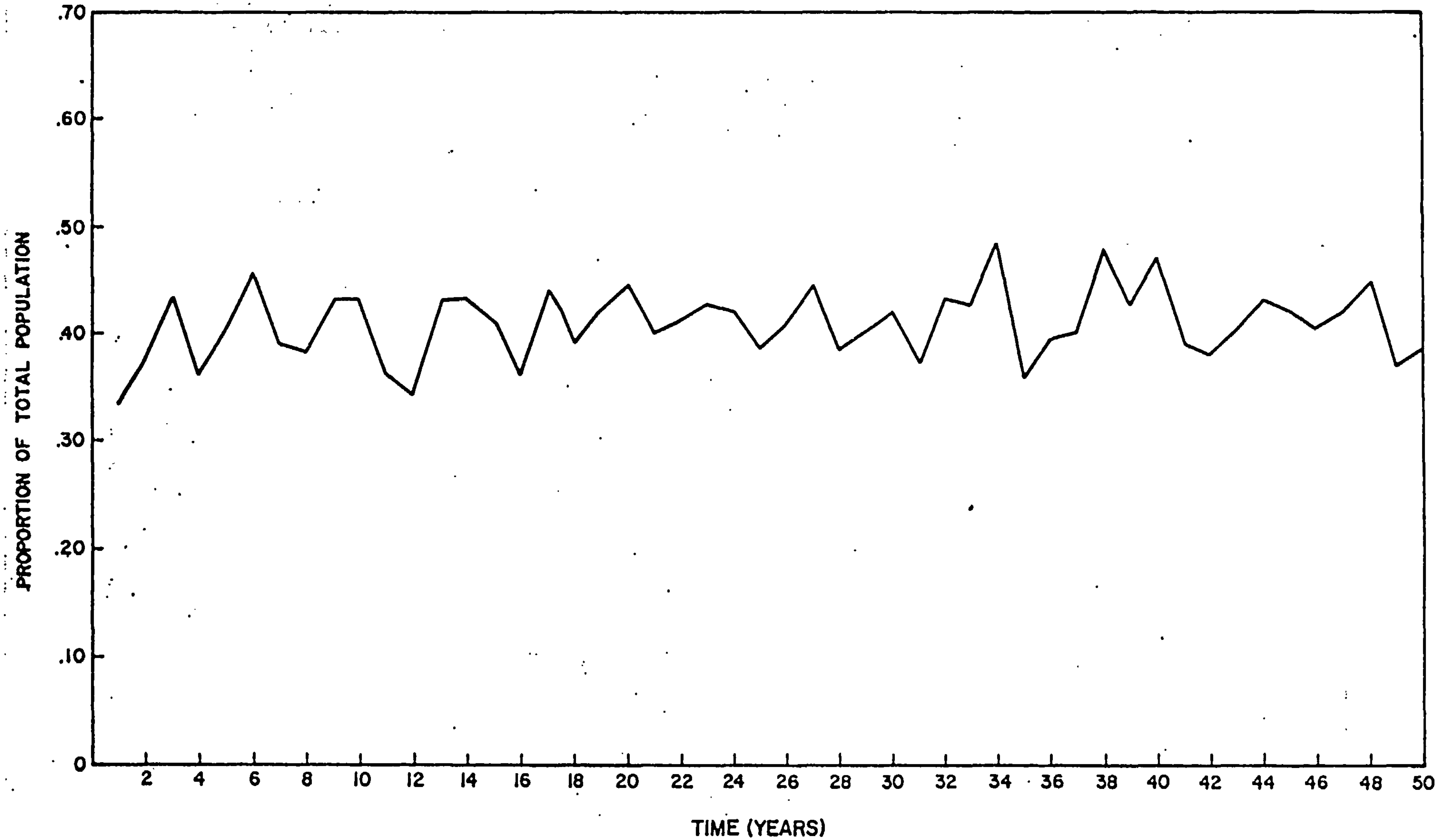
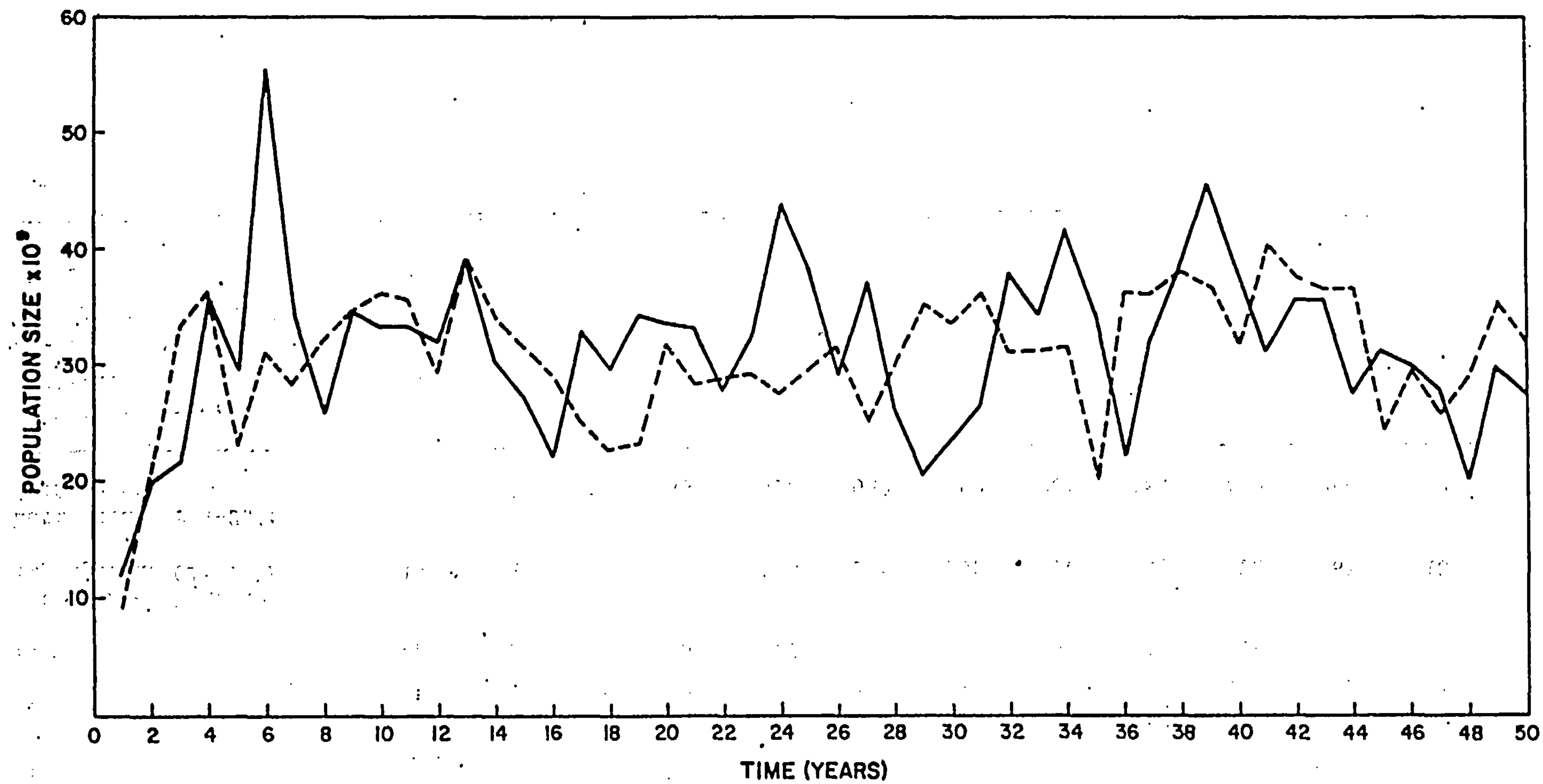


FIGURE 5.5-3
PROPORTION OF MENHADEN POPULATION IN THE NY-NJ AREA
MILLSTONE NUCLEAR POWER STATION



LEGEND
—— WITHOUT POWER PLANT
– – – WITH POWER PLANT

FIGURE 5.5-4
RESULTS OF STOCHASTIC DENSITY DEPENDENT SIMULATION
MILLSTONE NUCLEAR POWER STATION

TABLE 5.6-1. CALCULATION OF ESTIMATED NUMBER OF LOBSTERS KILLED ANNUALLY BY THREE-UNIT OPERATION

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1972					57	361	176	291	78	19	5	4
1973	1	2	22	130	308	185	137	181	38	117	88	20
1974	2	2	45	90	151	243	273	204	30	314	85	2
1975	40	3	25	67	78	272	176	30	18	29	83	46
Actual Mean Monthly Impingement (Unit 1)	14	2	31	96	148	265	190	176	41	120	65	18
Estimated Three-Unit Impingement	56	8	124	384	592	1,060	760	704	164	480	260	72

Toal Impingement Estimate	4,664
Percent Killed (Based on 1975 Data)	21
Number Killed	979

TABLE 5.6-2. CALCULATION OF ESTIMATED POUNDS OF LOBSTER IMPINGED ANNUALLY BY THREE-UNIT OPERATION

	Year			
	1972	1973	1974	1975
Number Impinged (Unit 1)	994	1,232	1,394	867
Estimated Mean Weight Per Lobster (Pounds)	0.75	0.75	0.75	0.75
Estimated Total Weight of Lobsters Impinged Annually	745	924	1,046	650
Estimated Mean Annual Weight of Lobsters Impinged (Pounds)		841		
Estimate of Annual Weight of Lobsters Impinged by Three-Unit Operation (Pounds)		3,364		

TABLE 6-1 Estimate of benthic invertebrate standing crop removed by placement of cofferdam. Based on Clapp Labs samples December, 1974.

Species	Standing Crop Estimate (No./m^2)	Estimated Loss Number of Organisms
Cumingia tellinoides	12.7	51,559
Lyonsia hyalina	12.7	51,559
Nucula proxima	12.7	51,559
Pitar morrhuana	12.7	51,559
Tellina agilis	178.4	721,823
Glyceridae	12.7	51,559
Glycera sp.	25.5	103,118
Nephytidae	12.7	51,559
Nephtys picta	25.5	103,118
Nephtys spp.	12.7	51,559
Phyllodoce sp.	12.7	51,559
Fabricia sabella	12.7	51,559
Terebellidae	25.5	103,118
Ampelisca macrocephala	203.8	824,940
Ampelisca verrilli	1,210.9	4,898,084
Ampelisca spp.	101.9	412,470
Corophium sp.	12.7	51,559
Leptocheirus pinguis	12.7	51,559
Pagurus longicarpus	12.7	51,559
Pinnixa sayana	12.7	51,559
Total	1,936.5	7,837,016
95% confidence interval	$828 \leq \mu \leq 3045$	$3,318,540 \leq \mu \leq 12,322,955$