Appendix C Continued

APPENDIX C

APPENDIX C1
EFFECTS OF THERMAL DISCHARGES ON PLANKTON, MACROINVERTEBRATES, AND FISH

Page

Page

Page

APPENDIX C2
EFFECTS OF THERMAL DISCHARGES ON MORTALITY OF
MERCENARIA MERCENARIA IN BARNEGAT BAY

APPENDIX C3
THE MARINE BORING AND FOULING INVERTEBRATE COMMUNITY

APPENDIX C4
WOODBORER STUDY ASSOCIATED WITH THE OYSTER CREEK
GENERATING STATION-ANNUAL REPORT FOR
JUNE 1, 1975 to MAY 31, 1976

APPENDIX C5

WOODBORER STUDY ASSOCIATED WITH THE OYSTER CREEK GENERATING STATION -ANNUAL REPORT FOR JUNE 1, 1976 TO NOVEMBER 30, 1977

APPENDIX C6

A SEASONAL PLANKTON CYCLE IN BARNEGAT BAY, NEW JERSEY

APPENDIX C7

COMPOSITION AND PERIODICITY OF PHYTOPLANKTON AND ZOOPLANKTON FROM BARNEGAT BAY

Page

APPENDIX C8
EFFECTS OF THERMAL DISCHARGES ON THE STRUCTURE
OF PERIPHYTIC DIATOM COMMUNITIES

APPENDIX C9
BENTHIC MACROINVERTEBRATES

Page

APPENDIX C10

FISHES OF BARNEGAT BAY, NEW JERSEY, WITH PARTICULAR REFERENCE WITH PARTICULAR REFERENCE TO SEASONAL INFLUENCES AND THE POSSIBLE EFFECTS OF THERMAL DISCHARGES

Page

APPENDIX C2

APPENDIX C2

EFFECTS OF THERMAL DISCHARGES ON MORTALITY OF MERCENARIA MERCENARIA IN BARNEGAT BAY, NEW JERSEY

By MICHAEL JOSEPH KENNISH

A thesis submitted to

The Graduate School

of

Rutgers University

in partial fulfillment of the requirements

for the degree of

Doctor of Philosophy

Written under the direction of

Dr. Richard K. Olsson

of the Department of Geology

New Brunswick, New Jersey

June, 1977

ABSTRACT OF THE THESIS

Effects of thermal discharges on mortality

of Mercenaria mercenaria in

Barnegat Bay, New Jersey

by MICHAEL JOSEPH KENNISH, Ph.D.

Thesis director: Professor Richard K. Olsson

Thermal discharges from the Oyster Creek Nuclear Generating Station do not affect mortality in natural populations of Mercenaria mercenaria in Barnegat Bay, New Jersey. The analyses of daily growth increments and disturbance bands in shell cross-sections of death assemblages of the pelecypods collected at the mouth of Oyster Creek (strongly affected by thermal discharges) and at three control sites (unaffected by thermal discharges) in the bay indicates that similar mortality patterns exist in all assemblages. This is revealed by mortality rate curves, survivorship curves, and life tables which are nearly identical for each assemblage.

Each death assemblage results from natural rather than census mortality as is evident from its corresponding death-frequency histogram which shows that individuals died at different times of the year. The peak frequency of stress and death occurs in older individuals of the populations and develops in the summer and winter. The high incidence of summer death may be associated with the effects of physiological stress during spawning and with increased activity of predators and parasites during the warmer months of the year, whereas high winter mortality seems to be caused by harsh environmental conditions.

Size distributions of death assemblages of natural populations of M. mercenaria at the mouth of Oyster Creek and at eight control sites in the bay are also alike. All of the distributions define unimodal, negatively skewed curves. This is a consequence of growth rates which decrease with age and mortality rates which increase with age in post-set clams. The similarity in the size distributions of death assemblages of clams throughout Barnegat Bay is additional evidence that the thermal discharges have not affected mortality in natural populations of M. mercenaria. The unimodal, negatively skewed curve describing the distribution of live clam sizes at the mouth of Oyster Creek also supports this contention.

Mortality data recorded on life assemblages of M. mercenaria transplanted to the substrate for one year at the mouth of Oyster Creek and at a single control site in the bay confirm that thermal discharges are not adversely affecting mortality in the bivalve. Mortality is significantly greater in the assemblage recovered at the control site one year after transplantation than in the assemblage retrieved at the mouth of Oyster Creek. Shell microgrowth analysis of the dead specimens collected at each locality reveals the following (1) maximum frequency of death in clams is between 50 mm and 65 mm in height', and 5 to 6 years of age; (2) peak frequency of death is in the summer; (3) no significant difference in the seasonal frequency of death exists between the two samples; and (4) natural rather than catastrophic mortality is evident.

It is concluded that mortality of <u>M. mercenaria</u> in Barnegat Bay is due to the normal population dynamics of the species, and is not associated with the thermal discharges. The pattern of ontogenetic mortality in the bivalve is high-low-high. Mortality is high during the planktonic larval stages, low subsequent to spat settlement, and high again in the gerontic stage. Mortality rates rise significantly after sexual maturity is attained.

TABLE OF CONTENTS
APPENDIX C2

LIST OF FIGURES

LIST OF FIGURES - Cont'd.

LIST OF FIGURES - Cont'd.

LIST OF TABLES

EXPLANATION OF PLATES

INTRODUCTION

One of the principal environmental concerns surrounding the operation of the Oyster Creek Nuclear Generating Station in Ocean County, New Jersey, is its influence on the ecological conditions in Barnegat Bay. Much of this concern centers around the vulnerability of many estuarine organisms to the effects of entrainment and passage through station condensers, impingement on intake screens, chemical and biocide releases, and thermal discharges. Research conducted by the Jersey Central Power and Light Company (United States Atomic Energy Commission, 1974) indicates that these factors are, in part, responsible for increased mortality of nekton and plankton at the station.

There has been much interest surrounding the possible relationship of thermal discharges to mortality of benthic organisms in the outfall canal and Barnegat Bay. For example, Loveland and others (1970) reporting on benthic faunal conditions in the bay for the first postoperational period of the station, 1969 to 1970, showed that a sharp reduction in the dominant benthic organisms, *Pectinaria gouldii* and *Mulinia lateralis*, had occurred in the region of Oyster Creek. During this interval *Pectinaria gouldii*, the golden bristled worm, increased in numbers at all sampled sites except Oyster Creek where it decreased 78 percent. *Mulinia lateralis* experienced a "crash" in the summer of 1970 from which it has not recovered, and the clam's density dropped significantly at Oyster Creek and throughout the bay. Loveland and others (1972) later suggested that the decrease in density of *Mulinia* in the vicinity of Oyster Creek might have evolved from thermal mortality of meroplankton larvae by entrainment. The effects of entrainment would have precluded adult populations from maintaining normal levels. Nevertheless, these changes could have been caused by natural processes, because they were so regional in scope (Loveland[1], personal communication, 1976).

In their last progress report Loveland and others (1974) noted that 1973 was an exceptionally poor year for benthic invertebrates throughout Barnegat Bay. All sampled sites showed a distinct decrease in diversity, biomass per meter squared, and the number of individuals per meter squared. The most significant change was a decrease in the density and dominance of the populations--a situation which seems to have persisted through the summer of 1976 (Voogleitois[2] personal communication, 1976). However, Loveland and others (1974) could not detect any statistically significant effect of the thermal dis-

[1] Robert E. Loveland, Department of Zoology, Rutgers University, New Brunswick, New Jersey.

[2] James J. Voogleitois, Jersey Central Power and Light Company, Morristown, New Jersey.

charges on the benthic faunal communities in the bay.

The abrupt changes in the population structure of Pectinaria gouldii and Mulinia lateralis subsequent to the initiation of operations of the nuclear power station raise a number of important questions pertaining to the possible connection between thermal discharges and mortality of benthic invertebrates in Barnegat Bay. Investigation of this problem requires a detailed analysis of the population dynamics of the benthos. Unfortunately, no complete population study of this kind has been undertaken in the past six years since the station went on line.

A benthic species in Barnegat Bay ideally suited for initiating this type of research is the pelecypod, Mercenaria mercenaria (Linnaeus). It has a wide distribution that includes areas under the influence of the thermal plume, is significantly abundant, is sensitive to temperature changes in the bay (Kennish and Olsson, 1975), and its ecology and physiology are well-known. The life span of many of the clams also transgresses the postoperational history of the station. In addition, the clam possesses a shell particularly useful for the study of population dynamics, because it exhibits internal growth increments and growth breaks which are of value in age, growth rate, and mortality determinations.

The objective of this research project was to examine mortality patterns in life and death assemblages of juvenile and adult mercenaria* in Barnegat Bay to determine the effects of thermal discharges on them. It was also hoped that the research would better develop the clam as a natural monitor of the thermal discharges (Kennish, 1976; 1977), and would allow formulation of predictive growth models for academic, practical, and economic use. A number of techniques were implemented to attain these objectives. These included: (1) shell microgrowth analysis of specimens from natural and transplanted populations to establish growth rates and seasonal mortality patterns; (2) application of mathematical functions to simulate and predict growth in the bivalve; and (3) construction of size- and age-frequency polygons, death-frequency histograms, and life tables to illustrate the type of clam mortality in different areas of the bay.

*For the convenience of the reader only the species name mercenaria will henceforth be used in the text.

STUDY AREA

Barnegat Bay, located along the east coast of New Jersey (Figure 1), is a lagoon-type estuary. A barrier island system borders the bay on the east, and the mainland bounds it on the west. A breach in the barrier island occurs at Barnegat Inlet and causes maximum tidal ranges and salinities in that region. Carpenter (1963) estimates exchange rates through Barnegat Inlet of approximately 7 percent per tide and a net discharge rate of 56.7 m^3 /sec. This amounts to a complete turnover of bay water every 96 tidal cycles.

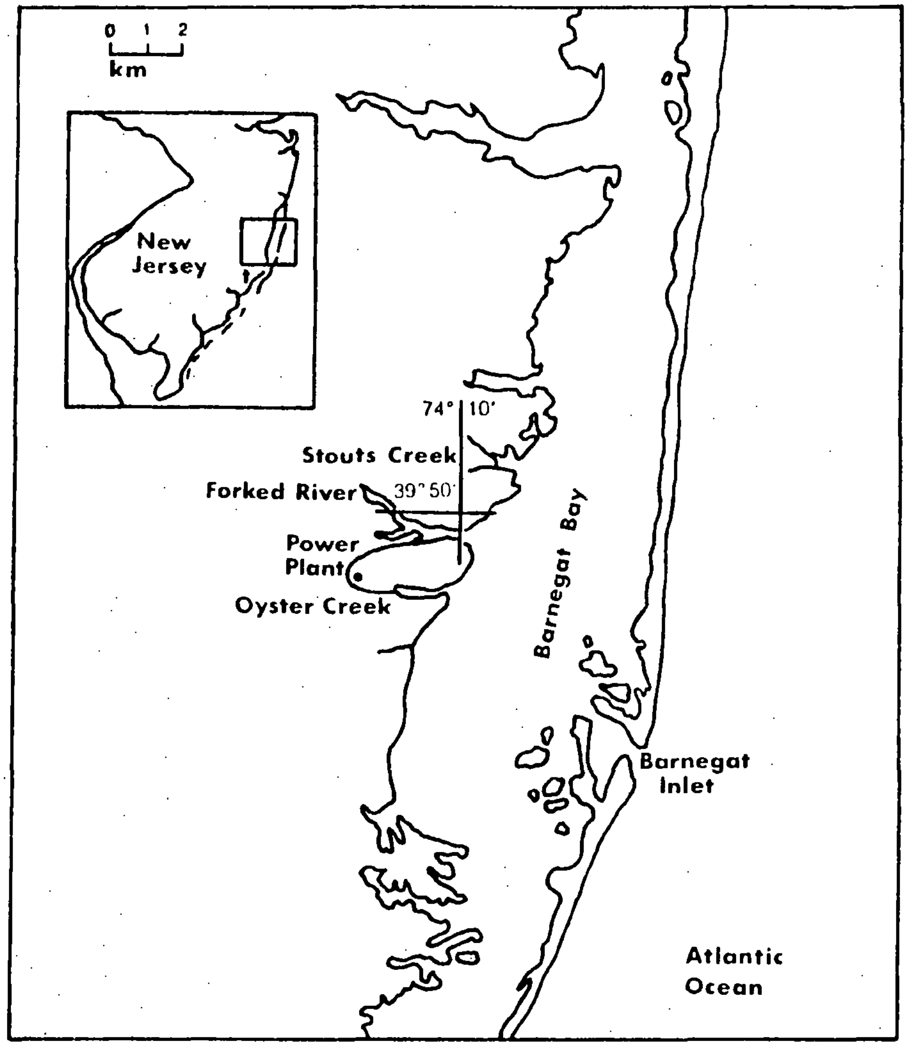
The bay stretches north-south for some 48 km, but it is only 2 to 6.5 km in width. Its depth averages 1.5 m. The surface area is about 167,000,000 sq m with the volume being 238,000,000 cu m. Table 1 (appendix) summarizes the physical characteristics of Barnegat Bay.

Salinity in the northern extremeties of the bay approaches a brackish condition due to the influx of freshwater dilution from drainage basins from the mainland and a decrease in the effect of tides. The position of Barnegat Inlet results in substantially higher salinities in the central and southern sectors. Tidal mixing is responsible for the uniform vertical salinity profiles observed by Carpenter (1963) in these areas. Data from Mountford (1971), Busch (1971), and Loveland and others (1972) indicate that salinities generally fall between 19 to 30% for the central bay.

Water temperatures recorded by Mountford (1971), Loveland and others (1972), and Kennish and Olsson (1975) outside of the effect of thermal discharges range from a winter low of approximately -1.5°C to a summer high of 28.0°C. Temperature inversions occur occasionally at the mouths of creeks when a wedge of warm, saline bay water intrudes upstream below a layer of cooler, fresher stream outflow. Local meteorological conditions play a major role in regulating water temperatures, because of the shallowness of the bay. A general condition of weak thermal stratification is often broken by wind action. Diurnal changes in temperature of 1 to 2°C are common.

Climatological records for the region recorded at Tuckerton, New Jersey from June, 1966 to June, 1976 (Table 2, appendix) demonstrate the influence of the Atlantic Ocean throughout the year. Summer air temperatures are lower and winter air temperatures higher than those farther inland. Minimum temperatures for the ten year period occur in January and February and maximum temperatures in July and August. Precipitation ranges from a minimum of 8.1 cm in October to a maximum of 11.8 cm in December. Winds predominate from the south and southeast in the summer, particularly after midday, and from the west and northwest during the winter. They are important in generating waves and affecting currents that transport a significant quantity of sediment.

Figure 1. Barnegat Bay, New Jersey. The inset at the upper left shows the location of Barnegat Bay in relationship to the state of New Jersey. t (in inset) = Tuckerton, New Jersey. (United States Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey, Nautical Chart 824-SC, 1973.)



0 1 2
km
New
Jersey
74° 10'
Stouts Creek
Forked River
39° 50'
Power
Plant
Oyster Creek
Barnegat Bay
Barnegat
Inlet
Atlantic
Ocean

Figure 1

The sediment in Barnegat Bay is broadly classified by Phillips (1972) and Kennish and Olsson (1975) as sand. The bay can be spatially subdivided on the basis of the character of its substrate (Figure 2). The well-sorted fine sand in the eastern perimeter of the bay from Cedar Creek to Gulf Point is derived either from the continental shelf or from the erosion of beach materials north or south of Barnegat Inlet. Medium sand exists in a tract in the western perimeter of the bay from Gulf Point to the mouth of Oyster Creek and in two restricted sections between Oyster Creek, Forked River, and Stouts Creek. The bulk of sediment in the western perimeter of the bay from Oyster Creek to Stouts Creek is a muddy sand. The mouths of the streams draining the mainland consist mainly of sandy mud as does the portion of the bay north of Cedar Creek. The finer, poorly-sorted sediment fraction in the western perimeter of the bay and north of Cedar Creek originates from the mainland, and it is deposited in areas away from the influence of tiday currents through Barnegat Inlet. The overall sediment distribution in Barnegat Bay forms a spatial mosaic. This mosaic is ecologically important, because it affects the distribution and density of benthic populations in the bay.

Figure 2. Sediment distribution in Barnegat Bay (Kennish and Olsson, 1975).

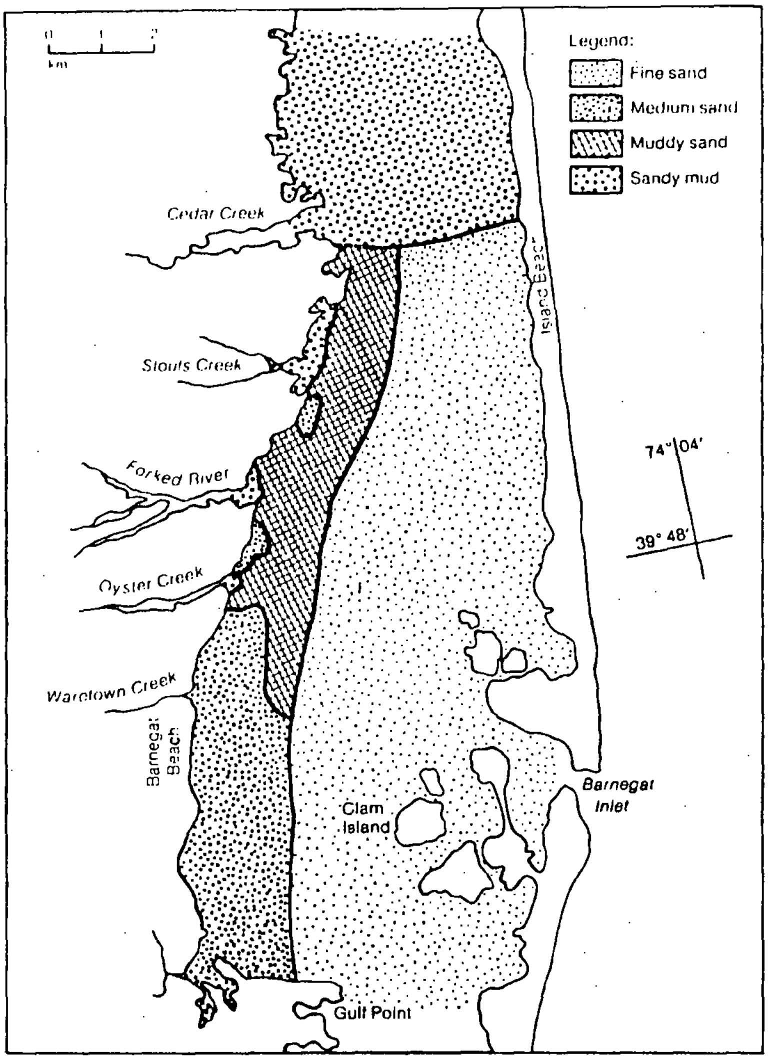

Legend:
Fine sand
Medium sand
Muddy sand
Sandy mud
Cedar Creek
Stouts Creek
Forked River
Oyster Creek
Waretown Creek
Barnegat Beach
Island Beach
74° 04'
39° 48'
Clam Island
Barnegat Inlet
Gulf Point

Figure 2

THERMAL DISCHARGES AND

THE OYSTER CREEK NUCLEAR GENERATING STATION

The Oyster Creek Nuclear Generating Station, in operation since December, 1969, consists of an open-cycle system with a forced circulation boiling water reactor. The turbine-generator uses steam produced in the reactor to yield 620 megawatts (net) of electric power. A maximum power level of 1930 megawatts thermal is obtainable.

At peak operating conditions approximately 1,703,250 liters of water per minute circulate through the condensers and 37,850 liters of water per minute circulate through the turbine and reactor buildings for cooling purposes. The station does not operate at peak levels throughout the year as is shown by flow measurements recorded at the station from June 18, 1975 to June 18, 1976 (Table 3, appendix). The temperature increase of cooling water across condensers, ΔT, amounts to a maximum of 23°C. Three axial flow dilution pumps, each with a 984,100 liter per minute capacity, are used to control the temperature level of the circulating water discharge.

The source of water for circulation and dilution is Forked River and Barnegat Bay. This water flows up a semicircular, dredged canal connecting the South Branch of Forked River to Oyster Creek (Figure 3). The canal averages 3 m in depth. Heated water discharged at the station flows down the outlet portion of the dredged canal into Barnegat Bay. The length of the discharge canal is about 3 km, and this distance allows a significant quanity of heat to be relased to the atmosphere from the effluent. The effluent takes more than two hours to reach the bay.

A thermal plume forms in the bay as the thermal effluent flows out of the discharge canal. The morphology of the plume varies temporally, and is confined to roughly a 1.6 km radius about the mouth of Oyster Creek. On calm days the plume often fans out about the mouth of Oyster Creek, its shape being affected by weak tidal currents (Kennish and Olsson, 1975). However, when strong winds predominate from the north or south, it often appears as a narrow band abutting the shoreline. If strong southeast winds occur concurrently with flooding tide, a situation that is common in the summer months, some of the thermal discharges recirculate into the intake canal. The distribution of thermal effluent in the bay appears to be sensitive to local wind conditions.

Loveland and others (1974) and Kennish and Olsson (1975) discuss the magnitude of water temperature changes in Barnegat Bay during station operations. At times of peak operations temperatures rise 3 to 5°C above ambient levels at the mouth of Oyster Creek (site 2, Figure 4). This increase in temperature dissipates rapidly with distance from Oyster Creek, and is undetectable along the substrate beyond a 1.6 km distance in the bay.

Figure 3. Flow characteristics at Forked River, Oyster Creek, and adjacent bay localities. (Jersey Central Power and Light Company, 1972.)

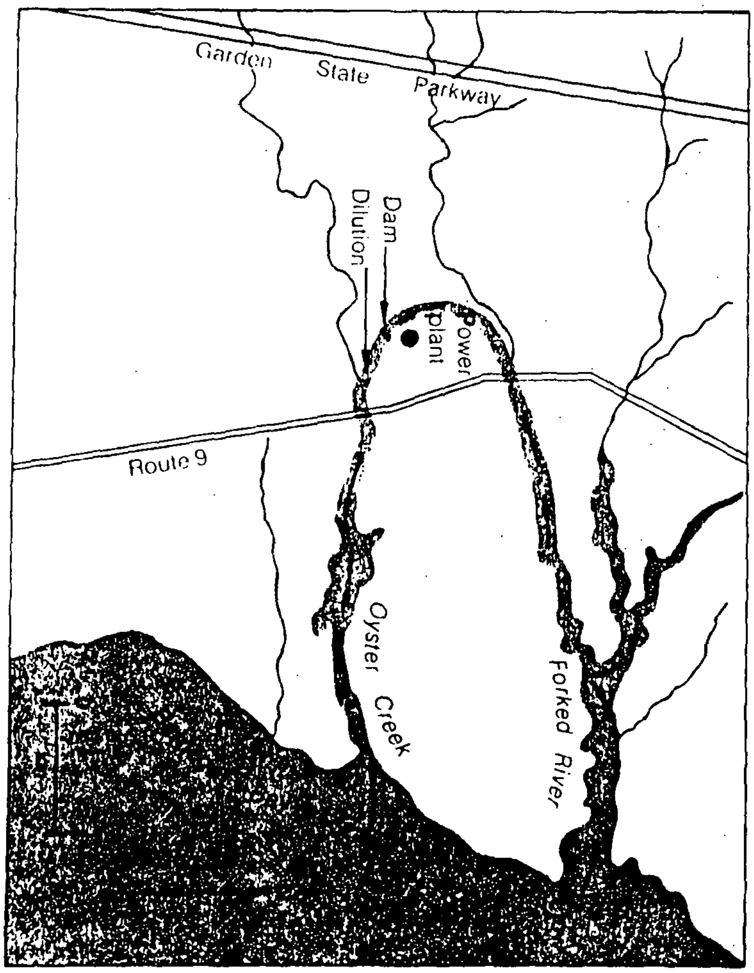

Garden State Parkway
Dam
Dilution
Power plant
Route 9
Oyster Creek
Forked River

Figure 3

Table 4 (appendix) shows mean monthly water temperatures recorded at site 2 from August 1, 1974 to September 15, 1976. The data represent mean monthly values based on one temperature reading per day taken at both the surface and bottom of the bay. Measurements could not be taken on a number of days, particularly in the winter, yiedling an incomplete set of data. Nevertheless, the constant similarity between surface and bottom temperatures is evident. This seems to be due to the shallowness of the bay at that point (approximately 1 m) and the close proximity to the discharge canal.

Mean monthly and seasonal water temperatures monitored in the subsurface within the mouth of Oyster Creek (site 1, Figure 4) and within the mouth of Forked River (site 3, Figure 4) from June 18, 1975 to June 18, 1976 by the Jersey Central Power and Light Company are illustrated in Table 5 (appendix). The data are based on water temperatures continuously recorded by thermistors (Teabody Ryan Model G-45) located 0.15 m below the surface.

A comparison of water temperatures observed at sites 1 and 3 (Table 5, appendix) with station operations (Table 6, appendix) conducted from Juen 18, 1976 indicates that significant temperature differences exist at the two sites when the station is operating. Thermal discharges strongly affect site 1 but not site 3 which is essentially at ambient bay conditions. Water temperatures are significantly higher at site 1 ($P<0.05$) for the summer and fall of 1975 and for the spring of 1976. There is no significant difference (at the 0.05 level) in temperatures at the two sites for the winter of 1976. The similarity in temperatures during the winter of 1976 reflects the effect of a long station shutdown from December 28, 1975 to March 10, 1976.

MATERIALS AND METHODS OF RESEARCH

Nine sampling sites were established in Barnegat Bay to examine the effects of thermal effluent on mortality of juvenile and audit clams (sites 2 and 4 through 11, Figure 4). Eight of these sites (sites 4 through 11) were located in areas unaffected by thermal effluent, and they served as controls in the experiment. Site 2 was selected as the major test site, because thermal effluent encompasses a natural population of mercenaria in that area.

In the summer of 1974 samples of death assemblages were collected at sites 2, 5, 6, and 9. Life and death assemblages of the bivalve were also sampled at these four sites and sites 4, 7, 8, 10, and 11 in the summer of 1976. Specimens were washed on .5 cm and 1 cm mesh screens, and were measured for size by means of vernier calipers accurate to .01 mm. Size-frequency polygons were constructed from these measurements.

Size measurements on the shells were made from the umbo to the ventral margin at a slight angle to the dorsal-ventral plane (Pl. 1, Fig. 1). Therefore, the dimension measured only approximates the true height of the organism. This dimension has been labeled height' to differentiate it from the true shell height.

Shells from the death assemblages gathered in 1974 were employed to generate growth rate data, season of death data, life tables, mortality rate curves, and survivorship curves for the clam. This was made possible using the method of Rhoads and Pannella (1970). Following this method, valves were sectioned from the umbo to the ventral margin along the height' plane, and acetate peel replicas of the valve cross-sections were prepared. A phase contrast petrographic microscope containing a graduated ocular was subsequently utilized to analyze microgrowth patterns in the peels. This technique yielded the observed growth and mortality data.

In addition to investigating mortality in natural populations, mortality was recorded in transplanted life assemblages. A total of 3,129 clams ranging from 20 mm to 75 mm in height' were transplanted in a series of separate experiments to sites 2 and 5 (control) in the summers of 1974 and 1975, and valves of dead specimens recovered from the transplanted assemblages were studied microscopically. Absolute age and season of death data were produced from the dead specimens.

Figure 4. Sampling localities in Barnegat Bay.

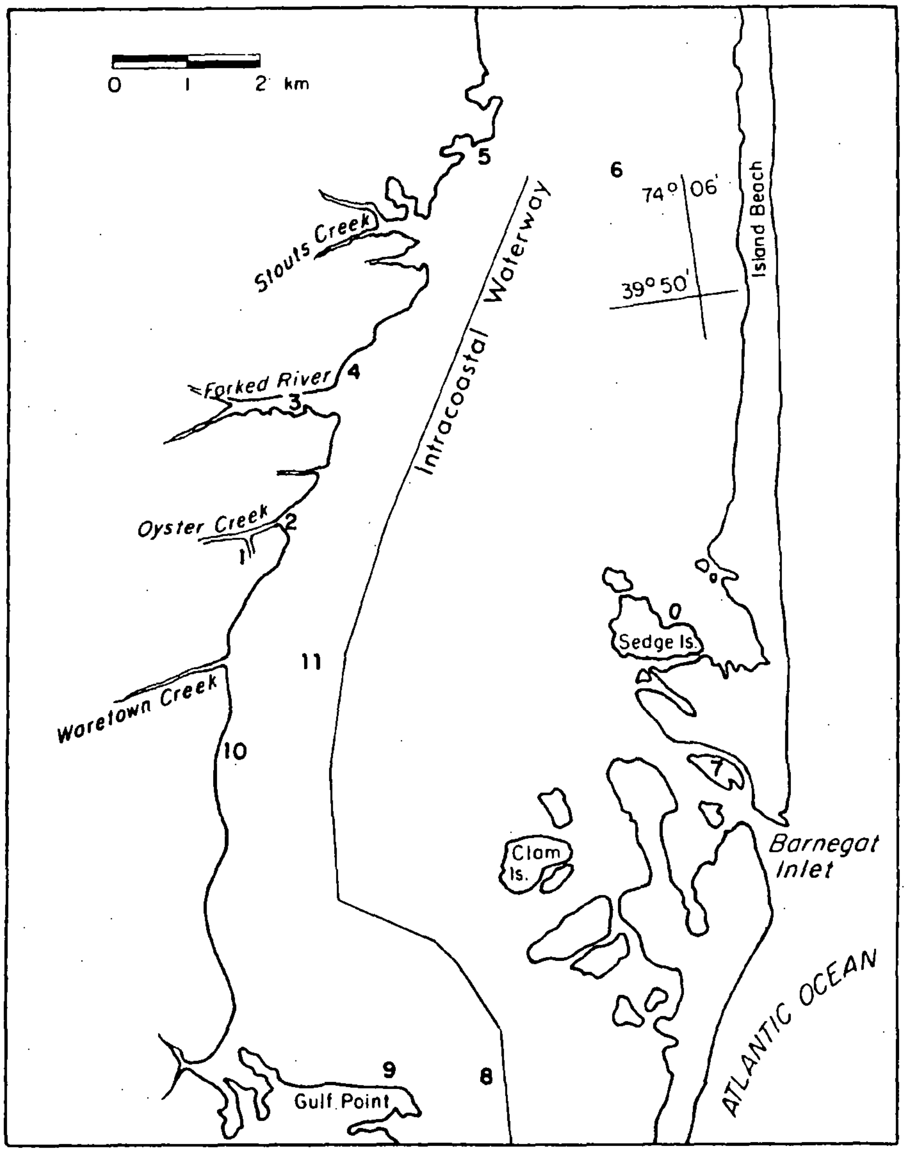

0 1 2 km
5
6
74° 06'
Island Beach
Stouts Creek
Intracoastal Waterway
39° 50'
Forked River
4
3
Oyster Creek
2
1
0
Sedge Is.
11
Waretown Creek
10
7
Barnegat
Inlet
Clam
Is.
ATLANTIC OCEAN
9
8
Gulf Point

Figure 4

DESCRIPTION AND APPLICATION OF

SHELL MICROGROWTH PATTERNS IN MERCENARIA MERCENARIA

Pannella and MacClintock (1968), Rhoads and Pannella (1970), Cunliffe (1974), Cunliffe and Kennish (1974), and Kennish and Olsson (1975) discuss shell microgrowth patterns of mercenaria in detail. Two categories are recognized: (1) cyclical patterns, and (2) growth breaks. Cyclical growth patterns include subdaily, daily, bidaily, fortnightly, lunar-monthly, and annual types. These reflect periodic fluctuations in environmental stimuli and the existence of a biological clock mechanism in the organism.

Viewed in cross-section cyclical patterns consist of sequential layers of calcium carbonate bounded by fine bands of conchiolin. The bands of conchiolin are secreted during the day, whereas the layers of calcium carbonate (in the mineral form aragonite) are deposited at night (MacClintock and Pannella, 1969). Secretion of calcium carbonate by the mantle is continuous in the sense that it occurs nearly everyday; however, the amount of shell accretion is quite variable.

Occasionally, daily secretion of calcium carbonate is interrupted by periods of environmental and physiological stress resulting in growth cessation. Growth cessation causes a break in the cyclical growth patterns of the shell. Such events are manifested in the shell microstructure as V-shaped indentations in the prismatic layer, and, in most cases, as a reduction in growth increment thicknesses on one or both sides of the break. Crossed-lamellar shell structure often marks the site of the break. Breaks in growth develop specifically from winter (freeze)-shocks, summer (heat)-shocks, artificially induced-shocks, spawning periods, storms, and neap tides.

Because the character of shell microgrowth patterns in mercenaria varies directly with cyclical and random fluctuations in environmental parameters such as temperature, salinity, tides, storms, and other variables, the shell of the bivalve is an effective tool for monitoring these factors. In addition to being of practical value in monitoring environmental parameters, the shell also records the physiological condition of the clam throughout ontogeny. In essence, the shell continuously records daily, monthly, seasonal, and annual changes in environmental and physiological conditions.

Because they record physiological and environmental conditions, shell microgrowth patterns of mercenaria can be applied to the study of growth rates and mortality. For example, counts of daily growth increments from the umbo to the ventral margin in valves of dead specimens yield data on absolute age at death (Rhoads and Pannella, 1970). If these daily increments are lumped together into annual units and measured, yearly growth rates can be established. Probably the most accurate method of determining season of death is to combine growth increment counting with the interpretation of growth patterns at the ventral margin of the shell (Tevesz, 1972). By relating the position of the last increment of growth before death to seasonal growth breaks incurred earlier in life, season of death can be estimated. A ventral margin preceded by a long period of winter growth suggests pring death (Pl. 1, Figs. 2, 3, 4, 5). Thick increments at the outer margin preceded by a winter (freeze)-shock break displaced 160 to 200 increments dorsally signify summer death (Pl. 1, Figs. 6, 7). A summer storm break (Pl. 1, Fig. 9), a summer (heat)-shock break (Pl. 2, Figs. 1, 2), or a spawn break (Pl. 2, Figs. 3, 4) bordering the leading edge of the shell likewise denote summer death. A margin following a complete sequence of summer growth increments implies fall death (Pl. 2, Figs. 5, 6, 7, 8). A winter (freeze)-shock break associated with thin growth increments adjacent to the ventral margin indicates winter death (Pl. 3, Figs. 1, 2, 3), as does thin increments at the shell edge following a summer (heat)-shock break located approximately 160 to 200 increments dorsally (Pl. 3, Fig. 4). Although this technique is efficient, it is desirable to verify data obtained in this manner with independent evidence drawn from daily growth increment counts across the shell.

Microgrowth analysis is valuable not only for generating information on the season of death and the age at the time of death on specimens from death assemblages, but also for differentiating a census mortality from a natural one in different populations. Since some growth breaks occur synchronously in a large part of a population (Pannella and MacClintock, 1968), it is possible to use them as microgrowth datum planes for purposes of correlation. Particularly useful in this respect are universal events such as major storm breaks and thermal shock-breaks that can be precisely dated by alternate means. Census mortality of a population is substantiated when growth breaks match up across many individuals in a death assemblage, and the terminal microgrowth patterns are alike. In this case, mortality is confined almost exclusively to a single season of the year. Natural mortality, on the other hand, is manifested as a high diversity in the growth patterns present at the ventral valve margins. This diversity reflects the high variability in seasonal mortality of members of the population.

These methods of analysis have been utilized successfully in the study of population dynamics in the past (Rhoads and Pannella, 1970; Tevesz, 1972; and Cunliffe, 1974). Because of this, all of them have been incorporated in this research project. Their use has generated data on growth and mortality in populations of mercenaria throughout Barnegat Bay. They have also provided evidence of significant temporal changes in the population dynamics of the clam.

GROWTH RATES AND GROWTH MODELS

OF MERCENARIA MERCENARIA IN BARNEGAT BAY

Growth rates of mercenaria in Barnegat Bay were determined by measuring annual increments of growth in valve cross-sections from the umbo to the ventral margin. The basic microgrowth analysis employed to obtain these measurements were daily growth increment and seasonal growth break counts. A total of 277 specimens from the death assemblages collected in 1974 at sites 2, 5, 6, and 9 were examined. This included 101 valves from site 2, 74 from site 5, 64 from site 6, and 38 from site 9. The valves ranged from 14.0 mm to 76.5 mm in height'. The simple age-height' statistics of these samples are presented in Table 7 (appendix).

Table 8 (appendix) summarizes the age-height' relationships observed in each assemblage, and Table 9 (appendix) records the pooled age-height' values as calculated by means of a Statistical Analysis Systems computer program run on an IBM 370/158 computer. Most of the clams are less than seven years old; thus, data for the older clams are based on fewer measurements. Inspection of the data reveals extremely uniform growth rates at all four localities, with growth being fastest and nearly linear for the first three years of life and dropping off gradually into the gerontic stage. Apparently, growth begins to slow when the organism attains sexual maturity, and energy is diverted into reproductive processes.

A comparison of the age-height' relationships of clams at site 2 with those at sites 5, 6 and 9 indicates that thermal discharges from the Oyster Creek Nuclear Generating Station have had little effect on the growth rates of clams in death assemblages of Barnegat Bay. There is excellent agreement of growth rates in clams at site 2 with those at all other locations. Juvenile and adult growth rates are nearly identical at sites 2 and 5, slightly greater at site 9, and somewhat reduced at site 6, but these differences are minor. Furthermore, a tendency exists for clams to reach a common size in old age in all assemblages due to a reduction in growth rates and a decline in absolute and relative variability of growth.

The clams are so regular in their growth characteristics that the analysis of growth in even one specimen within an assemblage can reveal a substantial amount of information concerning growth rates in the population as a whole. For example, table 10 (appendix) displays age-height' relationships of one clam from site 5. Note the close fit of the growth rate in this individual to that of the entire assemblage from which it was taken (Table 8, appendix). Only a few specimens per sample need be analyzed microscopically to obtain the overall growth plan of the species.

The growth pattern exhibited by mercenaria in Barnegat Bay, in which the bivalve tends to undergo a gradual, more or less exponential decline of growth rate with age, can be described mathematically. Three of the most frequently used equations in the study of metazoan growth are the logistic, Gompertz, and monomolecular (Price, 1970). Table 11 (appendix) gives the characteristics of these functions. They all have one concept in common--the tendency for the size of the organism to reach an asymptotic limit in a finite period of time.

A major objective is to establish which of these three expressions best represents the growth data shown in Tables 8 and 9 (appendix). This requires fitting each equation to the growth data, and selecting the best fitting model. Predictive growth curves can be constructed once parameters are estimated and predictive functions forumlated.

A new mathematical procedure developed by Loveland and Crossner (paper in preparation) allows for the rapid estimation of parameters in these equations and the selection of the best fitting model. Parameters can be estimated and the best fitting equation selected by means of a standard regression analysis subsequent to the linearization of the growth functions.

According to the Loveland and Crossner method, the observed array of growth data consisting of size elements and corresponding time units must be converted into a transformed data matrix. A linear regression is performed on the transformed data for all linearized functions. The function registering the highest correlation coefficient (r) represents the statistically best fitting model. The parameters N_{max} (asymptotic height') and r_o(maximal intrinsic rate of natural increase) are predicted directly from the correlation coefficient, slope, and X and Y intercepts of the regression analysis. The parameters b (the parameter which specifies the time or size at which inflection occurs), c (the complement of that proportion of N_{max} which specifies the initial condition N_o), and p (the proportion of N_{max} which specifies the initial condition N_o) are calculated separately by formulae to generate predictive growth equations.

This method has been applied to the study of mercenaria growth in Barnegat Bay. The logistic, Gompertz, and monomolecular equations were fitted to the growth data of death assemblages of clams at sites 2, 5, 6, and 9 on a PDP-10 computer. The parameters N_{max} and r_o in each equation were also calculated on the PDP-10 computer. The parameters b and p in the logistic and Gompertz equations were estimated on a Wang 600-6 programmable calculator, and the parameter c in the monomolecular equation was determined on a IBM 370/158 computer (Table 12, appendix).

Predictive growth models were produced for each equation using the estimated parameters (Tables 13-17, appendix). Calculated growth rates for the logistic and Gompertz models were generated on a Wang 600-6 programmable calculator, whereas growth rates for the monomolecular model were predicted on an IBM 370/158 computer. Predictive growth curves were drawn from these measurements (Figures 5a-5e).

Table 12 (appendix) lists the parameters of growth and the correlation coefficients recorded for each equation using the Loveland and Crossner method of curve fitting. Because parameters b, c, and p have no biological significance, it is unnecessary to compare them for the purpose of selecting the best model. Although the parameter r_0 has biological significance, it cannot be compared across parameters of the different models. Statistically, all of the equations fit the growth data of mercenaria quite well. The high correlation coefficient values (usually -0.900 or more) reflect this. The degree of fit is consistently best for the Gompertz function, with the lowest correlation coefficient being -0.970 for the growth data of clams from site 5 and the highest correlation coefficient being -0.994 for the growth data of clams from site 9. The monomolecular equation displays the poorest fit to the data, and the logistic equation in intermediate fit between the Gompertz and monomolecular.

In reality, the logistic equation is unacceptable as a model for mercenaria growth, because it predicts growth curves with inflections, and it underestimates asymptotic heights'. The observed growth curves for the clam reveal no such inflections (Figures 5a-5e). If an inflection occurs during ontogeny, it must be confined to the meroplanktonic stage.

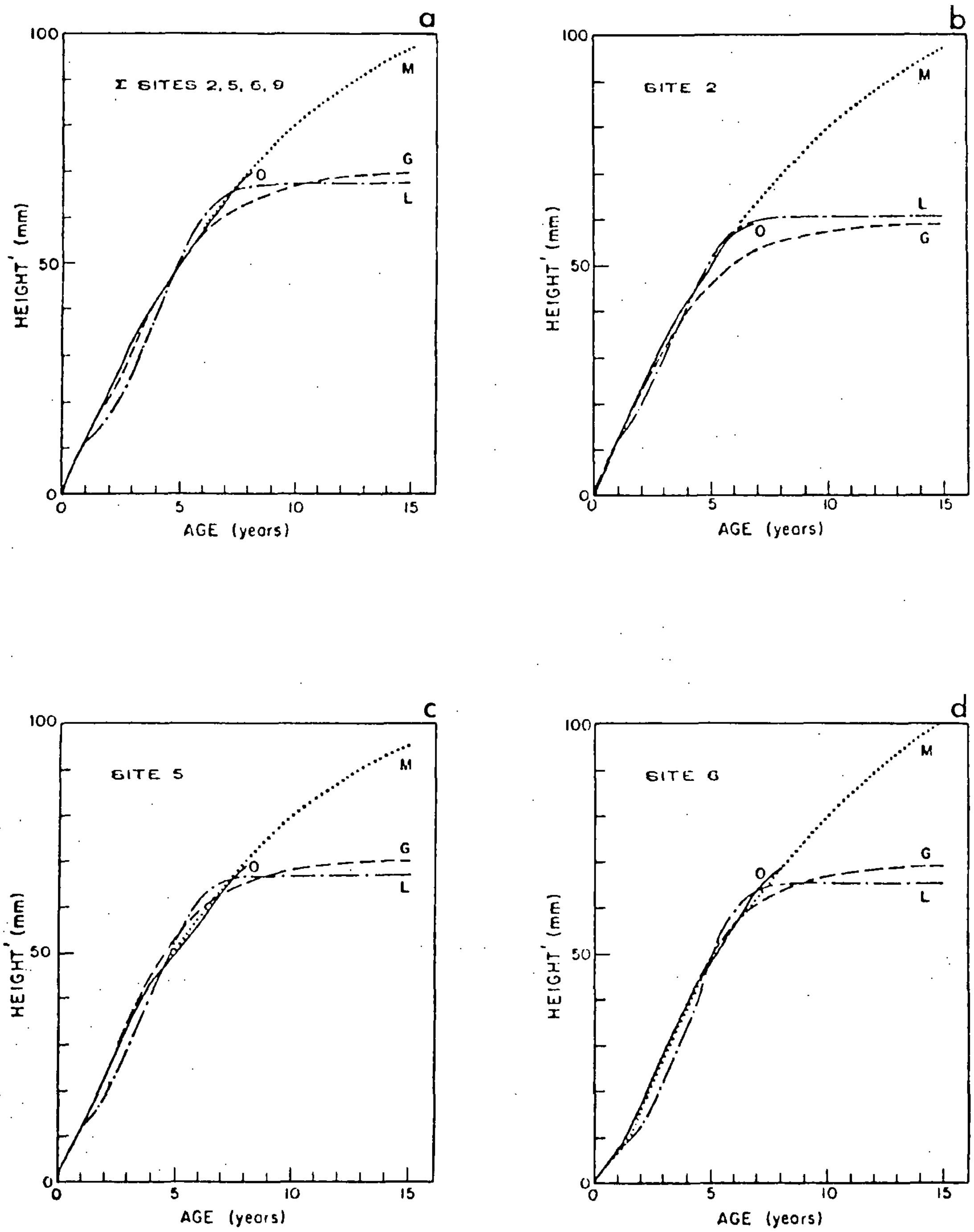
As with the logistic function, the Gompertz significantly underestimates asymptotic heights'. For example, the largest clams observed in the death assemblages at sites 2, 5, 6, and 9 have heights' ranging between 80 mm and 85 mm. Yet, the Gompertz model only estimates asymptotes between 67.19 mm and 74.22 mm (Table 12, appendix), and the logistic calculates asymptotes between 61.00 mm and 67.61 mm for clams at these sites. Both models yield growth rates that are too low for the oldest clams. Consequently, the projected growth curves for the models deviate appreciably from the observed values of the larger size clams (Figures 5a-5e).

The same effect is present in models of growth in other species of clams. For instance, when fitting the Gompertz equation to growth data of the razor clam, Siliqua patula, Weymouth, McMillin and Rich (1931) became aware of "growth being maintained at a higher rate than the first part of the curve would lead one to predict." Nevertheless, they fit the greater portion of the growth curve to the data. Laird, Tyler, and Barton (1965) explain the deviation in old age experienced by Weymouth et al., as due to additional, accretionary growth that is nearly linear with respect to time.

Although the monomolecular equation does not fit the growth data as well statistically as the logistic and Gompertz functions, it provides the most satisfactory description of absolute growth of mercenaria in Barnegat Bay. This is largely due to the higher asymptotic heights' that the function estimates. Obviously, these asymptotic estimates are well above the maximum clam heights' found in the death assemblages.

Figures 5a–5e. Observed and predicted cumulative growth curves for death assemblages of clams at sites 2, 5, 6, and 9.

O = observed growth
L = predicted growth -- logistic model
G = predicted growth -- Gompertz model
M = predicted growth -- monomolecular model



Figures 5a - 5e

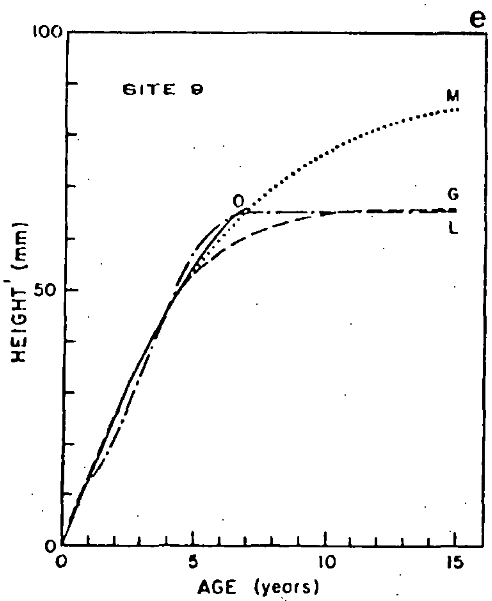


Figure 5e

This appears to be the result of a relatively short life span (eight to nine years) for clams in the bay. If mercenaria had a maximum longevity of 25 to 40 years in Barnegat Bay as it seemingly has in other waters along the Atlantic coast such as Delaware Bay (Hopkins, 1930; Kerswill, 1941; Haskin[1], personal communication, 1976), then the clam might conceivably attain maximum heights' from 87.67 mm to 133.41 mm as calculated. In this respect, the ecological longevity (the duration of life under natural conditions) of mercenaria in Barnegat Bay is far less than its physiological longevity (the life duration under optimum environmental conditions).

The monomolecular model closely fits the observed growth curves for sites 5, 6, and 9 and the pooled sites (Figures 5a, 5c, 5d, 5e). The divergence between the observed and predicted growth curves for site 2 (Figure 5b), on the other hand, suggests that the monomolecular probably overestimates growth of the oldest clams. In practice, however, it is more accurate than either the logistic or Gompertz models, because a greater portion of the growth curve can be fitted to the data. Because of this, it is useful for comparing and contrasting growth of clams in different areas of the bay.

In detail, shell growth of mercenaria is apparently more complex than that defined by the logistic, Gompertz, and monomolecular functions, because all fail to precisely account for growth of the oldest bivalves. The most accurate mathematical function would appear to be one possessing a combination of the characteristics of the Gompertz and monomolecular functions. Such a model should generate more realistic asymptotes, and should eliminate anomalous estimates of growth rates in older clams.

[1]Harold H. Haskin, Department of Zoology, Rutgers University, New Brunswick, New Jersey.

SIZE DISTRIBUTIONS OF LIFE AND DEATH

ASSEMBLAGES OF CLAMS IN BARNEGAT BAY

Table 18 (appendix) summarizes the size characteristics of life and death assemblages of mercenaria collected in Barnegat Bay during the summers of 1974 and 1976. The data indicate a remarkable similarity in clam sizes throughout the bay. Only at site 7, which is located in Barnegat Inlet, do the clam sizes diverge appreciably from the other samples.

Mean height' values of the death assemblages of clams gathered at sites 2, 5, 6, and 9 in the summer of 1974 are not all equal ($P<0.0005$). A Student-Newman-Keuls multiple range test performed on these samples shows that mean heights' are not significantly different ($P>0.05$) between the death assemblages at sites 5 and 6, but are significantly different ($P<0.05$) between all other death assemblages. The mean size of valves at the mouth of Oyster Creek (site 2) is significantly lower ($P<0.001$) than at all other locations.

A single factor analysis of variance on death assemblages sampled at sites 2, 4, 5, 6, 7, 8, 9, 10, and 11 in the summer of 1976 also reveals an inequality among the mean heights' of specimens ($P<0.0005$). A Student-Newman-Kuels test on these assemblages discloses no significant differences ($P>0.05$) in mean heights' between sites 2 and 4, 9 and 10, and 6, 8, and 11. With the exception of sites 4 and 7, the mean clam height' at site 2 is significantly lower ($P<0.05$) than at all other lcoations.

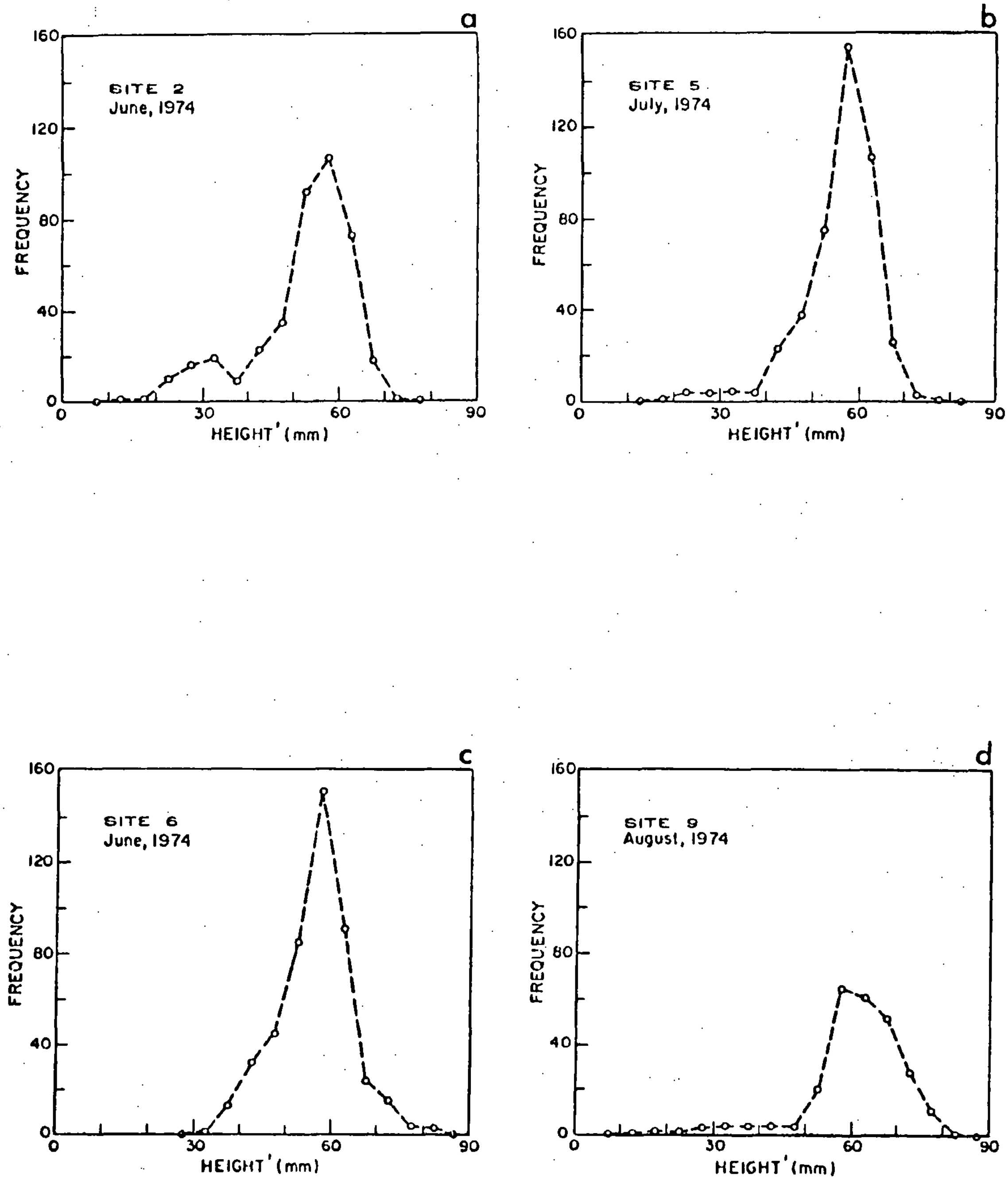
There is no significant difference ($P>0.05$) between the mean height' values of life assemblages of clams at sites 4, 5, and 6, and sites 2, 10, and 11, but there is a significant difference ($P<0.05$) between all other life assemblages. The life assemblage at site 2 has a higher mean value of height' than at all locations except site 9. This is opposite to the array of sizes observed in the corresponding death assemblages.

Significant differences ($P< 0.05$) in mean sizes exist between life and death assemblages at sites 2, 4, 6, 7, 8, and 11. No significant differences in mean heights' are found between life and death assemblages at site 9 ($0.10 < P < 0.20$) and site 10 ($0.20 < P < 0.50$).

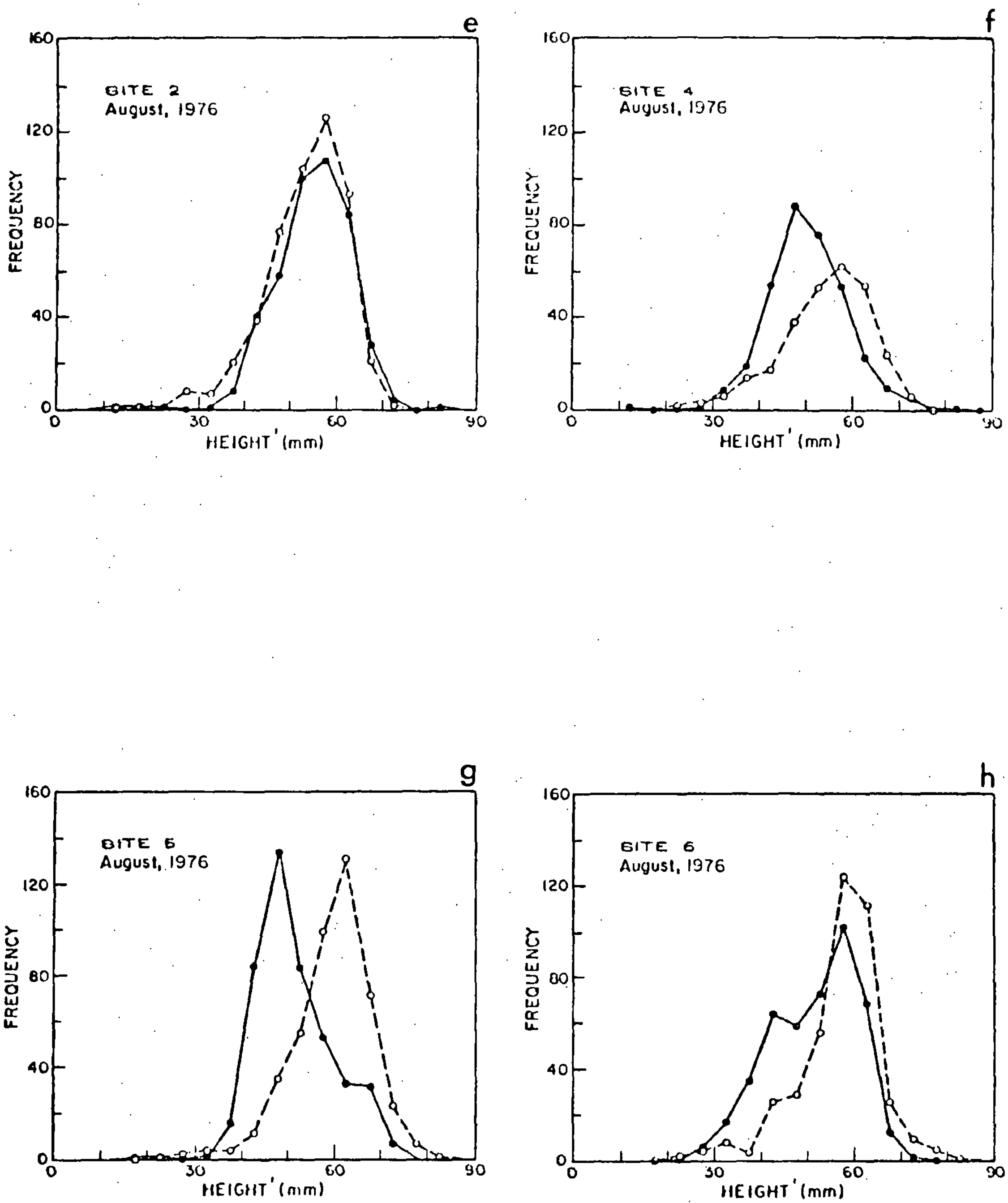
Thermal discharges from the Oyster Creek Nuclear Generating Station seem to have no effect on the distribution of clam sizes in Barnegat Bay. This is graphically reflected by the close agreement in size (height')-frequency distributions (Figures 6a-6m) of the life and death assemblages at site 2 (affected by thermal discharges) with those at the control sites (unaffected by thermal discharges). Moment measures about the mean sizes of the samples are also alike, and they clearly describe the size distributions (Table 19, appendix).

Figures 6a-6m. Size (height')-frequency distributions for life and death assemblages of Mercenaria mercenaria collected at sites 2, 4, 5, 6, 7, 8, 9, 10, and 11 in Barnegat Bay in 1974 and 1976.

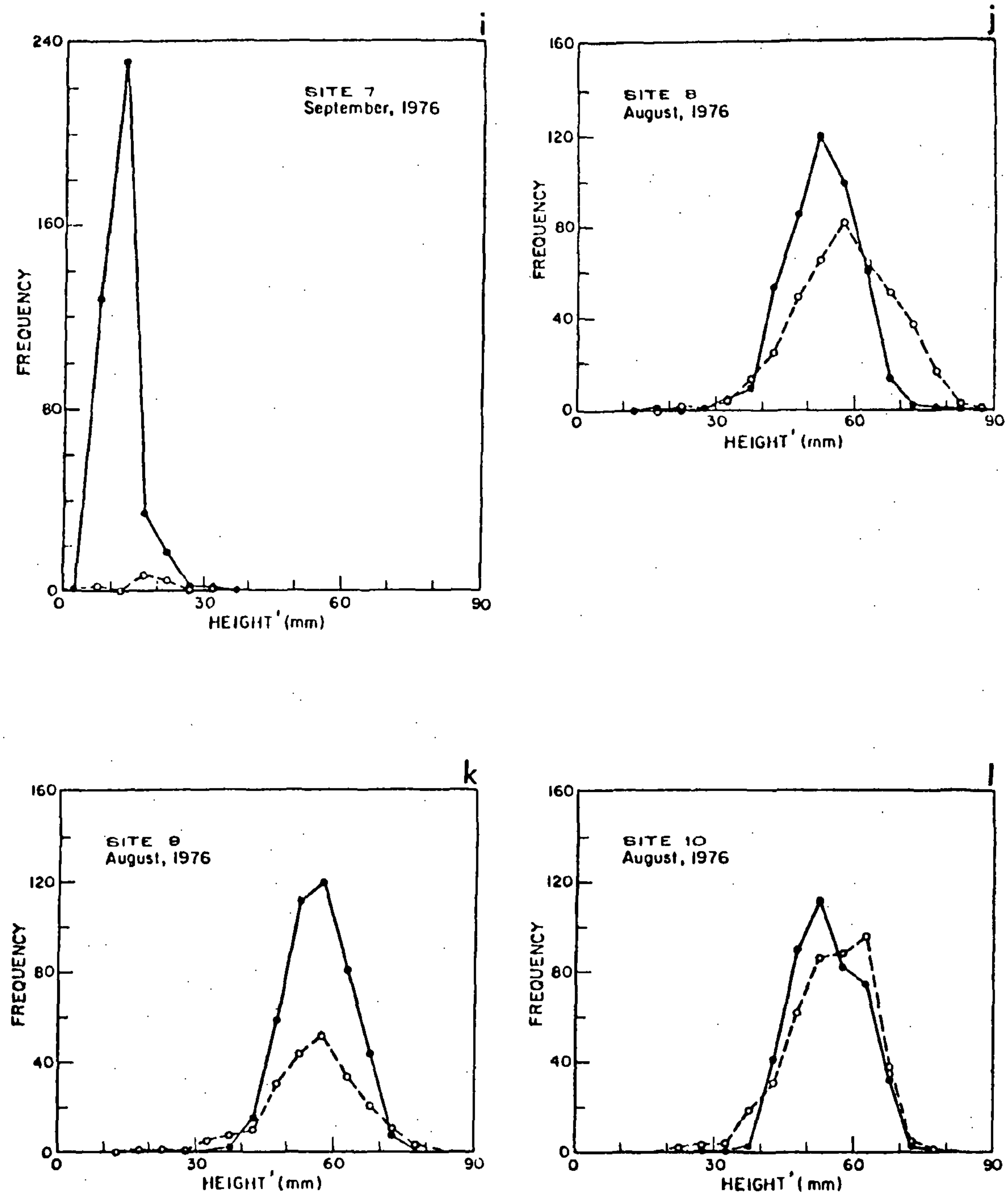
------ denotes death assemblage
______ denotes life assemblage



Figures 6a - 6d



Figures 6e - 6h



Figures 6i - 6l

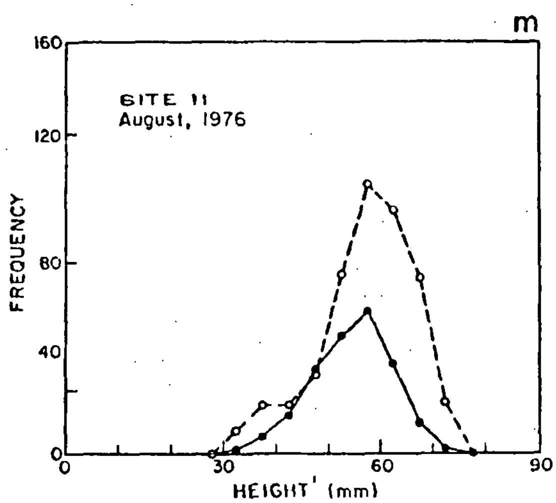

m
SITE 11
August, 1976
FREQUENCY
HEIGHT (mm)
160
120
80
40
0
0
30
60
90

Figure 6m

Size-frequency polygons constructed for the samples consist of unimodal curves with a negative skewness in all death assemblages and most of the life assemblages. The occurrence of a single mode dominating each death assemblage is not surprising. The death assemblages develop from the accumulation of many generations of clam shells which tends to smooth out the short term fluctuations in population structure. In essence, population stability is assumed over long periods of time. This assumption is born out by the research of Olson (1957) who found that in approximately 200 size-frequency distributions of fossil organisms about 85 percent were unimodal.

Polymodality in size-frequency distributions of death assemblages of mercenaria can arise in one of two ways (Sheldon, 1965): (1) by catastrophic death of the life assemblage which freezes the size distribution of the living population; and (2) by high mortality in the life assemblage within a short interval of time or during a period of little growth and at the same time each year. In the first case, successive modes correspond to distinct year classes of clams, because annual recruitment is confined to the summer months. In the second, they represent the accumulation of particular shell sizes each year, because high mortality coincides with times when the size structure of the life assemblage is similar.

Neither of the cases apply to death assemblages of mercenaria in Barnegat Bay. This is evident not only from the unimodel size-frequency distributions but also from the seasonal mortality patterns of the clam. Table 30 (appendix) illustrates that individuals from natural populations died at different times of the year as a result of natural rather than census mortality.

The unimodal nature of the life assemblage polygons, on the other hand, suggests a failure of annual recruitment. Because spawning and recruitment of mercenaria in New Jersey takes place within a short time span in the summer (Carriker, 1961; Haskin, personal communication, 1976), a series of modal peaks corresponding to successive yearly broods should be expected in these diagrams, if recruitment had been successful the past few years (Hallam, 1972). In such a case, troughs between modal peaks would coincide with periods of growth of each generation from one recruitment stage to the next (Craig and Hallam, 1963; Schmidt and Warme, 1969).

This situation can be simulated. For example, Table 9 (appendix) displays a growth rate for mercenaria in Barnegat Bay based on microgrowth analysis of 277 specimens from sites 2, 5, 6, and 9. Assuming these data represent the average rate of growth for mercenaria in the bay, and assuming the bay possesses a stable clam population with constant annual recruitment and no mortality, a polymodal size-frequency distribution can be produced (Figure 7). Of course, this model is unrealistic, because it fails to take into account natural fluctuations in mortality and recruitment. Nevertheless, it serves as an ideal, theoretical population structure for comparison to the observed size-frequency distributions of the life assemblages in Barnegat Bay.

Figure 7. Theoretical population model for eight years of growth of Mercenaria mercenaria in Barnegat Bay. The model assumes population stability with constant annual recruitment and zero mortality.

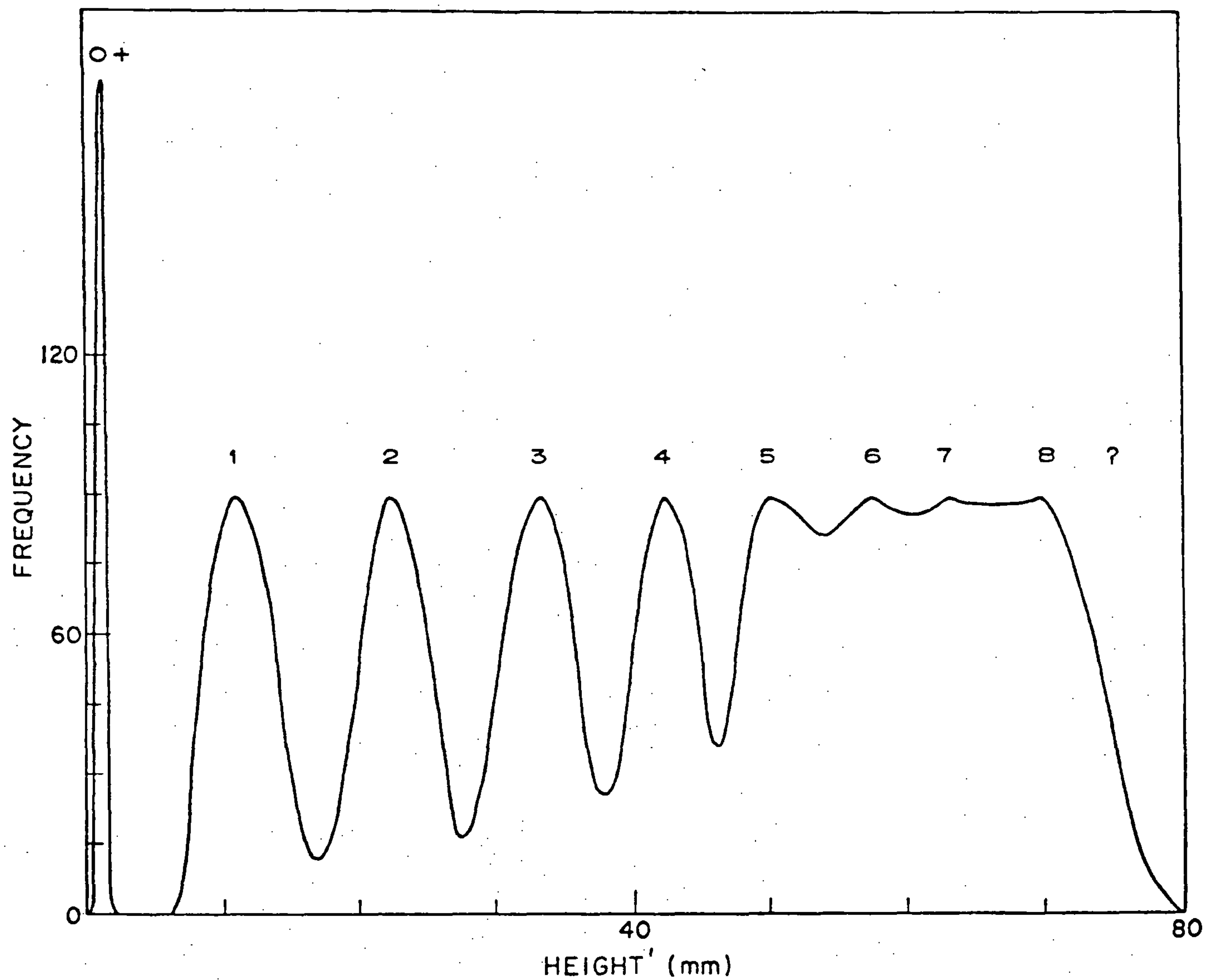


Figure 7

The model has well-defined, symmetrical peaks at 1.5 mm, 10.9 mm, 22.2 mm, 33.0 mm, and 42.4 mm which correlates with the 1976, 1975, 1974, 1973, and 1972 year classes respectively. Beyond 50 mm the modes tend to merge and the age classes become obscured due to the reduction in growth rates and the spread of sizes of older clams which causes an overlapping of the larger classes.

With the exception of site 7, there are no peaks in the observed size-frequency polygons of the life assemblages in Barnegat Bay that can be ascribed to single year classes from 1973 to 1976. Certainly, young mercenaria are not being added to the populations on a yearly basis, but sporadically. The effect of coalescing of the larger size classes is readily apparent as in the model. The rapid dissipation in the number of larger clams in the observed distributions compared to that of the model results from the precipitous increase of mortality in older clams.

Site 7 is composed of a juvenile population of clams--seemingly the only one in Barnegat Bay at present. The life assemblage polygon for site 7 contains a sharp peak at 11.8 mm, but no others at smaller or larger sizes. This peak corresponds to the 1975 year class, and relates favorably to that of the model. The absence of a peak between 0 mm and 5 mm is probably the consequence of poor recruitment in 1976, whereas the lack of peaks beyond 11.8 mm reflects the recent establishment of a clam population in this region of the bay.

It is not known exactly why recent recruitment has almost totally failed in the bay. Starypan (1976) notes the same effect in populations of Spisula solidissima all along the South Jersey coast. Evidence from the size-frequency distributions of both life and death assemblages of mercenaria suggests that the problem lies with the ineffectiveness of either the planktonic larval or pedoveliger stages. If clams had grown successfully through the juvenile plantigrade stage (approximately equal to 10 mm), live specimens and empty valves of dead juveniles should be present in the assemblages. That they are not (except at site 7) affirms this conclusion.

The variable nature of recruitment of mercenaria in Barnegat Bay is indirectly reflected in Table 20 (appendix). The data record the fluctuation of bivalve catches from 1960 to 1969, and some cyclicity is evident. However, no statistics are available on the changes in fishing effort during this interval which may have contributed to this cyclicity.

The recent failure of recruitment may be due to the normal population dynamics of the species. All bivalve species with a planktotrophic pelagic larval stage during ontogeny, like mercenaria, are subject to a significant wastage of numbers associated with predation and inadequate food supply (Thorson, 1950). Once the spat set, predation (Carriker, 1956; 1959; 1961) and disease during the pedoveliger and early plantigrade stages can reduce the population substantially. Complete failure of annual recruitment is known to occur in some pelecypods (Baxter, 1962; Coe, 1956). In the case of mercenaria, it seems possible for recruitment to fail for as long as five or even ten continuous years, with the proliferation of the population being dependent on a single good year of recruitment (Haskin, personal communication, 1976).

It is interesting to note that at sites 2, 4, 5, 6, 8, 9, 10, and 11, adult clams exist without any juveniles. At site 7, however, the opposite occurs--juveniles exist without any adults. This infers an inverse association between adults and juveniles. Possibly adult populations preclude successful settlement of young clams due to competition for food. Thus, successful recruitment of mercenaria may be regulated by a density-dependent factor. When the density of the adult population is high, juveniles are forced to settle in unoccupied areas of the bay which may be unfavorable for the species. In connection with this hypothesis, juveniles may reenter the adult population only when the adult population becomes depleted to a critical density level.

Another possible cause of the impoverished recruitment is entrainment of meroplankton of mercenaria in the Oyster Creek Nuclear Power Station. Laboratory experiments (Kennedy, Roosenberg, Castagna, and Mihursky, 1974) clearly demonstrate increased mortality of early cleavage stages (2 hours old), trochophore larvae (10-11 hours old), and straight-hinge veliger larvae (32-50 hours old) of mercenaria with increased temperature and, at higher temperatures, with increased exposure time. In subjecting clam larvae to temperatures ranging from 33.8 to 39.8°C for various lengths of time to simulate temperature conditions incurred while passing through a standard power plant, the following conclusions can be drawn. In the summer, 90 percent of the cleavage stages would be eliminated if entrained for one minute or less, 90 percent of the trochophores in five minutes, and 90 percent of the straight-hinge veligers in over three hundred and sixty minutes.

Because ambient summer water temperatures in Barnegat Bay range from 22 to 27°C (Loveland and others, 1966-1974), larvae would be subjected to a maximum temperature range of 34.5 to 39.5°C for one minute to two hours in the Oyster Creek Station (United States Atomic Energy Commission, 1974). The exact exposure time and temperature depend on the number of dilution pumps in operation. Water of comparable volume to that in the bay is turned over by the station within a period of one week (Roche[1], personal communication, 1976). Since under normal conditions larvae of mercenaria will set in one to two weeks (Carriker, 1959; 1961; Haskin, personal communication, 1976), a substantial quantity of meroplankton conceivably passes through the station. The exact amount of larval mortality caused by this passage is unknown, and the problem should be investigated in the future.

[1]Michael Roche, Jersey Central Power and Light Company, Morristown, New Jersey.

Some evidence indicates that entrainment of larvae by the power station is not responsible for the ineffective recruitment pattern in the bay. First of all, the station first came on line in December, 1969, yet recruitment was successful at a later postoperative period between 1970 and 1972 as inferred from the comparison of absolute growth rates of clams in the bay (Tables 8 and 9, appendix) with their size distributions (Figures 6a-6m). Secondly, recruitment failure has been so widespread, even in areas adjacent to Gulf Point some 7 km south of the power station, that it is difficult to envision larvae being pulled northward into the station from these marginal areas, especially when currents are not flowing toward the station. Furthermore, larvae originating in Little Egg Harbor and Manahawkin Bay to the south and floating northward should have set in the southern extremities of Barnegat Bay, if conditions were conducive for survival there. Thirdly, clams successfully set at site 7 in the summer of 1975 when the station was operating.

Survival of mercenaria seems to greatly improve once the larvae set and the spat pass through the early plantigrade stage. This is shown by the comparison of life and death assemblages collected at site 7. Of the 432 specimens in both assemblages, only 16 belong to the death assemblage, and they have a mean height' (17.52 mm) that is significantly larger than those of the life assemblage (11.84 mm). These differences reflect low mortality rates and high growth rates in the smaller size clams. The absence of juvenile valves in the death assemblages from the remaining sites also upholds this contention.

The absence of dead juvenile valves at all sites except site 7 is surprising considering the long list of predators capable of attacking young stages of post-set clams in the bay (Carriker, 1959; 1961). Barnegat Bay contains the following clam predators: *Callinectes sapidus* (the blue crab), *Neopanope texana* (the mud crab), *Carcinus maenas* (the green crab), *Limulus polyphemus* (the horseshoe crab), *Polinices duplicatus* (boring gastropod), *Urosalpinx cinerea* (boring gastropod), *Eupleura caudata* (boring gastropod), *Busycon carica* and *B. canaliculatum* (whelks). Nevertheless, there is little evidence that these predators are killing large numbers of clams. For instance, only four valves from all death assemblages sampled in 1976 are drilled, and very few have chipped or serrated margins.

One credible explanation for the absence of small valves in the death assemblages is size-preferential solution. Preferential solution of smaller valves of mercenaria no doubt occurs, because of their greater surface area per unit weight compared to larger valves (Driscoll, 1967; 1969). Evidence for this exists in the presence of small valves in the death assemblage at site 7, which has been forming only since the summer of 1975, and the absence of comparable size valves in the death assemblages at all other localities. Because the last successful settlement of spat at sites 2, 4, 5, 6, 8, 9, 10 and 11 was at least five or six years ago, there may have been sufficient time for dead juvenile valves to completely dissolve at these sites. The valves in the death assemblage at site 7, on the other hand, had been accumulating for only approximately one year prior to being collected, and this appears to be an inadequate length of time for the valves to dissolve completely.

The lack of small valves in death assemblages does not seem to be associated with their selective removal by currents. The similarities in the size-frequency distributions from site to site minimizes the probability of current sorting as a viable factor (Levinton and Bambach, 1970). Also, if smaller valves have been swept away from the larger ones due to wave or current sorting and deposited elsewhere in the bay, they should be located somewhere. Several years of intense sampling throughout Barnegat Bay have never unearthed valves less than 10 mm in height' except at site 7. This is true for both quiet, low evergy muddy areas as well as high energy, sandy regions. However, numerous minute shells of other species of organisms such as Gemma gemma, Mulinia lateralis, Spisula solidissima, and Pectinaria gouldii are common. These shells should also be missing, if currents have removed small mercenaria valves.

In addition, four death assemblages analyzed for valve ratios all show similar distributions (Table 21, appendix). Application of a chi-square (x^2) test on these samples reveals no significant difference ($P<0.05$) in the ratio of right to left valves in each assemblage. If these valves were allochtonous, there should be significant differences in their ratios. This would be particularly true for site 2 where the current flow from Oyster Creek is substantial. These conclusions parallel those of Craig (1967) and Cadée (1968) who rejected the importance of post-mortem transport of shells in many modern coastal environments.

The bulk of valve sizes in the death assemblages falls between 40 mm and 70 mm in height' which corresponds to clams of four to nine years of age (Tables 13-17, appendix). Obviously, mortality is extremely high in this interval and appears to be reflective of gerontic death. Fitch (1965) reports a similar increase in death during old age in the Pismo clam, Tivela stultorum. The negative skewness of clam sizes in the death assemblages is caused by growth rates that decrease with age and mortality rates that increase with age subsequent to spat settlement. Thus, the similar distribution of sizes of dead clams in Barnegat Bay results from similar growth and mortality rates throughout the bay.

Most of the sizes of live clams also range from 40 mm to 70 mm in height'. Therefore, the live clam populations in Barnegat Bay, are, for the most part, in old age. This is visually apparent from the equivalence of the size distributions of the life and death assemblage polygons (Figures 6a-6m). The predominence of mostly old clams in the life assemblages raises concern, because these populations should be experiencing high mortality rates and should be declining in size. If recruitment is not successful in the next few years, the pelecypod may become locally extinct in the bay. In any event, the clam industry in Barnegat Bay could encounter a reduction in total annual catches sometime in the near future.

MORTALITY PATTERNS OF MERCENARIA MERCENARIA IN BARNEGAT BAY

Thermal discharges from the Oyster Creek Nuclear Generating Station may be associated with mortality of mercenaria in Barnegat Bay in the following ways. First, mortality rates may be higher in the populations affected by thermal discharges, because the elevated water temperatures cause increased mortality especially in the summer. Second, mortality may be lower in these populations as a consequence of more optimum temperature conditions in the fall, winter, and spring. Third, mortality at the mouth of Oyster Creek may be a census (massive) type related to physiological shocks developing from rapid fluctuations in water temperatures in connection with abrupt changes in operations of the nuclear power station. Fourth, mortality in the populations at the mouth of Oyster Creek may be normal and totally unrelated to the effluent.

These possibilities have been investigated by examining mortality in both transplanted and natural populations of mercenaria in Barnegat Bay. Mortality in transplanted populations was studied using specimens planted directly into the substrate and individuals housed in cages. Shell samples collected from death assemblages in the summer of 1974 served as specimens for the analysis of mortality in natural populations.

Mortality in Populations Transplanted to the Substrate

An initial transplantation experiment was conducted on July 6, 1974, when 980 healthy mercenaria ranging from 20 mm to 40 mm in height' were transplanted from Little Egg Harbor, New Jersey to the substrate at site 2 in Barnegat Bay.

Prior to planting the clams, valves were measured for height' and sanded at their growing edge with fine and medium grained sandpaper to produce a microgrowth reference plane. They also received a coating of Volger's red ink to insure proper identification at the time of recovery.

These clams were sampled for mortality on September 10, 1974, but no dead specimens were found, although shell microgrowth analysis of ten live bivalves revealed a sharp reduction in growth following transplantation. The population was resampled for mortality in July, 1975 and June, 1976. A total of 217 live and 4 dead clams were recollected in July, 1975, and 74 live and no dead clams were gathered in June, 1976. Both years of data indicated low mortality under the influence of the thermal discharges.

Of the 980 mercenaria originally transplanted, 291 live and 4 dead specimens were retrieved. Thus, over a 23 month period, 30.1 percent of the bivalves were recovered. Only 1.3 percent mortality was observed in the recovered assemblage.

Transplantation experiments were continued in the summer of 1975 to establish seasonal mortality patterns of the clam and to correlate these patterns with operations of the nuclear power station (Table 6, appendix). A total of 1,486 clams ranging from 20 mm to 80 mm in height' were transplanted from Little Egg Harbor and site 6 in Barnegat Bay to the substrate at sites 2 and 5. Each location received 743 mercenaria of comparable size (Table 22, appendix) with the clams at site 5 acting as controls. The shell of every specimen was sanded at its growing edge, stained with Volger's red ink on the umbo, and numbered with enamel paint for purposes of recovery. The experimental populations were retrieved and measured for height' on June 23, 1976 (site 2) and June 24, 1976 (site 5), one year after transplantation. Empty valves were examined microscopically to specify their absolute age and season of death.

Remarkably, 67.29 percent of the clams transplanted to the two regions were recovered in the life and death assemblages. Recovery at site 2 was greater (74.15 percent) than that at site 5 (60.43 percent). Only 6.53 percent mortality was observed in the total assemblage retrieved at site 2, but 11.36 percent mortality occurred in the assemblage at site 5. A chi-square test (x^2) employed on these assemblages showed that mortality was significantly greater ($0.005 < P < 0.01$) at site 5 than at site 2.

Table 23 (appendix) discloses the size (height')-frequency distributions of the live and dead clams sampled at sites 2 and 5 one year after planting them. Broken valves are not included in the measurements. .The simple size statistics of the assemblages are presented in Table 24 (appendix). Student's t-tests performed on these specimens demonstrate that no significant difference (0.20 - P - 0.50) exists between the mean heights' of live clams sampled at the two sites. However, the mean heights' of the dead clams at site 2 are significantly less ($0.01 < P < 0.02$) than those at site 5. This appears to be mainly due to higher mortality in the 30 mm to 35 mm size class at site 2 and the 50 mm to 65 mm size classes at site 5.

Figure 8 compares the sizes of dead mercenaria at the two locations. The size-frequency polygon for site 2 consists of a bimodal distribution, but it is polymodal for site 5. With the exception of peaks in the 30 mm to 35 mm size class for site 2 and the 40 mm to 45 mm size class for site 5, the trends in mortality are similar at both locations. The most notable equivalence exists in the size range from 50 mm to 65 mm where mortality rises in each sample. The high mortality in this interval exactly parallels that in death assemblages of natural populations of mercenaria, and it reflects the increasing rate of mortality with age in the clam.

Figure 8. Size (height')-frequency distributions for death assemblanges of transplanted clams recovered from the substrate at sites 2 and 5 in June, 1976.

----- denotes site 2
——— denotes site 5

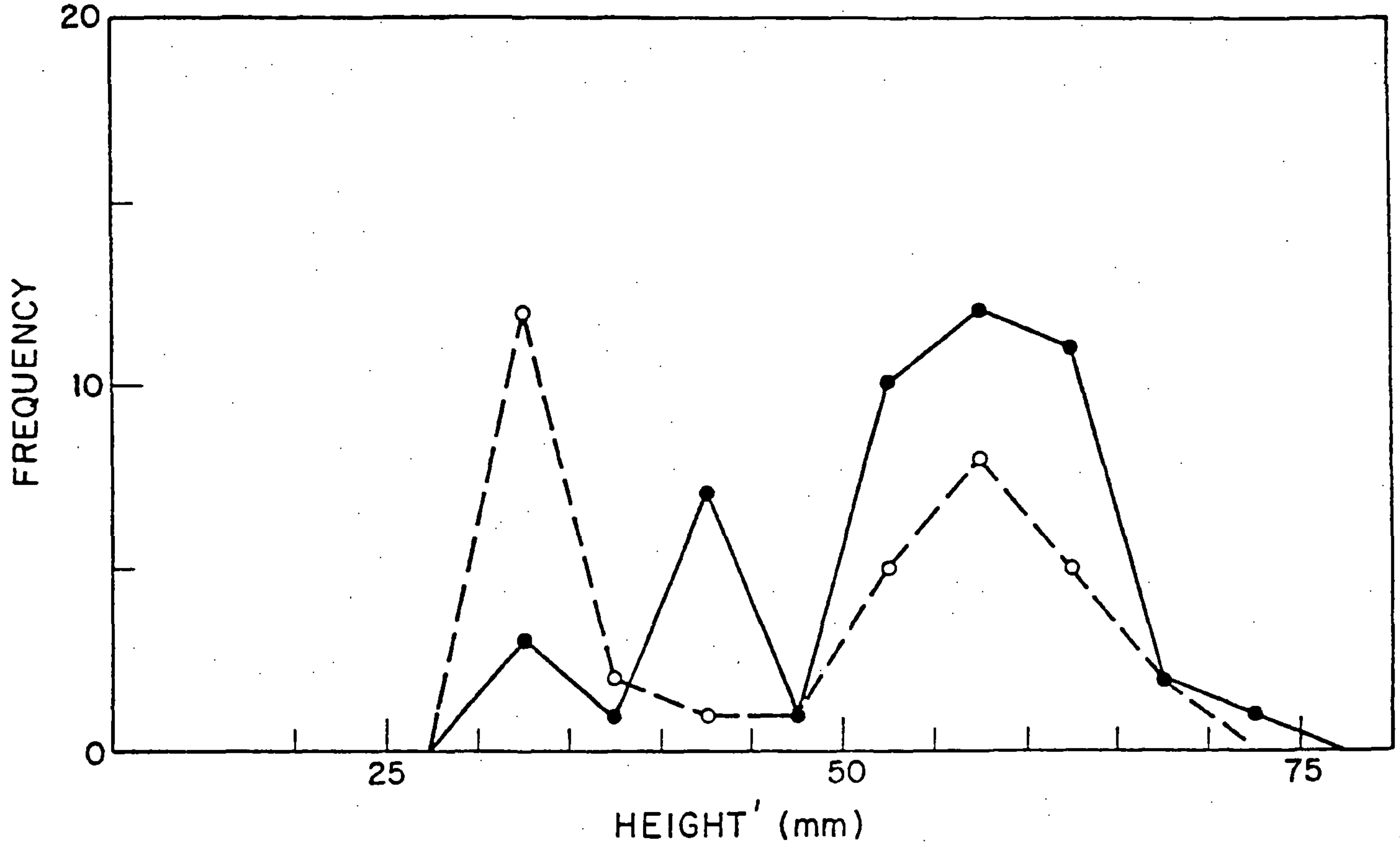


Figure 8

Shell microgrowth analysis of the majority of dead clams recovered reveals additional differences and similarities in mortality between the two regions of the bay. For example, the death assemblage at site 2 displays an absolute age distribution that is bimodal with highest frequencies of death between the ages of 2 and 3, and 5 and 6. However, the distribution of absolute age at death data for clams at site 5 approximates a unimodal, slightly negatively skewed curve with a maximum frequency of death between the ages of 5 and 6 (Figure 9). These age distributions clearly correspond to the size-frequency distributions of the death assemblages.

The seasonal frequency of death in both assemblages is also analogous. Death frequency diagrams constructed from data on 73 of the dead specimens (Figure 10) indicate that mortality is concentrated in the summer (Pl. 3, Figs. 9, 10, 11). Minimum frequency of death occurs in the winter, and intermediate frequency in the spring and fall. A chi-square test (X^2) executed on this data exhibits no significant difference ($0.10 < P < 0.25$) in the season of death between the two samples.

Although the clams died primarily in the summer, they did not do so simultaneously as is evident from the high variability in the terminal microgrowth patterns of their shells. In essence, the death assemblages developed from natural rather than massive mortality in the transplanted populations. The existence of mortality during other seasons of the year is added proof of this effect (Kurten, 1964; Rhoads and Pannella, 1970; Tevesz, 1972).

The high incidence of summer death correlates well with increased predator and parasitic activity during the warmer months of the year. Haskin (personal communication, 1976) notes this effect in populations of Crassostrea virginica in Delaware Bay, New Jersey, where much of the mortality is associated with parasitic activity of the haplosporidian, Minchinia nelsoni (MSX). High summer mortality in mercenaria may also be associated with the physiological stress of spawning. During spawning the percentage wet and dry flesh weights and the nitrogen content of the animal drops, and, in many clams, so does the carbohydrate content (Ansell and Lander, 1967). These changes may leave the bivalve particularly vulnerable to the vagaries of environmental stresses. Sellmer (1967) suggests the same possibility for populations of Gemma gemma, as does Paine (1963) for populations of Glottidia pyramidata.

High summer mortality does not appear to be associated with elevated water temperatures alone, otherwise mortality would have been higher in the population transplanted at site 2 which was subjected to water temperatures as high as 30 to 34° C in July and August. Ansell (1958) places the upper temperature threshold of stress on growth of mercenaria at 31°C, and he proposes that mortaility increases in populations continuously exposed to temperatures above this point. Henderson (1929) sets the lethal temperature level of mercenaria at 45.2 C which is far above the stress limit on growth.

The similarities and differences of mortality in the two transplanted assemblages strongly infer that thermal discharges do not adversely affect mortality in the pelecypod. In fact, given the above data, which disclose mortality to be significantly less at site 2, one might argue that the termal discharges are responsible for a reduction in mortality. The similarity in the size and age at which the peak frequency of death occurs in the two assemblages and the

Figure 9. Absolute age-frequency distributions for death assemblages of transplanted clams retrieved from the substrate at sites 2 and 5 in June, 1976.

----- denotes site 2
----- denotes site 5

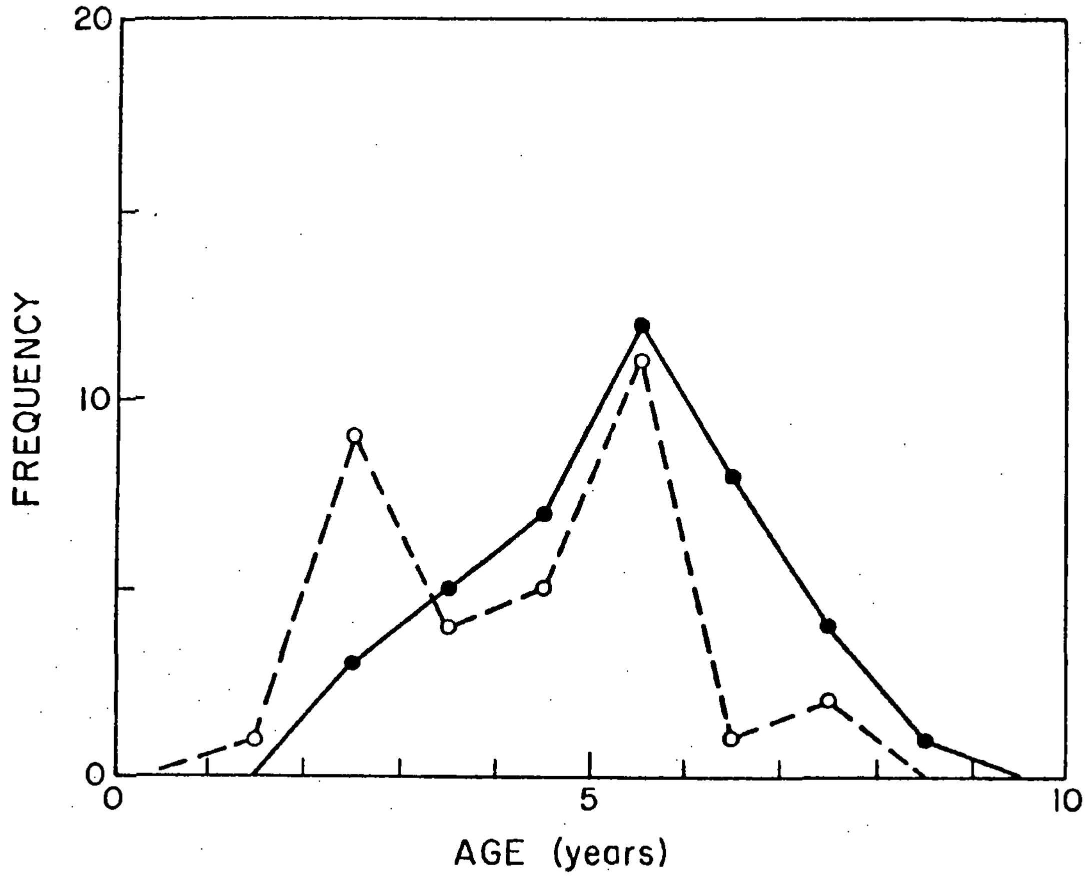
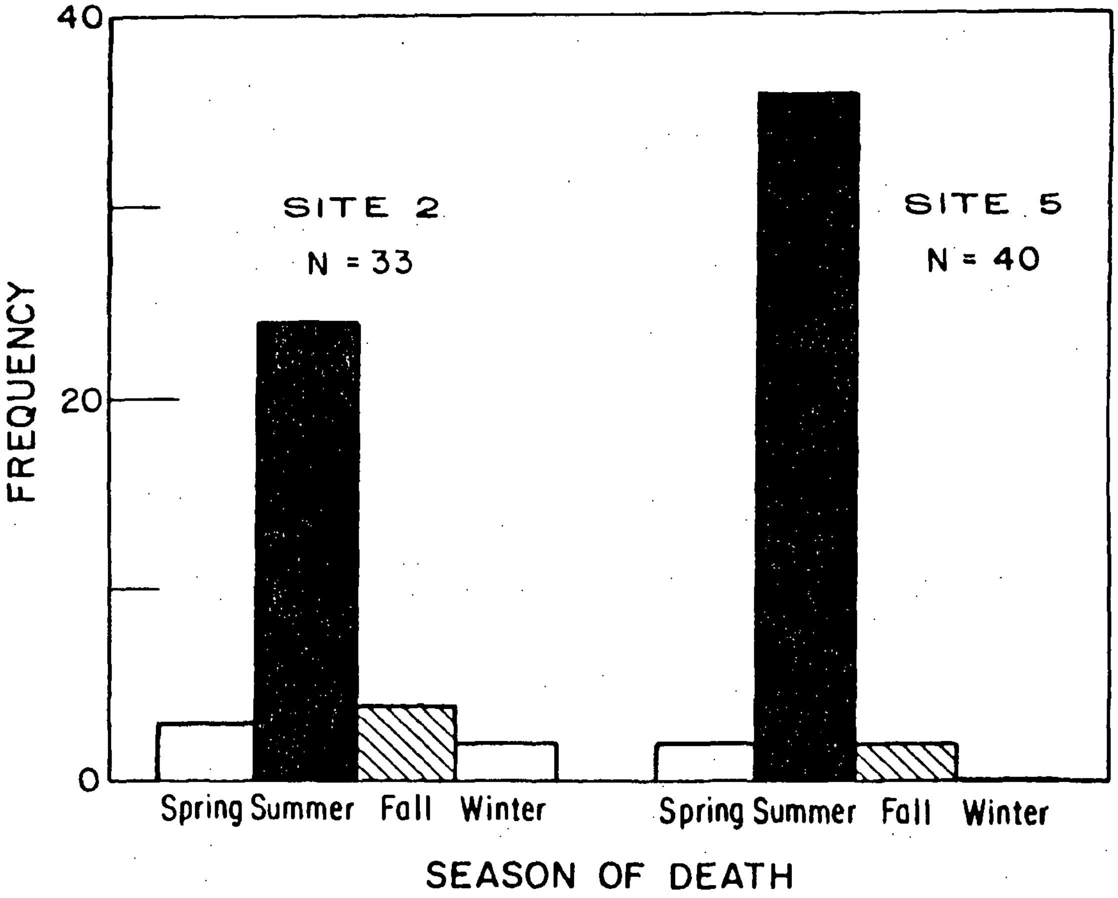


Figure 9

Figure 10. Death-frequency distributions per season for death assemblanges of transplanted clams collected from the substrate at sites 2 and 5 in June, 1976.



40
20
0
FREQUENCY
SITE 2
N = 33
SITE 5
N = 40
Spring
Summer
Fall
Winter
Spring
Summer
Fall
Winter
SEASON OF DEATH

Figure 10

and the nearly identical distribution of seasonal mortality suggest, however, that no relationship exists between the thermal effluent and mortality of the transplanted clams. Furthermore, charges in operations of the Oyster Creek Nuclear Generating Station during 1975 and 1976 do not correlate with periods of increased mortality in the population transplanted at site 2. These observations support the view that mortality in both assemblages results from the natural population dynamics of the species.

Mortality in Populations Transplanted in Cages

Several problems affecting the study of mortality in assemblages of clams transplanted to the substrate at sites 2 and 5 were the inability to completely remove the effects of predation and the incapacity to sort out those variables associated with the substrate that could have contributed to the observed mortality patterns. In addition, it was impossible to recover 100 percent of the specimens released. To alleviate these shortcomings a third transplantation experiment was attempted. On June 18, 1975, 676 marked clams ranging from 20 mm to 73 mm in height' were placed in plastic, cylindrical cages and anchored to the substrate at sites 2 and 5. Each cage measured 43.2 cm in length and 22.9 cm in diameter at its midpoint. Nine cages containing a total of 338 clams were planted at each location, but the ninth cage at site 5, holding 13 specimens, was lost several weeks after transplantation. This left only eight cages and 325 clams at that spot.

The cages were checked for mortality at the end of each season, and empty valves were removed, sectioned, and analyzed microscopically. The experiment yielded five seasons of mortality data for site 5 but only four seasons for site 2. Unfortunately, all nine cages at site 2 were lost in the summer of 1976. The cages planted at site 5 were subsequently removed on September 18, 1976.

The size (height')-frequency distributions of the transplanted clams are listed in Table 25 (appendix). These measurements do not include those of mercenaria lost with cage nine at site 5 in the summer of 1975. Table 26 (appendix) summarizes the seasonal mortality and survivorship observed at each location, and Figure 11 compares the frequency of seasonal mortality. The size specific mortality rate, defined as the percentage of the initial transplanted size class dying within each season, is included in Tables 27 and 28 (appendix).

Statistically, mortality is significantly greater each season at site 2 ($P<0.001$ for the summer and fall of 1975, and the spring of 1976; $0.01<P<0.025$ for the winter of 1976). The magnitude of these differences can be realized by noting the number of clams surviving after one year of transplantation. This amounts to 215 clams at site 5 but only 109 at site 2--a survival ratio of nearly 2 to 1. By far the largest differences in mortality appear in the summer and fall of 1975, when the frequency of death at site 2 was 2.7 and 3.3 times greater respectively than at site 5. As in the populations transplanted to the substrate, maximum frequency of death rises in the summer. This is manifested as well-defined peaks in the death-frequency diagrams. The variation in the season of death data, however, demonstrates that both assemblages have developed from natural rather than catastrophic mortality.

No relationship exists between the size of the organism and its frequency of death. This is evident from data in Tables 27 and 28 (appendix) which display uniform frequencies of death throughout the size classes. Mortality is not concentrated in the larger or older clams as in natural and transplanted

Figure 11. Death-frequency distributions per season for death assemblages of *Mercenaria mercenaria* retrieved from cages at sites 2 and 5 in 1975-1976.

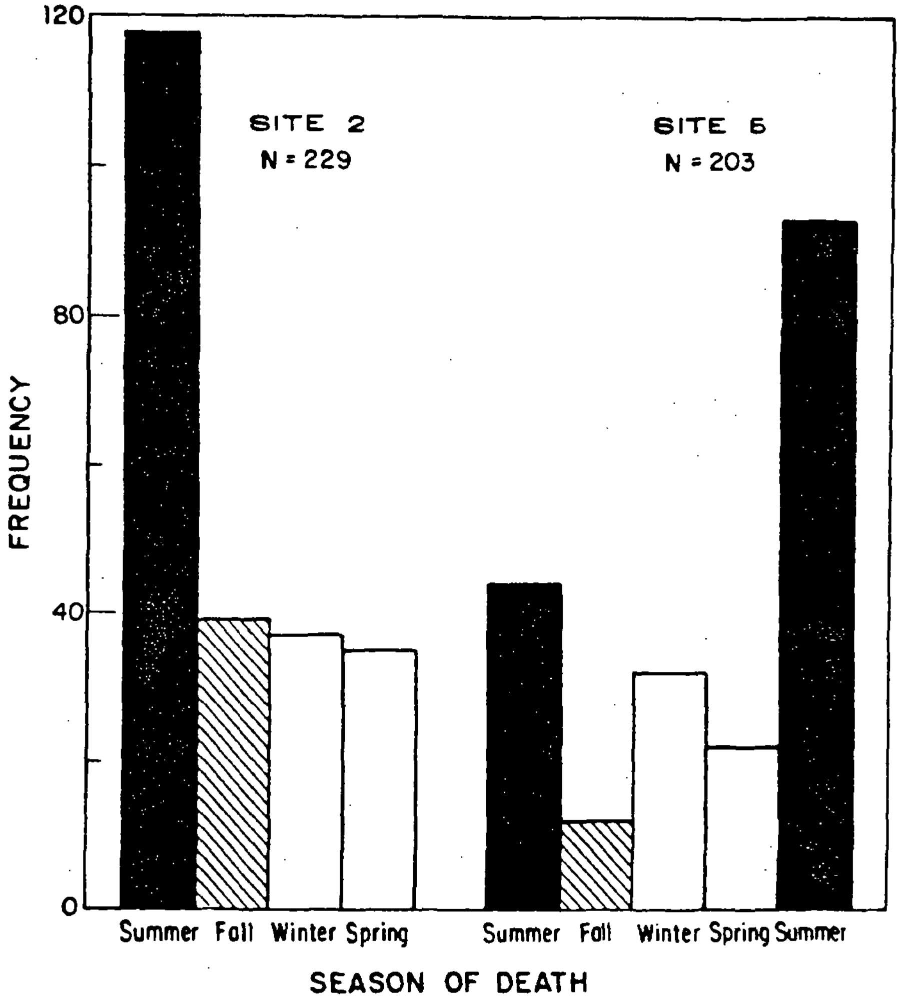

120
80
40
0
FREQUENCY
SITE 2
N = 229
SITE 5
N = 203
Summer Fall Winter Spring
Summer Fall Winter Spring Summer
SEASON OF DEATH

Figure 11

substrate populations, but fewer, larger clams were initially transplanted which could account for this result. The persistent trend of constant mortality irrespective of size class might well be a consequence of the unnatural, epifaunal habit forced upon the transplanted specimens. This change in life-style was apparently detrimental to the normal physiology of the clam. For instance, shell growth was extremely impaired following transplantation to cages (Pl. 3, Figs. 6, 7, 8) with the amount of accretion of calcium carbonate ranging from 0 microns to 387 microns per specimen (Table 29, appendix). Some clams did not grow at all during the experiment. Mortality was also far greater in the populations placed in cages than in those planted in the substrate. The number of dead clams in cages after one year of transplantation amounted to 67.8 percent of the original assemblage at site 2 and 33.8 percent of the original assemblage at site 5. The number of dead specimens in cages at site 5 rose to 62.5 percent of the original assemblage only one year and three months after transplantation.

These percentages represent exceptionally high mortality rates. Obviously, mercenaria requires a natural, granular substratum for proper growth and survival. The overall impact of the cages has been to accentuate the mortality rates of the bivalve without influencing the seasonal distribution of death. The similarity of the death-frequency diagrams of the assemblages transplanted to the substrate and to the cages is reflective of this.

The significantly higher rates of mortality in cages at site 2 than in those at site 5 may be due to a number of factors. For example, the higher mortality rates at site 2 might be a consequence of an inadequate nutrient supply. Perhaps the quality or quantity of phytoplankton at site 2 is insufficient to support the high density of clams in the cages. Another possible cause of the high mortality rates at site 2 is elevated water temperatures associated with the thermal discharges. Finally, the high mortality rates may be the result of two or more variables acting together (synergistic effects). Possibly the thermal discharges may be working in association with an inadequate food supply or some other variable to adversely affect the bivalves.

The exact cause of the higher mortality rates of specimens in cages at site 2 is unknown. This problem should be investigated in future research.

Mortality in Natural Populations

The effects of thermal discharges on mortality of natural populations of mercenaria were examined by utilizing death assemblages collected in 1974 at sites 2, 5, 6, and 9. The death assemblages at sites 5, 6, and 9 acted as controls for comparison to the assemblage affected by thermal discharges at site 2. Death-frequency histograms, mortality rate curves, survivorship curves, and life tables were constructed for each assemblage.

Table 30 (appendix) records the seasonal frequency of death of mercenaria at all four sites based on microgrowth analysis of 278 specimens. Trends in mortality are conspicuous (Figure 12); the frequency of death reaches a maximum in the summer and winter and a minimum in the spring and fall. There is no significant difference in the distribution of seasonal mortality between sites 2 and 5 ($0.50<P<0.75$), sites 2 and 6 ($0.25<P<0.50$), and sites 2 and 9 (0.10 P 0.25). This implies that the termal discharges have not affected seasonal mortality patterns of mercenaria in the past.

Mortality ranges from 12 percent (site 2) to 24 percent (site 9) in the spring, 30 percent (site 6) to 42 percent (site 9) in the summer, 17 percent (site 5) to 25 percent (site 2) in the fall, and 16 percent (site 9) to 33 percent (site 5) in the winter. The variation in the distribution of seasonal mortality indicates that each death assemblage is the result of natural rather than census mortality. As in the transplanted populations, high summer mortality in natural populations may be caused by physiological stress associated with spawning and increased predator and parasitic activity. The organism spawns at water temperatures of approximately 24 to 25° C which are beyond the optimum temperature for growth in the species. Thus, environmental stress concurrent with the physiological stress of spawning might also contribute to the observed summer frequency of death. Increased winter mortality seems to be associated mainly with harsh environmental conditions. Low food supply and low water temperatures force the pelecypod to live on stored carbohydrate reserves, and these reserves may be insufficiently low in some individuals.

The high frequency of death in the winter in death assemblages of natural populations does not correspond to the low winter frequencies found in the transplanted populations. However, death assemblages of the transplanted populations represent only one year of seasonal mortality data, whereas those of natural populations depict cumulative mortality over many years. This difference may be responsible for the observed divergences in the seasonal mortality data. Because death assemblages of natural populations record long term trends in mortality of mercenaria, they are more reflective of the true population dynamics of the species.

Life tables have been formulated for natural populations of mercenaria in Barnegat Bay by determining the age at death of death assemblages of clams at sites 2, 5, 6, and 9. These tables (Tables 31 to 34, appendix) give the most concise summary of mortality in the clam. The method of computation of a life table is reviewed by Deevey (1947), Barclay (1958), Reyment (1971), and Gani (1973). Mortality rates (q_x) are calculated first from the original array of mortality data, and the remaining entries in the table are calculated from them. Because mortality in the meroplanktonic and pedoveliger stages of mercenaria was not examined in this study, life tables have been built beginning at age one of a hypothetical cohort (radix) of 1,000 clams.

The entries in the four life tables can be compared for the purpose of studying mortality characteristics in populations from different areas of the bay. This is possible, because the entries are structured with respect to a common variable--age. Comparisons of mortality on any other basis would be far less accurate.

Figures 13a to 13d illustrate the mortality rates of clams at sites 2, 5, 6, and 9. The similarity of the curves is quite evident. The greatest agreement of the data occurs between the ages of one and four when mortality rates are extremely low and uniform at all locations. After the fourth year of life mortality increases markedly, although less consistently, from one site to the next. The probability of death decreases somewhat between the ages of six and seven for mercenaria at sites 2 and 9 only to increase precipitously in the age interval from seven to eight. Site 6 shows the same trend with a decline in the probability of death between the ages of seven and eight, but an acute rise from the age of eight to nine. Only at site 5 does the rate of mortality increase continuously through all the age intervals. These effects are also

Figure 12. Death-frequency distributions per season for death assemblages of natural populations of *Mercenaria mercenaria* at sites 2, 5, 6, and 9.

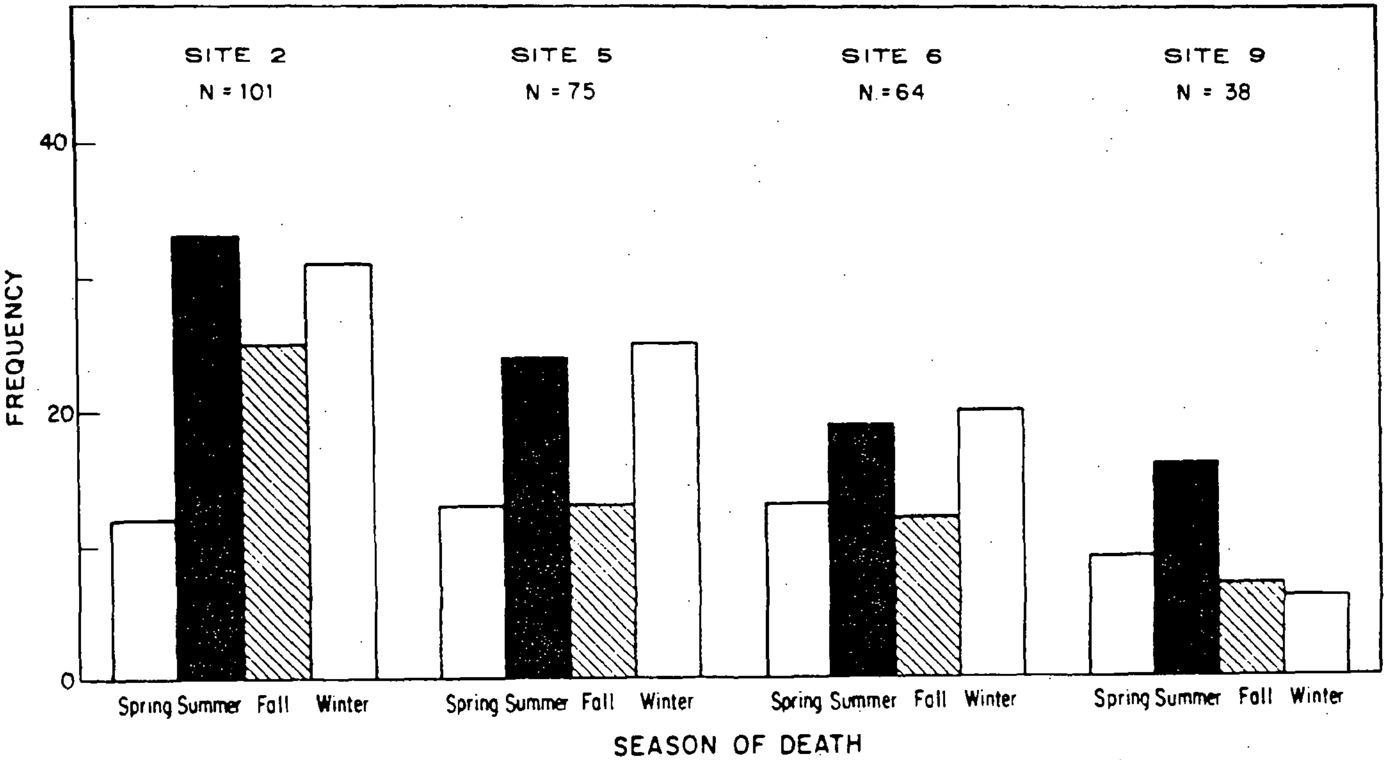

SITE 2
N = 101
SITE 5
N = 75
SITE 6
N = 64
SITE 9
N = 38
FREQUENCY
40
20
0
Spring Summer Fall Winter
Spring Summer Fall Winter
Spring Summer Fall Winter
Spring Summer Fall Winter
SEASON OF DEATH

Figure 12

Figures 13a-13d. Mortality rate curves for natural populations of *Mercenaria mercenaria* at sites 2, 5, 6, and 9. Data presented as mortality rate per 1,000 for each age interval of 1 year (1,000 q_x), plotted against the start of the interval.

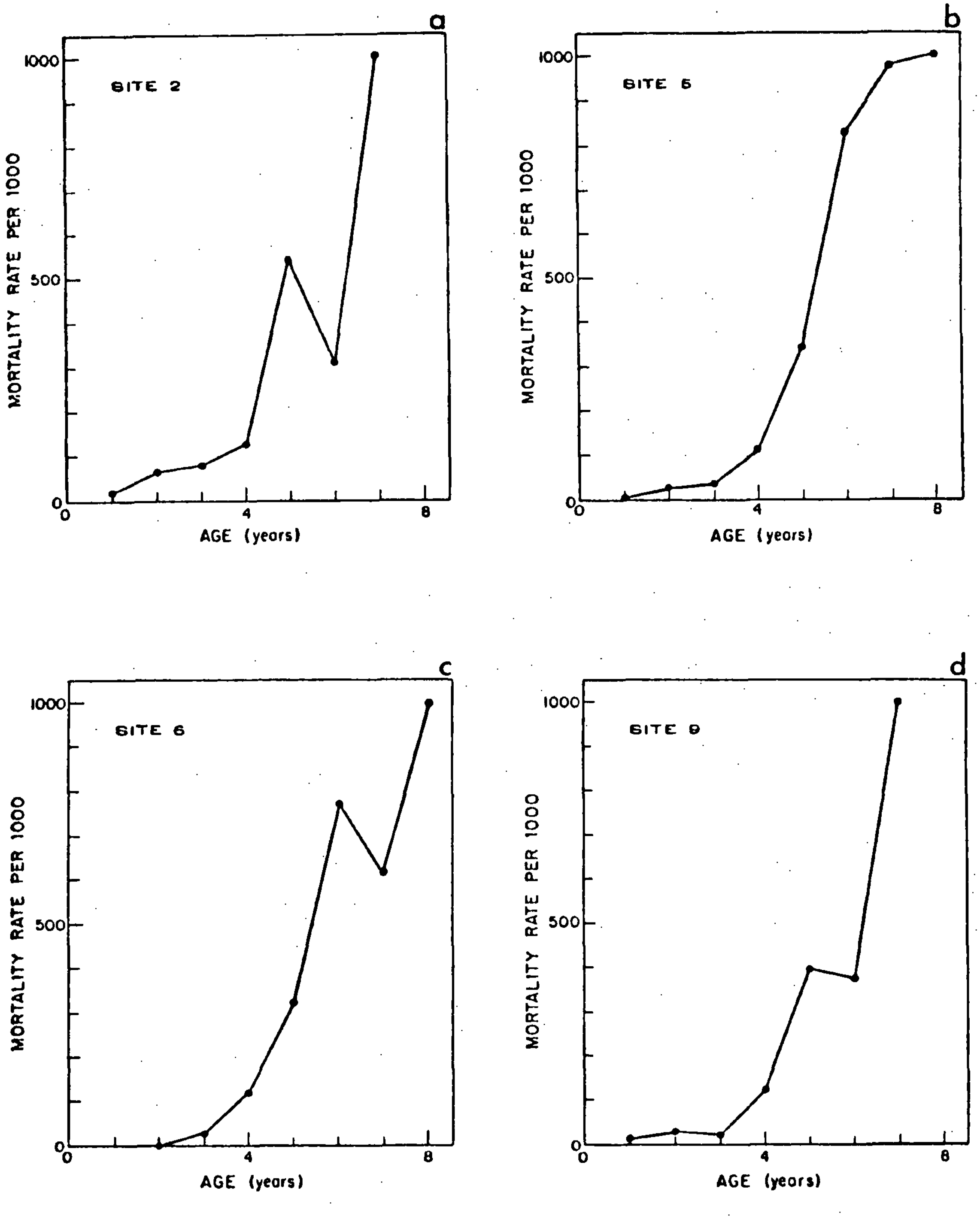


Figure 13a - 13d

apparent from the age-specific mortality rates estimated for each population (Table 35, appendix).

Survivorship curves (Figures 14a to 14d) constructed from each life table display a strongly convex morphology indicative of populations that experience low mortality until near the end of their life span. However, mortality is known to be heavy during the meroplanktonic stages of mercenaria (Thorson, 1950; Carriker, 1961). In respect to this phenomenon, the survivorship curve for the entire ontogeny of the pelecypod must be sigmoidal. A high risk of death exists during the free-swimming larval stages, a low risk ensues once the organism becomes established on a favorable substrate, but the risk rises again in old age. This pattern corresponds to the type B_3 survivorship curve of Odum (1971, p. 174).

The clam stretches its mean life span toward the maximum after successfully setting in an area. This insures the survival and proliferation of the species because mercenaria has a relatively long generation time and does not reach sexual maturity until the age of three. If mortality were great from the setting stage to age three, populations might not attain the proper density for successful spawning to take place. Once sexual maturity is acquired, mortality rates increase significantly into old age.

The abrupt rise in mortality between the ages of five and nine seems to be ultimately controlled by the effects of endorgenous and exogenous senescence. The onset of senescence in mercenari is reflected in its outer shell layer as a permanent alteration of prismatic to crossed-lamellar structure concomitant with the development of frequent growth breaks. This alteration in shell microstructure occurs exclusively in oder specimens ranging from 50 mm to 65 mm in height'. This correlates well with Hopkins's (1930) finding of a diminishing metabolism with increasing age in the species. Thus, the clam must be less capable of coping with periods of physiological and environmental stress as it ages. In essence, high mortality appears to be associated with both physiological degeneration and ecological influences, although no clear distinction can be made concerning the relative contribution of either factor to the observed mortality rates.

There is no apparent impact of the thermal discharges on these mortality patterns. Clearly, the four life tables, mortality rate curves, and survivorship curves for the population investigated are remarkably similar. If the thermal discharges were affecting mortality patterns in populations of mercenaria in Barnegat Bay, significant variations should be expected between the life table for site 2 (affected by thermal discharges) and those for sites 5, 6, and 9 (unaffected by thermal discharges). It is reasonable to conclude, therefore, that no relationship exists between mortality in post-set mercenaria and thermal discharges from the Oyster Creek Nuclear Generation Station.

Figures 14a-14d. Survivorship curves for natural populations of *Mercenaria mercenaria* at sites 2, 5, 6, and 9. Data plotted as the number of clams surviving at the beginning of each age interval (l_x) from an initial cohort of 1,000 specimens.

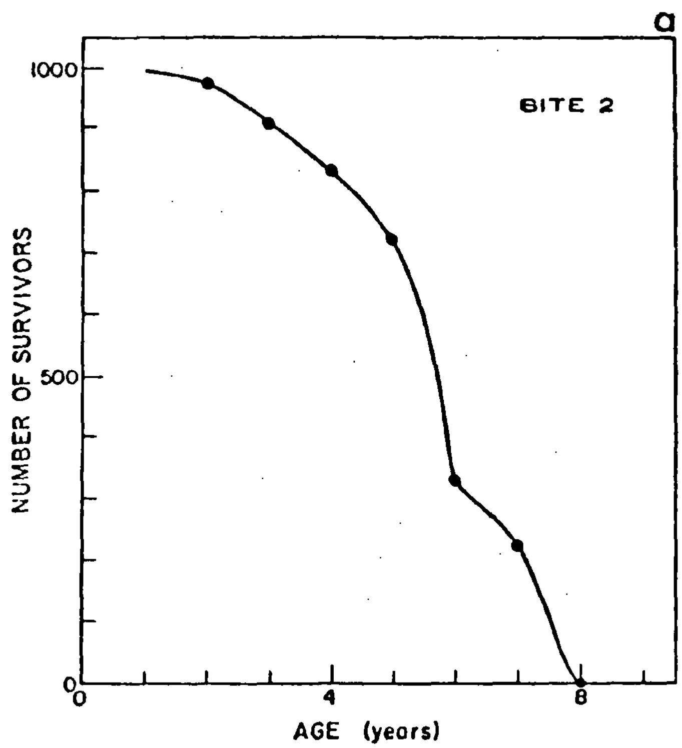
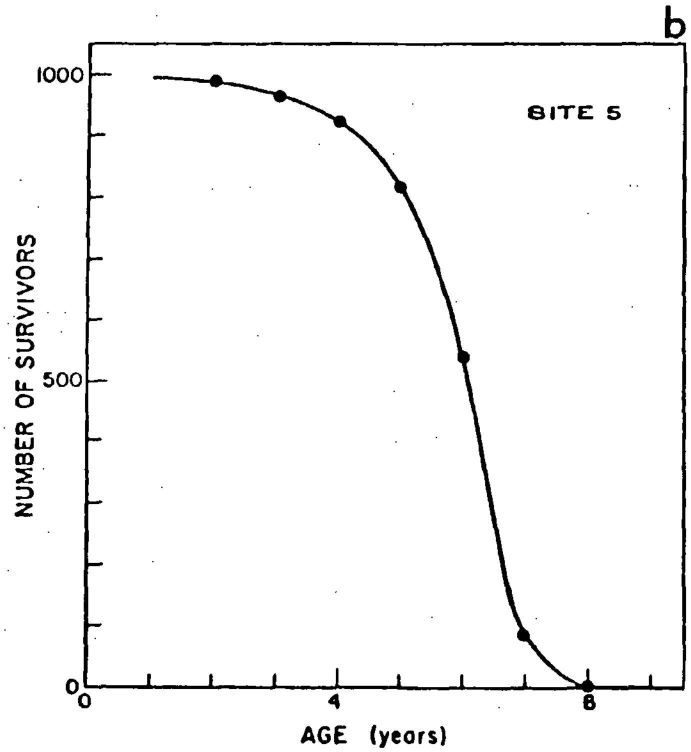
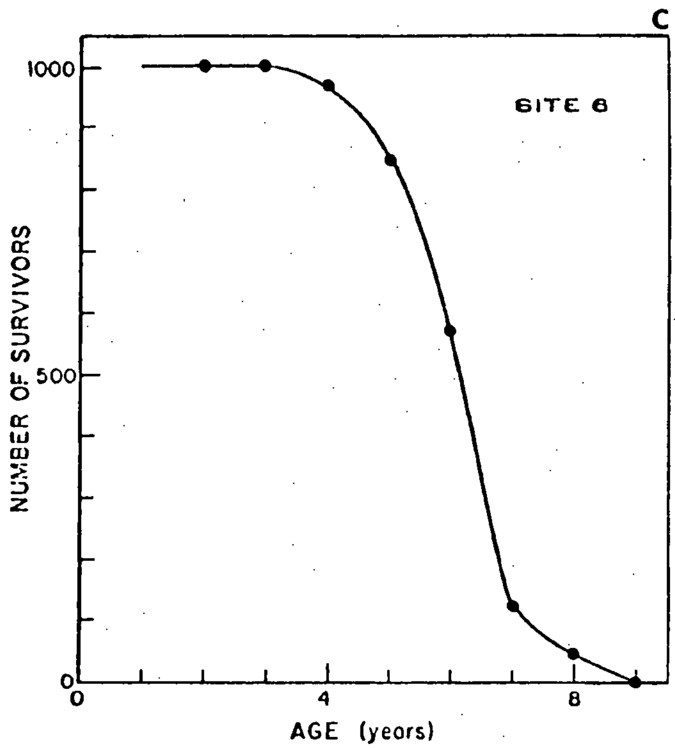
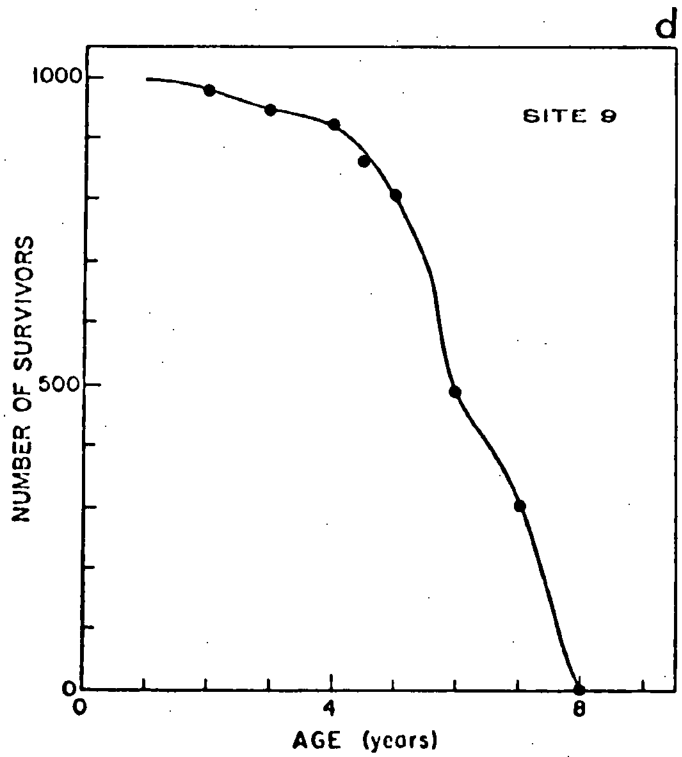


Figure 14a - 14b





Figures 14c - 14d



SUMMARY AND CONCLUSIONS

The relationship of thermal discharges from the Oyster Creek Nuclear Generation Station to morality of Mercenaria mercenaria (Linnaeus) in Barnegat Bay, New Jersey has been investigated using life and death assemblages of the pelecypod. Observations were made on natural and transplanted samples in an effort to establish growth rates, size and age distributions, and seasonal and absolute mortality rates in populations from areas that are both affected and unaffected by thermal discharges. Data were collected by means of shell mircrogrowth analysis of the specimens.

The study of life and death assemblages of natural clam populations in the bay yields the following information:

1. *M. mercenaria* undergoes a slow, exponential decline of growth with increasing age. The monomolecular equation adequately models growth in the species.

2. Mortality rates of *M. mercenaria* vary significantly with age. The trend of mortality during ontogeny is high-low-high with mortality being great in the planktonic larval stages, low subsequent to spat settlement, and high again in the gerontic stage. The probability of death is very low for clams between the ages of one and three, but it increases after sexual maturity is attained. Between the ages of four and nine the probability of death rises sharply and appears to be associated with the effects of senescence.

3. Mortality rates and survivorship curves of *M. mercenaria* subjected to the thermal effluent are remarkably similar to those of *M. mercenaria* from control sites unaffected by it.

4. The season of death and absolute age at the time of death of *M. mercenaria* are alike irrespective of location in the bay. Maximum frequency of death in post-set clams occurs in the summer and winter, and it is concentrated in individuals between the ages of five and nine. Variation in the season of death data shows that death assemblages have developed from natural rather than census mortality.

5. The maximum longevity of *M. mercenaria* in Barnegat Bay is eight to nine years.

6. Size-frequency distributions of death assemblages of natural populations throughout Barnegat Bay exhibit unimodel, negatively skewed curves. The bulk of dead specimens ranges from 40 mm to 70 mm in height'. These size distributions result from an interplay of growth and mortality rates, although mortality rates exert the major controlling influence.

7. Unimodal, negatively skewed curves are also common in the size-frequency distributions of life assemblages of natural populations. With the exception of the population in Barnegat Inlet, the majority of live clams range from 40 mm to 70 mm in height'. Thus, most live *M. mercenaria* in Barnegat Bay are in old age. This raises concern, because mortality rates should be high in these clams. This implies, in turn, that Barnegat Bay represents a declining clam resource. In fact, unless successful recruitment of *M. mercenaria* occurs in the next few years, the clam industry in Barnegat Bay may become completely exhausted.

8. Recruitment is not a dependable annual event in Barnegat Bay. The unimodal nature of the size-frequency distributions of the life assemblages reflects this. The last successful spat settlement was in Barnegat Inlet during the summer of 1975. The remainder of the bay has not experienced successful recruitment since at least as far back as the summer of 1972.

Examination of assemblages of M. mercenaria transplanted to the substrate at the mouth of Oyster Creek (affected by thermal discharges) and at a control site adjacent to Stouts Creek (unaffected by thermal discharges) in Barnegat Bay reveals:

1. Mortality in the assemblages transplanted at the control site is significantly greater than in the assemblage transplanted at the mouth of Oyster Creek.

2. The greatest frequency of death at both localities develops in individuals between 50 mm and 65 mm in height'. This size interval corresponds to clams between 5 and 6 years of age. These mortality patterns correlate well with those of natural populations, and they appear to be reflective of gerontic death.

3. The seasonal frequency of death is analogous in the two assemblages. Mortality peaks in the summer and subsides in the spring, fall, and winter. Mortality is a consequence of natural rather than catastrophic effects.

Seasonal observations made on assemblages of clams transplanted in cages at the mouth of Oyster Creek and at the control site adjacent to Stouts Creek show:

1. Seasonal and annual mortality are significantly greater in the assemblage affected by thermal effluent than in the assemblage unaffected by it.

2. The frequency of death in cages does not vary significantly with either the size or age of the organism.

3. The seasonal distribution of death is similar at each site. Mortality reaches a maximum in the summer and declines in the spring, fall, and winter. This pattern, which parallels that of specimens transplanted to the substrate, results from natural rather than massive mortality.
4. Clams transplanted in cages display aberrant growth and mortality patterns. Little or no shell growth occurred in specimens subsequent to transplantation, whereas their rate of mortality attained abnormally high levels.

Mercenaria mercenaria requires a granular substratum for adequate growth and survival. The unnatural conditions of the cage experiments preclude an accurate evaluation of the effects of thermal discharges on mortality in the bivalve. No clear distinction can be made between the effect on mortality rates of ecological and physiological factors and of the experiment itself. The exact cause of the higher mortality rates of clams in cages at the mouth of Oyster Creek as compared to the control site is unknown and should be investigated in future research.

The effects of thermal discharges on mortality of M. mercenaria are manifested most succinctly by death assemblages of natural populations and by populations transplanted to the substrate. The equivalence of life table data and size distributions for death assemblages of natural populations at the mouth of Oyster Creek and for death assemblages at control sites indicates that the thermal discharges have no effect on mortality of juvenile and adult M. mercenaria.

The similarity in the seasonal frequency of death of specimens in these assemblages adds further support to this contention.

Populations transplanted to the substrate also record no adverse effects because of the thermal discharges. This is readily apparent from the significantly higher mortality rates in clams transplanted to the substrate at the control site adjacent to Stouts Creek than at the mouth of Oyster Creek. In addition, the season of death and the absolute age at the time of death of transplanted M. mercenaria are nearly idential at both localities. The time of death of individuals subjected to the thermal effluent also does not correlate with changes in operations at the Oyster Creek Nuclear Generation Station.

Mortality of M. mercenaria in Barnegat Bay appears to be controlled by the natural population dynamics of the species. Peak frequency of death in natural populations of post-set clams occurs in older individuals and develops predominantly in the summer and winter months. It is proposed that high summer mortality is associated with the physiological stress of spawning which would partially account for the large number of post-reproductive clams in the death assemblages, and with the increased activity of predators and parasites during the warmer months of the year. High winter mortality, however, seems to be caused mainly by ecological factors such as low food supply and low water temperatures concurrent with inadequate carbohydrate reserves.

Subsequent to setting on a favorable substrate, M. mercenaria extends its mean life span to a maximum. This allows most individuals in a population to reach sexual maturity and to perpetuate the species. The stability of the clam during this period of life tends to offset the totally unpredictable nature of its meroplanktonic stages. Thus, a young population can persist relatively intact for several years at a time without the need of recruitment.

One important problem that must be examined in future research is the absolute mortality patterns of the planktonic larval stages of M. mercenaria. Data collected on mortality during these stages should enable the construction of a complete life table for the species. If this research were undertaken in Barnegat Bay, it would also serve the dual purpose of determining what role, if any, the thermal discharges and entrainment effects of the Oyster Creek Nuclear Generation Station play on the early ontogenetic stages of the pelecypod.

Another problem that needs to be focused upon in the future is to determine how many shells per sample need to be analyzed microscopically to derive the overall mortality plan of the population. This statistical approach would have great application to the investigation of the population dynamics of M. mercenaria as well as many other pelecypods.

REFERENCES

Ansell, A. D., 1968, The rate of growth of the hard clam Mercenaria mercenaria (L) throughout the geographical range: Jour. Du Conseil. Conseil International Pour L'Exploration De La Mer., v. 31, p. 364-409.

Ansell, A. D., and K. F. Lander, 1967, Studies on the hard-shell clam, Venus mercenaria, in British waters. III. Further observations on the seasonal biochemical cycle and on spawning: Jour. Appl. Ecol., v. 4, p. 425-435.

Barclay, G. W., 1958, Techniques of population analysis: New York, John Wiley, Inc., 311 p.

Baxter, J. L., 1962, The Pismo clam in 1960: California Fish and Game, v. 48, p.35-37.

Busch, D. A., 1971, Tube building, growth and sediment relationships in populations of Pectinaria gouldii from Barnegat Bay: Rutgers Univ., unpub. M.S. thesis, 74 p.

Cadee, G. C., 1968, Molluscan biocoenoses and thanatocoenoses in the Ria de Arosa, Galiocia, Spain: Leiden, E. J. Brill., 121 p.

Carpenter, J. H., 1963, Concentration distribution for material discharges into Barnegat Bay: Pritchard-Carpenter, Consultants, and the John Hopkins University, Baltimore 18, Maryland, unpub., rept. 13 p.

Carriker, M. R., 1956, Biology and propagation of young hard clams, Mercenaria mercenaria: Jour. Elisha Mitchell Sci. Soc., v. 72, p. 57-60.

________________, 1959, The role of physical and biological factors in the culture of Crassostrea and Mercenaria in a salt-water pond: Ecol. Monogr., v. 29, p. 221-226.

________________, 19611, Interrelation of functional morphology, behavior, and autoecology in early stages of the bivalve Mercenaria mercenaria: Jour. Elisha Mitchell Sci. Soc., v. 77, p. 168-241.

Coe, W. R., 1956, Fluctuations in populations of littoral marine invertebrates: Jour. Mar. Res., v. 15, p. 212-232.

Craig, G. Y., 1967, Size-frequency distributions of living and dead populations of pelecypods from Bimini, Bahamas, B.W.I.: Jour. Geol., v. 75, p. 34-45.

Craig, G.Y., and A. Hallam, 1963, Size-frequency and growth-ring analyses of Mytilus edulis and Cardium edule, and their palaeoecological significance: Palaeontology, v. 6, p. 731-750.

Cunliffe, J. E., 1974, Description, interpretation, and preservation of growth increment patterns in shells of Cenozoic bivalves: Rutgers Univ., unpub. Ph.D. dissert. 171 p.

Cunliffe, J.E., and M. J. Kennish, 1974, Shell growth patterns in the hard-shelled clam: Underwater Naturalist, v. 8, p. 20-24.

Deevey, E. S., 1947, Life tables for natural populations of animals: Quart. Rev. Biol., v. 22, p. 283-314.

Driscoll, E. G., 1967, Experimental field study of shell abrasion: Jour. Sed. Petrol., v. 37, p. 1117-1123.

________________, 1970, Selective bivalve shell destruction in marine environments, a field study: Jour. Sed. Petrol., v. 40, p. 898-905.

Fitch, J. E., 1965, A relatively unexploited population of Pismo clams, Tivela stultorum (Mawe, 1823) (Veneridae): Proc. Malacol. Soc. London, v. 36, p. 309-312.

Gani, J., 1973, Stochastic formulations for life tables, age distributions and mortality curves, in Bartlett M.S., and R. W. Hiorns, eds., The mathematical theory of the dynamics of biological populations: New York, Academic Press, p. 291-302.

Hallam, A., 1972, Models involving population dynamics, in Schopf, T. J. M., ed., Models in paleobiology: San Francisco, Freeman, Cooper and Co., p. 62-80.

Henderson, J. T., 1929, Lethal temperatures of lamellibranchiata: Contr. Can. Biol. Fish., v. 4, p. 399-411.

Hopkins, H. S., 1930, Age difference and the respiration in muscle tissues of molluscs: Jour. Exp. Zool., v. 56, p. 209-239.

Jersey Central Power and Light Company, 1972, Oyster Creek Nuclear Generating Station, Environmental Report, Amendment 68 to "The application for construction permit and operating license",: AEC Docket No. 50-219.

Kennedy, V. S., W. H. Roosenburg, M. Castagna, and J. A. Mihursky, 1974, Mercenaria mercenaria (Mollusca: Bivalvia): Temperature-time relationships for survival of embryos and larvae: U.S. Department of Interior, Fish and Wildlife Service, Fishery Bulletin, v. 72, p. 1160-1166.

Kennish, M. J., 1976, Monitoring thermal discharges: a natural method: Underwater Naturalist, v. 9, p. 8-11.

________________, 1977, Growth increment analysis of Mercenaria mercenaria from artificially heated coastal marine waters: a practical monitoring method: Chronobiology, (in press).

Kennish, M. J., and R. K. Olsson, 1975, Effects of thermal discharges on the microstructural growth of Mercenaria mercenaria: Environ. Geol., v. 1, p. 41-64.

Kurten, B., 1964, The population dynamic approach to paleoecology, in Imbrie, J., and N. D. Newell, eds., Approaches to paleoecology: New York, John Wiley, Inc., p. 91-106.

Laird, A. K., S. A. Tyler, and A. D. Barton, 1965, Dynamics of normal growth: Growth, v. 29, p. 233-248.

Levinton, J. S., and R. K. Bambach, 1970, Some ecological aspects of bivalve mortality pattersn: Am. Jour. Sci., v. 268, p. 97-112.

Loveland, R. E., and others, 1972, The qualitative and quantitative analysis of the benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition: eighth progress rept., Rutgers Univ., unpub. research rept., 81 p.

_______________, 1974, The qualitative and quantitative analysis of the benthic flora and fauna of Barnegat Bay before and after the onset of thermal addition: ninth progress rept., Rutgers Univ., unpub. research rept., 67 p.

MacClintock, C., and G. Pannella, 1969, Time of calcification in the bivalve mollusk Mercenaria mercenaria during the 24 hour period (abs.): Geol. Soc. America, Ann. Mtg. Program, v. 1, p. 140.

Mountford, K., 1971, Plankton studies in Barnegat Bay: Rutgers Univ., unpub. Ph.D. dissert. 147 p.

Odum, E. P., 1971, Fundamentals of ecology: Philadelphia, W. B. Saunders Co., 574 p.

Olson, E. C., 1957, Size-frequency distributions in samples of extinct organisms: Jour. Paleontology, v. 65, p. 309-333.

Paine, R. T., 1963, Ecology of the brachiopod Glottidia pyramidata: Ecol. Monogr., v. 33, p. 255-280.

Pannella, G., and C. MacClintock, 1968, Biological and environmental rythms reflected in molluscan shell growth: Paleontological So., Mem. 42, p. 64-80.

Phillips, F. X., 1972, The ecology of the benthic macroinvertebrates of Barnegat Bay, New Jersey: Rutgers Univ., unpub. Ph.D. dissert. 156 p.

Price, C. A., 1970, Molecular approaches to plant physiology: New York, McGraw-Hill Book Co., 398 p.

Reyment, R. A. 1971, Introduction to quantitative paleoecology: Amsterdam, Elsevier Publishing Co., 226 p.

Rhoads, D. C., and G. Pannella, 1970, The use of molluscan shell growth pattersn in ecology and paleoecology: Lethaia, v. 3, p. 143-161.

Schmidt, R. R., and J. E. Warme, 1969, Population characteristics of Protothaca staminea (Conrad) from Mugu Lagoon, California: The Veliger, v. 12, p. 193-199.

Sellmer, G. P., 1967, Functional morphology and ecological life history of the gemclam Gemma gemma (Eulamellibranchia: Veneridae): Malacologia, v. 5, p. 137-233.

Sheldon, R. W., 1965, Fossil communities with multimodal size-frequency distributions: Nature, v. 206, p. 1336-1338.

Starypan, G., 1976, Abundance, size distribution and early growth of Spisula solidissima in the inshore waters of the south Jersey coast: Rutgers Univ., unpub. M.S. thesis, 113 p.

Tevesz, M. J. S., 1972, Implications of absolute age and season of death data compiled for Recent Gemma gemma: Lethaia, v. 5, p. 31-38.

Thorson, G., 1950, Reproductive and larval ecology of marine bottom invertebrates: Biol. Rev., v. 25, p. 1-45.

United State Atomic Energy Commission, 1974, Final environmental statement related to operation of the Oyster Creek Nuclear Generating Station: AFC Docket No. 50-219.

Weymouth, F. W., H. C. McMillin, and W. H. Rich, 1931, Latitude and relative growth in the razor clam, Siliqua patula: Jour. Exp. Biol., v. 8, p. 228-249.

APPENDIX I. Tables referred to in the text.

Table 1. Characteristics of Barnegat Bay, New Jersey

Length*	48 km
Width*	2-6 km
Average Depth*	1.5 m
Surface Area*	167,400,000 sq m
Volume*	238,000,000 cu m
Mean Tidal Range (Barnegat Inlet)*	0.95 m
Mean Tidal Range (Mouth of Oyster Creek)*	0.15 m
Tidal Flow**	22,326,350 cu m/12.7 hrs.
Salinity Range*	12-32 %
Temperature Range (Natural Conditions)***	-1.5-28 °C

*(United States Atomic Energy Commission, 1974)

**(Carpenter, 1963)

***(Mountfort, 1971; Loveland and others, 1972; and Kennish and Olsson, 1975).

Table 2. Summary of climatological conditions at Tuckerton, New Jersey (39°36' N - 74°21'W) from July, 1966 to July, 1976.

Temperatures in °C

Month	Normal air temperature: Mean maximum	Mean minimum	Mean	Extreme air temperature: High	Low	Precipitation: Total (cm)
Jan	5.4	- 4.9	0.3	16.1	-15.0	8.2
Feb	6.3	- 4.3	1.0	16.2	-15.6	9.1
Mar	10.2	- 0.2	5.0	22.3	- 8.8	9.7
Apr	16.3	3.9	10.2	27.9	- 4.4	9.7
May	20.7	9.4	15.1	30.2	1.6	8.8
June	26.1	15.6	20.8	33.7	7.3	9.0
July	28.6	18.4	23.5	34.6	11.4	9.9
Aug	28.9	18.1	23.5	34.7	10.6	10.5
Sep	25.2	13.9	19.6	32.0	4.3	9.2
Oct	19.6	7.9	13.8	27.8	- 2.4	8.1
Nov	13.4	2.7	8.1	23.7	- 7.0	10.5
Dec	8.1	- 1.6	3.3	17.6	-10.8	11.8

Table 3. Water flow through the Oyster Creek Nuclear Generating Station from 6/18/75 to 6/18/76.

Flow in liters/day x 10^6

Dates	Number of days monitored	Mean flow	Std. dev.
6/18/75 - 6/30/75	13	4768.81	272.86
7/1/75 - 7/31/75	31	5212.31	71.58
8/1/75 - 8/31/75	31	4421.25	1224.30
9/1/75 - 9/30/75	30	2865.62	818.63
10/1/75 - 10/31/75	31	3642.76	1008.56
11/1/75 - 11/30/75	30	4014.25	859.78
12/1/75 - 12/31/75	31	3879.38	1309.21
1/1/76 - 1/31/76	31	2626.42	265.89
2/1/76 - 2/29/76	29	2592.20	375.23
3/1/76 - 3/31/76	31	3932.62	1358.55
4/1/76 - 4/30/76	30	5230.87	0.0
5/1/76 - 5/31/76	31	4002.45	443.87
6/1/76 - 6/18/76	18	4407.84	621.23
6/18/75 - 9/22/75 summer	97	4428.18	1087.14
9/23/75 - 1/2/76 fall	102	3687.48	1146.07
1/3/76 - 3/24/76 winter	82	2883.52	870.91
3/25/76 - 6/18/76 spring	86	4615.81	676.58

Table 4. Water temperatures recorded at site 2 from August, 1974 to September, 1976.

Temperatures in °C

Month	Number of days monitored	Mean water temperature Surface	Std. dev.	Bottom	Std. dev.
8/74	28	30.89	1.73	29.79	1.64
9/74	28	25.79	3.54	25.14	3.26
10/74	30	17.13	1.97	16.77	1.79
11/74	25	13.92	4.89	13.40	4.43
12/74	26	8.15	1.69	7.85	1.49
1/75	29	6.74	2.55	6.60	2.60
2/75	20	6.74	2.99	6.39	2.67
3/75	21	9.12	2.48	8.78	2.36
4/75	18	10.01	2.66	9.73	2.63
5/75	19	20.52	2.94	20.22	2.89
6/75	28	25.89	2.10	25.27	2.00
7.75	29	27.47	1.42	27.17	1.64
8.75	27	28.24	2.07	28.03	2.14
9/75	25	23.61	2.02	23.26	1.92
10/75	26	18.98	.91	18.78	1.12
11/75	24	13.87	3.32	13.65	3.16
12/75	28	7.08	2.57	7.01	2.48
1/76	17	----	----	1.12	.95
2/76	19	----	----	5.26	3.05

Table 4. Continued.

Temperatures in °C

Month	Number of days monitored	Mean water temperature Surface	Std. dev.	Bottom	Std. dev.
3/76	20	11.26	3.62	11.24	3.59
4/76	30	16.73	4.08	16.58	3.94
5/76	31	21.05	1.45	21.00	1.45
6/76	--	----	----	----	----
7/76	28	26.29	1.37	26.22	1.34
8/76	29	26.21	1.14	26.05	1.05
9/76	15	25.30	1.28	25.18	1.28

Table 5. Subsurface (0.15 m) water temperatures recorded by the Jersey Central Power & Light Company at sites 1 and 3 (see Figure 4) from June 18, 1975 to June 18, 1976.

Temperatures in °C

Dates	No. of days	Mean water temperature Site 1	Std. dev.	Site 3	Std. dev.
6/18/75 - 6/30/75	13	28.63	1.19	25.17	1.03
7/1/75 - 7/31/75	31	29.13	1.74	25.82	1.64
8/1/75 - 8/31/75	31	28.31	2.63	25.10	1.69
9/1/75 - 9/30/75	30	23.83	3.07	20.09	1.08
10/1/75 - 10/31/75	31	20.09	2.03	17.67	1.85
11/1/75 - 11/30/75	30	14.53	4.45	12.13	3.45
12/1/75 - 12/31/75	31	5.75	3.32	4.46	2.80
1/1/76 - 1/31/76	31	- 0.48	1.30	0.59	1.19
2/1/76 - 2/29/76	29	3.77	3.29	4.12	3.27
3/1/76 - 3/31/76	31	10.57	3.96	8.62	1.99
4/1/76 - 4/30/76	30	17.83	3.95	13.64	3.74
5/1/76 - 5/31/76	31	23.19	2.28	19.40	2.38
6/1/76 - 6/18/76	18	26.76	2.23	23.70	2.47
6/18/75 - 9/22/75 summer	97	27.85	2.68	24.26	2.60
9/23/75 - 1/2/75 fall	102	13.77	7.07	11.86	6.34
1/3/76 - 3/24/76 winter	82	3.72	4.54	3.89	3.65
3/25/76 - 6/18/76 spring	86	21.51	4.69	17.65	5.07

Table 6. Operational history of the Oyster Creek Nuclear Generating Station from June 18, 1975 to June 18, 1976

Dates of operation	Dates of outage
6/18/75 - 8/27/75	8/28/75 - 9/2/75
9/3/75 - 9/23/75	9/24/75 - 10/3/75
10/4/75	10/5/75
10/6/75 - 11/24/75	11/25/75 - 12/1/75
12/2/75 - 12/19/75	12/20/75
12/21/75 - 12/27/75	12/28/75 - 3/10/76
3/11/76 - 6/18/76	

(James J. Voogleitois, Jersey Central Power and Light Company, 1976)

Table 7. Age-height' statistics for samples of clams from sites 2, 5, 6, and 9.

Site	No. of clams	Mean height' (mm)	Std. dev.	Mean age (yrs)	Std. dev.
2	101	43.12	12.81	3.92	1.70
5	74	46.82	12.57	4.25	1.72
6	64	49.74	9.65	5.03	1.31
9	38	46.82	17.05	4.03	1.79

Table 8. Mean age-height' relationships observed in death assemblages of clams at sites 2, 5, 6, and 9.

	Site 2, N* = 101			Site 5, N* = 74			Site 6, N* = 64			Site 9, N* = 38		
Age	N**	Mean height' (mm)	Std. dev.	N**	Mean height' (mm)	Std. dev.	N**	Mean height' (mm)	Std. dev.	N**	Mean height' (mm)	Std. dev.
1	101	12.39	3.76	74	11.36	4.16	64	7.04	2.71	38	12.72	5.15
2	89	23.00	4.49	68	23.51	4.96	64	17.70	4.24	35	25.61	6.19
3	65	32.91	4.49	63	35.01	4.89	63	29.54	5.22	25	37.30	6.42
4	50	42.36	5.26	44	43.78	4.15	54	39.55	5.23	19	46.97	5.25
5	28	49.37	6.27	19	49.89	3.01	28	47.75	5.81	12	55.58	7.05
6	16	57.61	7.76	9	56.18	3.94	10	55.11	4.05	6	62.13	8.88
7	6	59.52	5.41	6	63.60	1.70	7	63.30	4.56	3	65.80	3.04
8	0	-	-	4	70.60	1.75	3	69.13	5.95	0	-	-

N* = number of clams

N** = number of size measurements per age

Table 9. Mean age-height' relationships for the pooled death assemblages of clams from sites 2, 5, 6, and 9.

		N* = 277	
Age	N**	Mean height' (mm)	Std. dev.
1	277	10.92	4.44
2	256	22.17	5.51
3	216	33.05	5.67
4	167	42.35	5.47
5	87	49.82	6.11
6	41	57.35	6.65
7	22	62.69	4.37
8	7	69.97	3.73

N* = number of clams

N** = number size measurements per age

Table 10. Observed age-height' relationships for a single specimen from the death assemblage at site 5.

Age (yrs)	Height' (mm)
1	11.2
2	23.9
3	34.5
4	43.8
5	50.9
6	56.9
7	63.3
8	70.2

Table 11. Three mathematical equations applied to the study of shell growth in <u>Mercenaria Mercenaria</u>. N and t are variables of size and time respectively. N_{max}, b, c, p, r_o, and r_t are constants (parameters of growth). N_t = height' at a given time t, N_{max} = asymptotic height' or maximum height' attainable, b = the parameter which specifies the time or size at which inflection occurs, c = the complement of that proportion of N_{max} which specifies the initial condition N_o, p = the proportion of N_{max} which specifies the initial condition N_o, r_o = the maximal intrinsic rate of natural increase, r_t = the specific rate of growth, e = the base of the natural logarithms. (Loveland and Crossner, in preparation).

	Differential form	Integrated form	Linearized form
logistic	$dN/dt = r_oN_t - bN_t^{-2}$	$N_t = r_o/b\left[1 + e^{-r_ot} \cdot \frac{N_{max} - N_o}{N_o}\right]^{-1}$	$r_t = r_o(1 - \frac{N_t}{N_{max}})$
Gompertz	$dN/dt = r_oN(\ln \frac{N_o}{N_{max}})$	$N_t = N_{max}e^{-pe^{-r_ot}}$	$r_t = r_o\ln N_{max} - r_o\ln N_t$
monomolecular	$dN/dt = n_{max}r_o - r_oN_t$	$N_t = N_{max}(1 - ce^{-r_ot})$	$r_t = r_o(\frac{N_{max}}{N_t} - 1)$

Table 12. Estimated parameters (r_o, N_{max}, b, c, p) and correlation coefficients (r) of the logistic, Gompertz, and monomolecular growth equations. The data represent the best fit of the linearized equations to the mean annual growth rates of *Mercenaria mercenaria* at sites 2, 5, 6, and 9.

		Curve fitting after Loveland and Crossner											
		Logistic				Gompertz				Monomolecula			
Site	No. of clams	r	r_o	N_{max}	b	r	r_o	N_{max}	b	r	r_o	N_{max}	b
2	101	-.966	.755	61.00	.012	-.987	.437	67.19	1.49	-.809	.165	87.67	1.02
5	74	-.906	.767	67.05	.011	-.970	.455	72.24	1.77	-.858	.122	144.30	1.01
6	64	-.925	.868	65.35	.013	-.987	.463	72.44	2.20	-.902	.097	133.41	1.05
9	38	-.965	.837	65.45	.013	-.994	.495	70.87	1.57	-.961	.191	90.77	1.05
all sites	277	-.927	.745	67.61	.013	-.982	.424	74.22	1.79	-.914	.109	121.35	1.01

Table 13. Observed and predicted age-height' relationships for the pooled death assemblages of clams at sites 2, 5, 6, and 9. Astericks give predictive models. t = age in years. N = height' in mm. Data based on 277 specimens.

t	Observed N	Gompertz N*	Logistic N**	Monomolecular N***
1	10.92	11.70	10.92	11.34
2	22.17	21.71	17.74	22.70
3	33.05	32.54	27.49	32.89
4	42.35	42.40	39.64	42.03
5	49.82	50.41	51.85	50.22
6	57.35	56.46	60.85	57.57
7	62.69	60.81	65.38	64.16
8	69.97	63.83	66.99	70.07
9	———	65.89	67.45	75.36
10	———	67.27	67.57	80.11
11	———	68.19	67.60	84.37
12	———	68.80	67.61	88.19
13	———	69.21	67.61	91.62
14	———	69.47	67.61	94.69
15	———	69.64	67.61	97.44

$$N_t^* = .745/.011 \quad 1 + e^{-.745t} \cdot \left(\frac{67.61 - 10.92}{10.92}\right)^{-1}$$

$$N_t^{**} = 74.22e^{-1.79e^{-.424t}}$$

$$N_t^{***} = 121.35(1 - 1.01e^{-.109t})$$

Table 14. Observed and predicted age-height' relationships for the death assemblages of clams at sites 2. Astericks give predictive models. t = age in years. N = height' in mm. Data based on 101 specimens.

t	Observed N	Gompertz N*	Logistic N**	Monomolecular N***
1	12.39	13.46	12.39	11.34
2	23.00	22.77	19.85	22.70
3	32.91	31.99	29.95	32.89
4	42.36	39.85	41.46	42.03
5	49.37	45.92	51.49	50.22
6	57.61	50.33	57.55	57.57
7	59.52	53.41	60.00	64.16
8	____	55.49	60.74	70.07
9	____	56.88	60.93	75.36
10	____	57.80	60.98	80.11
11	____	58.40	60.99	84.37
12	____	58.79	60.99	88.19
13	____	59.05	60.99	91.62
14	____	59.21	60.99	94.69
15	____	59.32	60.99	97.44

$$N_t^* = .755/.012 \left[1 + e^{-.755t} \cdot \frac{(61.00 - 12.39)}{12.39}\right]^{-1}$$

$$N_t^{**} = 61.00e^{-1.49e^{-.437t}}$$

$$N_t^{***} = 61.00(1 - 1.02e^{-.165t})$$

Table 15. Observed and predicted age-height' relationships for the death assemblages of clams at site 5. Astericks give predictive models. t = age in years. N = height' in mm. Data based on 74 specimens.

t	Observed N	Gompertz N*	Logistic N**	Monomolecular N***
1	11.36	12.05	11.36	12.10
2	23.51	23.00	18.59	23.80
3	35.01	34.65	28.90	34.17
4	43.78	44.95	41.52	43.34
5	49.89	53.01	53.65	51.47
6	56.18	58.86	61.88	58.66
7	63.60	62.91	65.55	65.03
8	70.60	65.62	66.68	70.68
9	—	67.40	66.97	75.67
10	—	68.55	67.03	80.09
11	—	69.29	67.05	84.01
12	—	69.77	67.05	87.48
13	—	70.07	67.05	90.55
14	—	70.26	67.05	93.27
15	—	70.39	67.05	95.68

$$N_t^{*} = .767/.011 \left[1 + e^{-.767t} \cdot \frac{(67.05 - 11.36)}{11.36}\right]^{-1}$$

$$N_t^{**} = 72.24e^{-1.77e^{-.455t}}$$

$$N_t^{***} = 114.30(1 - 1.01e^{-.122t})$$

Table 16. Observed and predicted age-height' relationships for the death assemblages of clams at site 6. Astericks give predictive models. t = age in years. N = height' in mm. Data based on 64 specimens.

t	Observed N	Gompertz N*	Logistic N**	Monomolecular N***
1	7.04	7.66	7.04	6.80
2	17.70	17.33	12.49	18.46
3	29.54	28.95	21.26	29.05
4	39.55	39.98	33.71	38.66
5	47.75	48.98	47.87	47.38
6	55.11	55.66	58.99	55.30
7	63.60	60.32	63.97	62.49
8	69.13	63.45	65.15	69.02
9	———	65.50	65.32	74.95
10	———	66.82	65.35	80.33
11	———	67.67	65.35	85.22
12	———	68.21	65.35	89.66
13	———	68.55	65.35	93.69
14	———	68.77	65.35	97.34
15	———	68.90	65.35	100.67

$$N_t^* = .868/.013 \left[1 + e^{-.868t} \cdot (65.35 - 7.04)\right] -1$$

$$N_t^{**} = 72.44e^{-2.20e^{-.463t}}$$

$$N_t^{***} = 133.41(1 - 1.05e^{-.097t})$$

Table 17. Observed and predicted age-height' relationships for the death assemblages of clams at site 9. Astericks give predictive models. t = age in years. N = height' in mm. Data based on 38 specimens.

t	Observed N	Gompertz N*	Logistic N**	Monomolecular N***
1	12.72	13.65	12.72	12.34
2	25.61	25.22	21.31	25.98
3	37.30	36.68	33.34	37.25
4	46.97	46.08	47.04	46.56
5	55.58	52.96	58.12	54.25
6	62.13	57.65	63.57	60.60
7	65.80	60.70	65.10	65.85
8	———	62.64	65.39	70.18
9	———	63.86	65.44	73.76
10	———	64.61	65.45	76.72
11	———	65.07	65.45	79.16
12	———	65.36	65.45	81.18
13	———	65.53	65.45	82.85
14	———	65.63	65.45	84.23
15	———	65.70	65.45	85.36

$$N_t^{*} = .837/.013 \left[1 + e^{-.837t} \cdot \frac{(65.45 - 12.72)}{12.72}\right]^{-1}$$

$$N_t^{**} = 70.87e^{-1.57e^{-.495t}}$$

$$N_t^{***} = 90.77(1 - 1.05e^{-.191t})$$

Table 18. Size statistics for life and death assemblages of <u>Mercenaria mercanaria</u> in Barnegat Bay.

		Life assemblage				Death assemblage			
(Fig. 4)	Year	No. of clams	Mean height'(mm) + 95% C.I.	Std. dev. for mean	Median height' (mm)	No. of clams	Mean height'(mm) + 95% C.I.	Std. dev. for mean	Median height' (mm)
2	1974	no data				405	51.75 ± 1.06	10.81	54.50
5	1974	no data				446	55.38 ± 0.74	7.91	57.00
6	1974	no data				464	55.89 ± 0.73	7.97	56.50
9	1974	no data				261	60.47 ± 1.29	10.56	62.00
2	1976	435	54.56 + 0.75	7.97	55.20	499	53.36 ± 0.76	8.69	54.45
4	1976	342	50.33 + 0.91	8.52	49.60	280	54.16 ± 1.11	9.47	55.48
5	1976	446	51.07 + 0.78	8.38	49.45	445	59.17 ± 0.78	8.37	60.60
6	1976	441	51.24 + 0.88	9.41	52.70	408	56.45 ± 0.87	8.95	57.80
7	1976	416	11.84 + 0.37	3.85	11.10	16	17.52 ± 3.44	6.45	16.85
8	1976	450	52.52 + 0.70	7.54	52.63	413	57.78 ± 1.02	10.53	57.80
9	1976	436	56.26 + 0.63	6.64	56.25	214	55.25 ± 1.30	9.63	56.30
10	1976	440	54.24 + 0.70	7.51	53.77	436	54.62 ± 0.84	8.89	55.60
11	1976	208	54.20 + 1.04	7.63	55.00	438	57.27 ± 0.85	9.07	58.60

Table 19. Moment measures about the mean height' for life and death assemblages of <u>Mercenaria mercenaria</u> in Barnegat Bay.

Site	Sample	Mean height' (mm)	Moment measures m_2	m_3	m_4	K*	S_k*
2	death assemblage, 1974	51.75	116.82	-1442.51	52318.14	3.85	-1.14
5	death assemblage, 1974	55.38	62.59	- 739.34	25745.93	6.60	-1.50
6	death assemblage, 1974	55.89	63.53	- 39.71	13883.51	3.45	-0.08
9	death assemblage, 1974	60.47	111.45	-1904.20	85648.74	6.95	-1.63
2	death assemblage, 1976	53.36	75.61	- 554.99	22083.39	3.88	-0.85
4	death assemblage, 1976	54.16	89.77	- 562.22	26125.33	3.26	-0.66
5	death assemblage, 1976	59.17	70.11	- 447.50	21064.05	4.30	-0.76
6	death assemblage, 1976	56.45	80.04	- 628.25	29662.52	4.65	-0.88
7	death assemblage, 1976	17.52	41.60	- 34.76	4321.23	2.83	-0.14
8	death assemblage, 1976	57.78	110.79	- 223.40	35463.95	2.90	-0.19
9	death assemblage, 1976	55.25	92.80	- 586.28	38287.19	4.49	-0.66
10	death assemblage, 1976	54.26	79.15	- 467.54	21520.60	3.45	-0.67
11	death assemblage, 1976	57.27	82.36	- 534.88	22036.53	3.26	-0.72
2	life assemblage, 1976	54.56	63.66	- 333.34	20355.23	5.05	-0.66
4	life asemblage, 1976	50.33	72.66	97.89	23053.99	4.39	0.16
5	life assemblage, 1976	51.07	70.38	229.43	16685.61	3.38	0.39
6	life assemblage, 1976	51.23	88.58	- 349.19	19407.02	2.49	-0.42
7	life assemblage, 1976	11.84	14.83	99.03	1743.31	7.95	1.74
8	life assemblage, 1976	52.52	56.99	- 154.32	12621.92	3.90	-0.36
9	life assemblage, 1976	56.26	44.15	- 67.62	7113.87	3.67	-0.23
10	life assemblage, 1976	54.24	56.40	2.79	8013.65	2.53	0.01
11	life assemblage, 1976	54.20	58.27	- 156.08	9528.10	2.83	-0.35

K* = Kurtosis

S_k* = Skewness

Table 20. Catches of *Mercenaria mercenaria* in Barnegat Bay (1960-1969). Data in kilograms of shell weight.

Year	Catch (kg.)
1960	1,186,609.8
1961	794,702.0
1962	714,868.9
1963	812,845.9
1964	1,005,896.8
1965	1,082,463.9
1969	1,808,219.2
1967	1,353,533.5
1968	1,267,531.5
1969	1,215,277.1

(United States Atomic Energy Commission, 1974)

Table 21. Valve ratios in death assemblages of clams from Barnegat Bay.

Site	Year collected	No. of specimens	No. of left valves	No. of right valves	No. articulated
2	1976	499	230	223	46
6	1974	464	228	236	—
6	1976	408	185	181	42
11	1976	438	196	182	60

Table 22. Size (height')-frequency distributions for clams transplanted to the substrate at sites 2 and 5 in June, 1975.

Size class (mm)	Frequency of clams transplanted to site 2	Frequency of clams transplanted. to site 5
20-25	1	0
25-30	9	10
30-35	103	103
35-40	69	68
40-45	116	117
45-50	115	114
50-55	124	124
55-60	103	103
60-65	66	67
65-70	24	24
70-75	10	10
75-80	3	3
	N* = 743	N* = 743

N* = Total number of clams

Table 23. Size (height')-frequency distributions for live and dead clams recovered from the substrate at sites 2 and 5 in June, 1976. Clams originally transplanted in June, 1975.

Size class (mm)	Frequency of live clams recovered from site 2	Frequency of dead clams recovered from site 2	Frequency of live clams recovered from site 5	Frequency of dead clams recovered from site 5
20-25	0	0	0	0
25-30	0	0	0	0
30-35	11	12	20	3
35-40	43	2	31	1
40-45	86	1	73	7
45-50	104	1	90	1
50-55	97	5	62	10
55-60	113	8	64	12
60-65	49	5	44	11
65-70	11	2	12	2
70-75	1	0	2	1
75-80	0	0	0	0
				+3 (broken)
	N* = 515	N* = 36	N* = 398	N* = 51

N* = Total number of clams

Table 24. Size statistics for live and dead clams recovered from the substrate at sites 2 and 5 in June, 1976. Clams transplanted in June, 1975.

Site	No. of clams	Mean height' (mm)	Std. dev.
2 (live clams)	515	50.31	7.99
2 (dead clams)	36	47.72	12.74
5 (live clams)	398	49.77	8.66
5 (dead clams)	48*	53.50	9.23

*three broken valves not included in analysis

Table 25. Size (height')-frequency distributions for clams transplanted in cages at sites 2 and 5 in June, 1975.

Size class (mm)	Frequency of clams transplanted to site 2*	Frequency of clams transplanted. to site 5**
20-25	3	4
25-30	26	27
30-35	81	83
35-40	47	50
40-45	60	48
45-50	37	42
50-55	32	30
55-60	31	26
60-65	19	15
65-70	1	0
70-75	1	0
	N* = 338	N* = 325

* includes measurements of clams in nine cages

** includes meansurements of clams in eight cages

N* = Total number of clams

Table 26. Summary of seasonal mortality of <u>Mercenaria mercenaria</u> transplanted in cages at sites 2 and 5. Mortality rate per season in parentheses.

Season	Frequency of death site 2	Frequency of survival site 2	Frequency of death site 5	Frequency of survival site 5
Summer, 1975 6/38/75-9/22/75	118 (34.91%)	220	44 (13.53%)	281
Fall, 1975 9/22/75-1/2/76	39 (11.53%)	181	12 (3.69%)	269
Winter, 1976 1/2/76-3/24/76	37 (10.94%)	144	32 (9.84%)	237
Spring, 1976 3/24/76-6/18/76	35 (10.35%)	109	22 (6.76%)	215
Summer, 1976 6/18/76-9/18/76	——	——	93 (28.61%)	122

Table 27. Summary of seasonal mortality of <u>Mercenaria mercenaria</u> transplanted in cages at sites 2 and 5. Mortality rate per season in parentheses.

Size class (mm)	Frequency of death 6/18/75-9/22/75	Frequency of death 9/22/75-1/2/76	Frequency of death 1/2/76-3/24/76	Frequency of death 3/24/76-6/18/76
20-25	2 (66.66%)	0 (0.00%)	1 (33.33%)	0 (0.00%)
25-30	9 (34.61%)	0 (0.00%)	4 (15.38%)	1 (3.84%)
30-35	16 (19.75$)	3 (3.70%)	2 (2.45%)	12 (14.81%)
35-40	18 (38.29%)	3 (6.38%)	3 (6.38%)	2 (4.25%)
40-45	22 (36.66%)	9 (15.00%)	6 (10.00%)	11 (18.33%)
45-50	15 (40.54%)	7 (18.91%)	5 (13.51%)	2 (5.40%)
50-55	13 (40.62%)	7 (21.87%)	6 (18.75%)	4 (12.50%)
55-60	14 (45.16%)	7 (22.58%)	8 (25.80%)	2 (6.45%)
60-65	8 (42.10%)	2 (10.52%)	2 (10.52%)	1 (5.26%)
65-70	1 (100.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)
70-75	0 (0.00%)	1 (100.00%)	0 (0.00%)	0 (0.00%)

Table 28. Seasonal mortality per size class of clams transplanted in cages at site 5. Specific mortality rate per size class given in parentheses.

Size class (mm)	Frequency of death 6/18/75-9/22/75	Frequency of death 9/22/75-1/2/76	Frequency of death 1/2/76-3/24/76	Frequency of death 3/24/76-6/18-76	Frequency of death 6/18/76-9/18/76
20-25	1 (25.00%)	0 (0.0%)	0 (0.00%)	1 (25.00%)	0 (0.00%)
25-30	8 (29.62%)	2 (7.40%)	2 (7.40%)	2 (7.40%)	1 (3.70%)
30-35	20 (24.09%)	3 (3.61%)	7 (8.43%)	4 (4.81%)	11 (13.25%)
35-40	6 (12.00%)	4 (8.00%)	4 (8.00%)	3 (6.00%)	10 (20.00%)
40-45	3 (6.25%)	0 (0.00%)	3 (6.25%)	3 (6.25%)	15 (31.25%)
45-50	3 (7.14%)	1 (2.38%)	1 (2.38%)	4 (9.52%)	21 (50.00%)
50-55	1 (3.33%)	1 (3.33%)	6 (20.00%)	2 (6.66%)	14 (46.66%)
55-60	2 (7.69%)	1 (3.84%)	7 (26.92%)	2 (7.69%)	9 (34.61%)
60-65	0 (0.00%)	0 (0.00%)	2 (13.33%)	1 (6.66%)	12 (80.00%)
65-70	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)
70-75	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)

Table 29. Size-age characteristics for clams transplanted in cages at sites 2 and 5. Clams transplanted in June, 1975.

Site	No. of clams	Mean age (years)	Mean growth after transplantation (microns)	Mean no. increments after transplantation
2	62	4.48	60.44	6.23
5	35	3.87	78.71	6.77

Table 30. Death-frequency distributions per season for natural populations of *Mercenaria mercenaria* at sites 2, 5, 6, and 9. Percentage of mortality per season in parentheses.

Site	No. of clams	Season of Death			
		Spring	Summer	Fall	Winter
2	101	12 (11.88%)	33 (32.67%)	25 (24.75%)	31 (30.69%)
5	75	13 (17.33%)	24 (32.00%)	13 (17.33%)	25 (33.33%)
6	64	13 (20.31%)	19 (29.69%)	12 (18.75%)	20 (31.25%)
9	38	9 (23.68%)	16 (42.11%)	7 (18.42%)	6 (15.79%)
all sites	278	47 (16.91%)	92 (33.09%)	57 (20.50%)	82 (29.50%)

Table 31. Life table for *Mercenaria mercenaria* at site 2.

Age interval x to x + 1 years	Proportion dying in interval (x, x + 1)	Number living at age x	Number dying in interval (x, x + 1)	Number of time-spans lived in interval (x, x + 1)	Total number of time-spans lived past age x	Average life expectency (in years) at age x	Proportion surviving in interval (x, x + 1)
	$1000\ q_x$	l_x	d_x	L_x	T_x	e_x	p_x
1-2	22.00	1000	22	989.0	4508.0	4.5080	0.9780
2-3	68.51	978	67	944.5	3519.0	3.5982	0.9315
3-4	83.42	911	76	873.0	2574.5	2.8260	0.9166
4-5	130.54	835	109	780.5	1701.5	2.0377	0.8695
5-6	544.08	726	395	528.5	921.0	1.2686	0.4559
6-7	314.20	331	104	279.0	392.5	1.1858	0.6858
7-8	1000.00	227	227	113.5	113.5	0.5000	0.0000

Table 32. Life table for <u>Mercenaria mercenaria</u> at site 5.

Age interval x to x + 1 years	Proportion dying in interval (x, x + 1)	Number living at age x	Number dying in interval (x, x + 1)	Number of time-spans lived in interval (x, x + 1)	Total number of time-spans lived past age x	Average life expectency (in years) at age x	Proportion surviving in interval (x, x + 1)
	$1000\ q_x$	l_x	d_x	L_x	T_x	e_x	p_x
1-2	7.00	1000	7	996.5	4844.0	4.8440	0.9930
2-3	27.19	993	27	979.5	3847.5	3.3746	0.9728
3-4	39.34	966	38	947.0	2868.0	2.9689	0.9607
4-5	113.15	928	105	875.5	1921.0	2.0700	0.8869
5-6	343.86	823	283	681.5	1045.5	1.2704	0.6561
6-7	829.63	540	448	316.0	364.0	0.6741	0.1704
7-8	978.26	92	90	47.0	48.0	0.5217	0.0217
8-9	1000.00	2	2	1.0	1.0	0.5000	0.0000

Table 33. Life table for *Mercenaria mercenaria* at site 6.

Age interval x to x + 1 years	Proportion dying in interval (x, x + 1)	Number living at age x	Number dying in interval (x, x + 1)	Number of time-spans lived in interval (x, x + 1)	Total number of time-spans lived past age x	Average life expectency (in years) at age x	Proportion surviving in interval (x, x + 1)
	$1000\ q_x$	l_x	d_x	L_x	T_x	e_x	p_x
1-2	0.00	1000	0	1000.0	5074.0	5.0740	1.0000
2-3	0.00	1000	0	1000.0	4074.0	4.0740	1.0000
3-4	30.00	1000	30	985.0	3074.0	3.0740	0.9700
4-5	122.68	970	119	910.5	2089.0	2.1536	0.8773
5-6	324.32	851	276	713.0	1178.5	1.3848	0.6757
6-7	775.65	575	446	352.0	465.5	0.8095	0.2244
7-8	620.16	129	80	89.0	113.5	0.8798	0.3798
8-9	1000.00	49	49	24.5	24.5	0.5000	0.0000

Table 34. Life table for Mercenaria mercenaria at site 9.

Age interval x to x + 1 years	Proportion dying in interval (x, x + 1)	Number living at age x	Number dying in interval (x, x + 1)	Number of time-spans lived in interval (x, x + 1)	Total number of time-spans lived past age x	Average life expectency (in years) at age x	Proportion surviving in interval (x, x + 1)
	$1000\ q_x$	l_x	d_x	L_x	T_x	e_x	p_x
1-2	19.00	1000	19	990.5	4951.0	4.9510	0.9810
2-3	34.66	981	34	964.0	3960.5	4.0372	0.9653
3-4	24.29	947	23	935.5	2996.5	3.1642	0.9757
4-5	124.46	924	115	866.5	2061.0	2.2305	0.8755
5-6	398.02	809	322	648.0	1194.5	1.4765	0.6020
6-7	377.82	487	184	395.0	546.5	1.1222	0.6222
7-8	1000.00	303	303	151.0	151.5	0.5000	0.0000

Table 35. Age-specific mortality rates computed for death assemblages of natural populations of *Mercenaria mercenaria* at sites 2, 5, 6, and 9.

Age (years)	Specific mortality rate Site 2	Site 5	Site 6	Site 9
1-2	0.0222	0.0070	0.0000	0.0192
2-3	0.0709	0.0276	0.0000	0.0353
3-4	0.0871	0.0401	0.0305	0.0246
4-5	0.1397	0.1199	0.1307	0.1327
5-6	0.7474	0.4153	0.3871	0.4969
6-7	0.3728	1.4177	1.2670	0.4658
7-8	2.0000	1.9149	0.8989	2.0000
8-9	------	2.0000	2.0000	------

EXPLANATION OF PLATE 1

NOTE: The direction of shell growth (from the umbo to the ventral margin) in each figure is from left to right.

The scale for figures 4, 5, 6, 7, and 8 is equal to that of figure 3. The scale for figure 9 is equivalent to that of figure 2.

Fig. 1 Shell of the northern quahog, Mercenaria mercenaria. The solid line (h) defines the true height of the organism. The dashed line (h') represents the dimension of height' utilized in this investigation.

Figs. 2, 3, 4. Early spring death recorded in shells of M. mercenaria from Barnegat Bay, New Jersey. Growth breaks (downward pointing arrows) lie adjacent to the ventral margins. Crossed-lamellar shell structure and thin increments of growth characterize the margins.

Fig. 5. Late spring death as reflected in the ventral valve margin of a specimen from site 5. Note the relatively large daily growth icrements as compared to those of figures 2, 3, and 4. Also note the well-developed prismatic shell structure.

Figs. 6, 7. Typical microgrowth patterns of clams which expired in the summer. The shell edge is preceded by large increments of growth diagnostic of the summer season.

Fig. 8. Daily summer growth. Note the conchiolin layers (thin, dark bands) separating large, undivided calcium carbonate layers (thick, light bands). Summer growth patterns are distinctive, and their position in the shell can be used to accurately determine season of death.

Fig. 9. Summer storm break (downward pointing arrow) in an individual from site 2. Note the sudden occurrence of the break and the silt grains at the base of the break. These silt grains were trapped between the shell and the organism's mantle during the storm and subsequently incorporated into the shell. This growth break indicates that the organism died in the summer season.

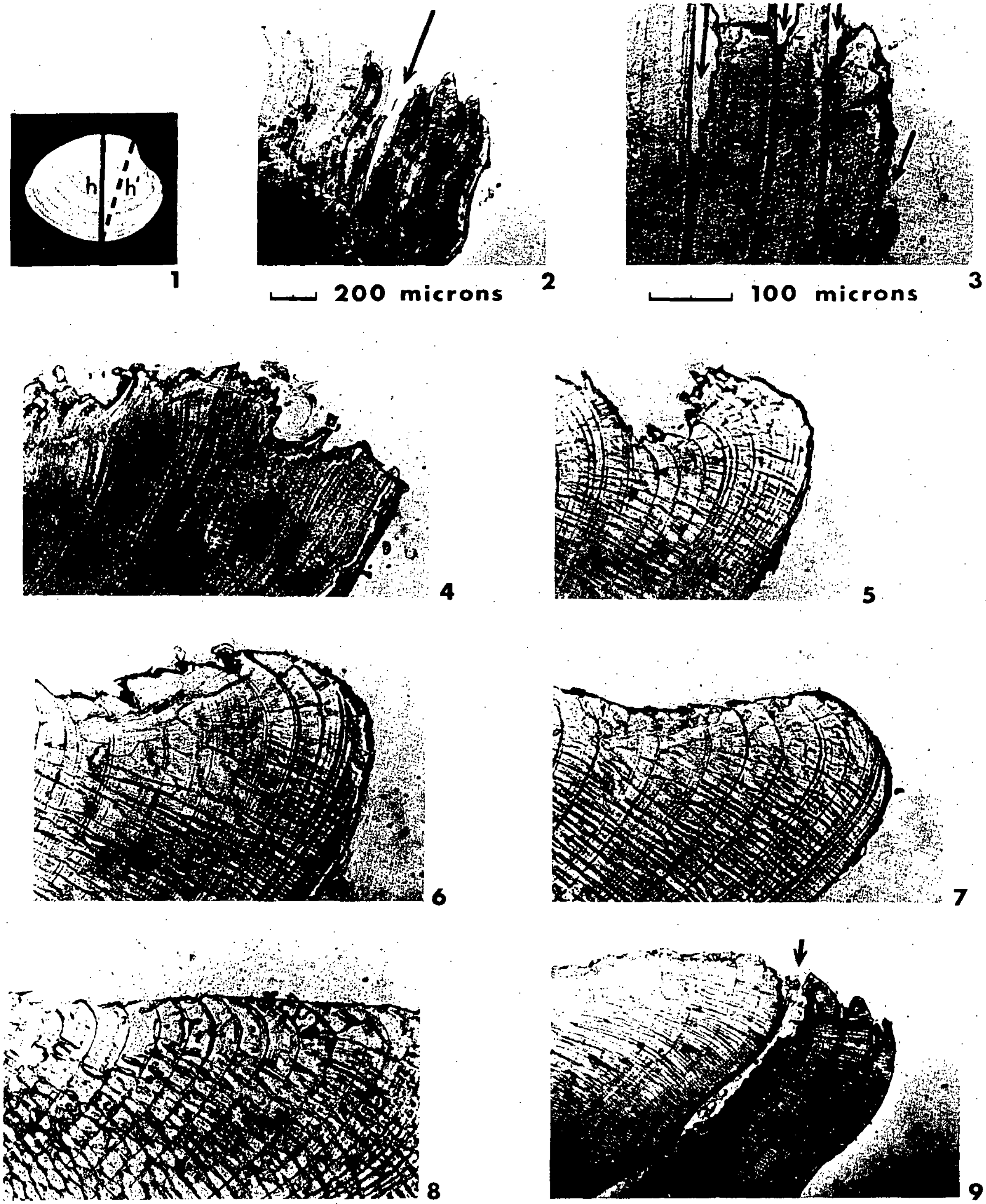


Plate 1

EXPLANATION OF PLATE 2

NOTE: The direction of shell growth (from the umbo to the ventral margin) in each figure is from left to right.

The scale for figures 2, 3, 4, 5, 6, 7, and 8 is the same as that for figure 1.

Figs. 1, 2. Shell microgrowth patterns of specimens which died in the summer. Summer death is manifested by summer (heat)-shock breaks (downward pointing arrows) which border the margins. Transgressing crossed-lamellar shell structure (horizontal arrows) marks the growth breaks.

Figs. 3, 4. Summer death monitored in shells of *M. mercenaria*. Spawn breaks (downward pointing arrows) rim the leading edge of the shells. The existence of spawn breaks at the valve margins signifies summer mortality, because spawning of *M. mercenaria* in Barnegat Bay is confined to the summer season.

Figs. 5, 6, 7, 8. Ventral valve margins of clams which died in the fall. Growth increments are of intermediate thickness between those of summer and winter. Fall microgrowth patterns are differentiated from spring patterns by the occurrence of summer growth patterns immediately dorsal to them. Note the slowdown in growth as the ventral margin is approached. This slowdown in growth denotes a moribund condition prior to death. A break in growth (downward pointing arrow) is present in figure 5.

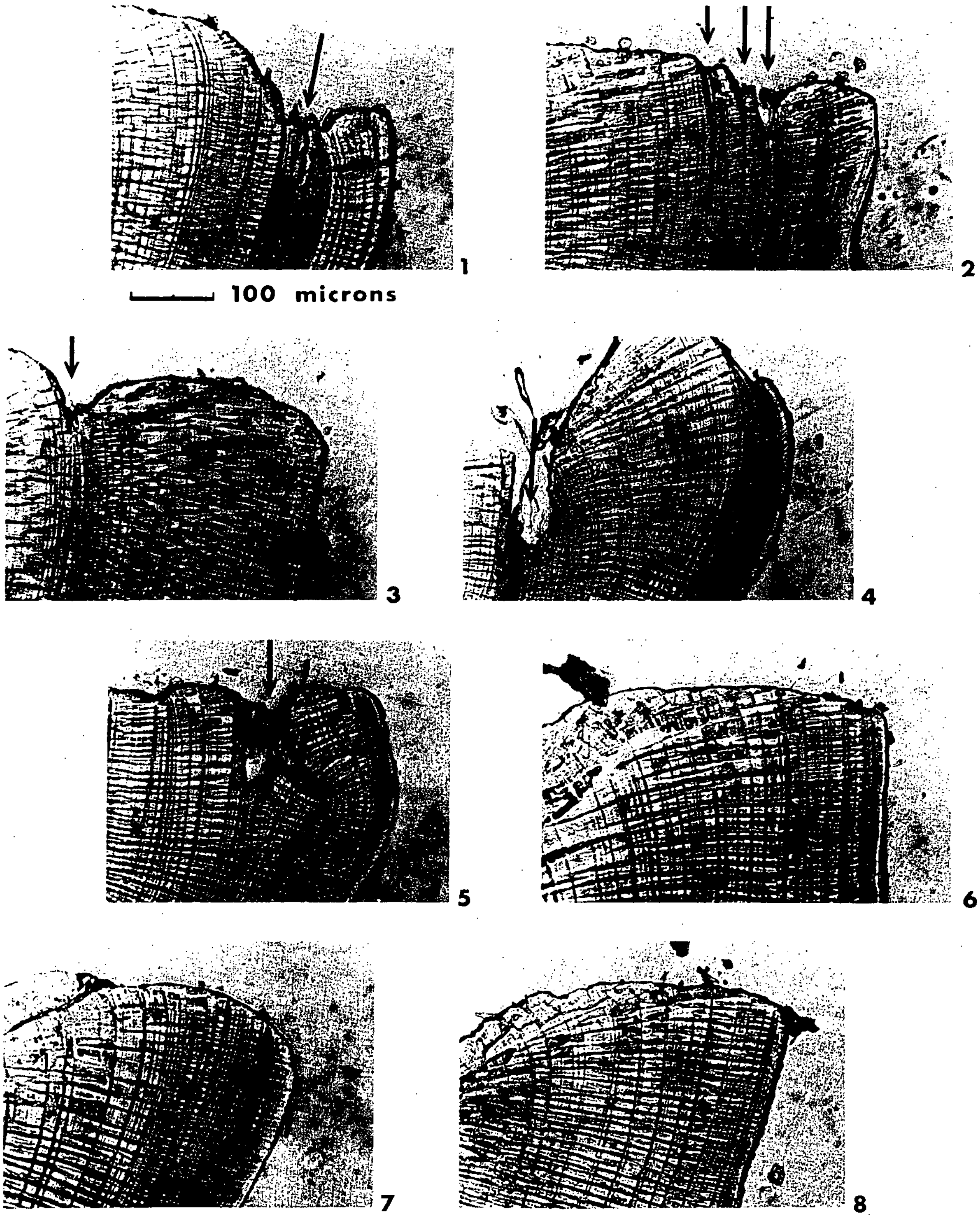


Plate 2

EXPLANATION OF PLATE 3

NOTE: The direction of shell growth (from the umbo to the ventral margin) in each figure is from left to right.

The scale for figures 2, 3, 6, 7, 8, and 9 equals that of figure 1. The scale for figures 10 and 11 is equivalent to that of figure 4.

Figs. 1, 2, 3, 4. Winter death recorded in shell microgrowth patterns of *M. mercenaria* from Barnegat Bay. The ventral valve margins are preceded by winter (freeze)-shock breaks (downward pointing arrows) and thin increments of growth typical of the winter season. Crossed-lamellar shell structure (horizontal arrows) lines the growth breaks.

Fig. 5. Daily winter growth. Note the extremely thin growth increments as compared to those of the summer (Pl. 1, Fig. 8). The location of winter growth in relationship to the ventral margin of the shell is critical in the determination of the season of death of the organism (see text).

Figs. 6, 7, 8. Shell microgrowth patterns of clams transplanted in cages for one year in Barnegat Bay. Arrows point to shell growth subsequent to transplantation. Note the aberrant growth patterns, with little shell being added after transplantation. Shell added during the experiment has failed to reach the upper margin of the prismatic layer; this indicates an abnormal growth condition.

Figs. 9, 10, 11. Summer mortality patterns reflected in the shell microstructure of clams transplanted to the substrate in Barnegat Bay in 1975. Horizontal and vertical arrows point to the time of notching (transplantation). Note the reduction in growth and th alteration of prismatic to crossed-lamellar shell structure following transplantation. The number of growth increments added after transplantation signifies summer death for all three specimens. Summer mortality is common in transplanted populations.

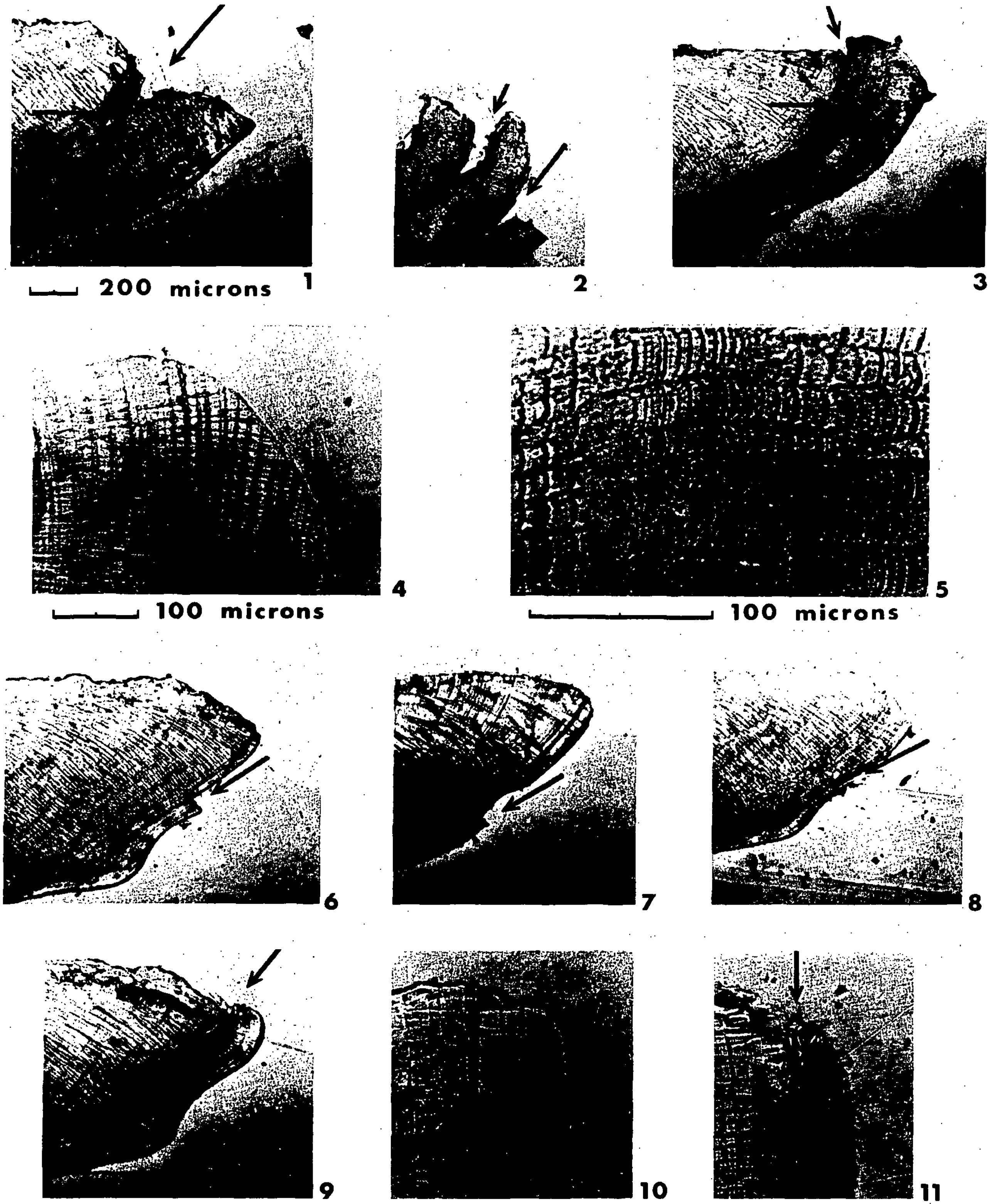


Plate 3

VITA

Michael Joseph Kennish

1950	Born April 23 in Vineland, New Jersey.
1968	Graduated from Williamstown High School, Williamstown, New Jersey.
1968-72	Attended Rutgers University, Camden, New Jersey; majored in Geology.
1972	B.A. in Geology, Rutgers University.
1972-77	Graduate work in Geology, Rutgers University, New Brunswick, New Jersey.
1973-74	Teaching Assistantship, Department of Geology.
1974	M.S. in Geology.
1974-77	Graduate Assistantship, Marine Sciences Center.
1974	Article: "Shell growth patterns in the hard-shelled clam," Underwater Naturalist, vol. 8, pp. 20-24.
1975	Article: "Effects of thermal discharges on the microstructural growth of *Mercenaria mercenaria*," Environmental Geology, vol. 1, pp. 41-64.
1976	Article: "Monitoring thermal discharges: a natural method," Underwater Naturalist, vol. 9, pp. 8-11.
1977	Article: "Growth increment analysis of *Mercenaria mercenaria* from artificially heated coastal marine waters: a practical monitoring method," Chronobiology, (in press).
1977	Ph.D in Geology.

APPENDIX C3

APPENDIX C3

THE MARINE BORING AND FOULING

INVERTEBRATE COMMUNITY

OF BARNEGAT BAY, NEW JERSEY

BY:

SYLVIA SMOKER SHAFTO

APPENDIX C3

Table of Contents

The marine boring and fouling community is of great economic importance particularly in estuaries. The invertebrates and algae that settle on and bore into pilings and ships generally shorten the life of those structures. Consequently this community has been studied extensively. The present paper discusses previous research on the marine boring and fouling community and similar marine communities, and presents data on the sublittoral estuarine invertebrate boring and fouling community of Barnegat Bay, New Jersey.

The paper is presented in two parts: GENERAL COMMUNITY STRUCTURE including total species composition and the role of species dominance in relation to environment, and SPECIFIC COMMUNITY STRUCTURE including settling patterns of the dominant species with respect to depth and spatial orientation of settling surfaces.

PART I: GENERAL COMMUNITY STRUCTURE THE RELATIONSHIP OF HYDROGRAPHY TO DOMINANT SPECIES AND COMMUNITY COMPLEXITY

I. Introduction

The marine boring and fouling community has been studied extensively (Clapp and Kenk, 1963; DePalma, 1968). Most of the ecological studies that have been done on this community have been autecological, that is, confined to the life cycles and salinity and temperature tolerances of the dominant species of a given locale (Ray, 1959). This type of study provides information about the geographical limits of important species along the salinity gradient from ocean to fresh water, and the geographical and temporal limits along temperature gradients.

An example of the useful prediction of geographical limits of an organism based on previous autecologic analysis is the study of the wood boring clam, Bankia setacea, in the Fraser River which was done by Tabata and LeBrasseur (1958). They analyzed the salinity changes that were caused by enclosing a harbor in the river with a breakwater. This analysis was used to predict whether the clam could become a problem by intruding into previously uninfested, fresh water areas, and destroying wooden pilings and ships. Even after the breakwater was put in there was usually only fresh water in the harbor after the tide went out. The clams suddenly appeared in harbor pilings, however. This appearance was satisfactorily explained by locating the depressions on the harbor floor produced by the dredging. Enough salt water was retained in these depressions to maintain the known minimum salinity necessary for the survival of larval and adult clams.

The usual philosophy for studying estuarine communities is that first a complete taxonomy of the species present must be generated, with subsequent analyses of tolerances of individual species to hydrographic conditions (Hedgepeth, 1952). It is implicitly assumed that a thorough understanding of the properties of all the species should permit description of their geographic distributions and prediction of the total community structure. But the value of hydrographic tolerance data for predicting the habitat of a single species is limited because of differences between races within a species. For instance, populations of the barnacle Balanus balanoides taken from Woods Hole, Massachusetts, and from Britain, showed markedly different developmental and reproductive rates when placed under the same temperature regime (Crisp, 1964). Thus in order to make accurate predictions about distribution of a species in a given locale, it is probably necessary to evaluate tolerances of local populations.

There are few synecological studies of the marine invertebrate boring and fouling community. Studies of this nature would seek to define the community in terms of variables that respond to changes in environmental parameters. In discussing the definition of a community, Odum (1971) mentions the following classes of variables: 1) the dominant species (possibly including trophic level analysis); 2) species diversity; and,

3) patterns in the community including spatial stratification and zonation, temporal activity, and reproductive, social, and coactive patterns.

Many benthic and intertidal communities have been described in terms of dominant species. Studies range from catalogued descriptions of the species that were present in visibly different intertidal environments (Ricketts and Calvin, 1952; Lewis, 1964) to more recent attempts to distinguish benthic communities based on methods of data simplification such as automatic classification or cluster analysis (Jones, 1969). The Ricketts and Calvin (1952) Study primarily described the invertebrate members of several North American Pacific Coast intertidal communities. Lewis (1964) similarly focused on algal members of British rock shore intertidal communities. Jones (1969) used recurrent group analysis and hierarchical cluster analysis to distinguish communities of benthic macrofauna off Southern California. In this study, quantitative samples of the general community were taken and computer programs were used to analyze these data with respect to associations among dominant species. All of these studies define a community by the associations of dominant species; any changes in the dominance structure are presumed to be due to environmental changes.

The number of species and the relative species dominance are community variables that can be quantified and statistically related to changes in the environment (Pielou, 1969). Moskowitz (1971) evaluated the effect that thermal addition from a nuclear power plant had on the benthic macro-invertebrate community in Barnegat Bay, New Jersey. The variables analyzed included the number of species, the Shannon-Weaver Diversity Index (Margalef, 1958), and the Evenness Index (Pielou, 1966). The assumption is that a lowering of any of these values reflects a simplification of the community. The further assumption is that a simplified community is less resilient to stress. Any changes in the numerical value of the above values presumably relates to environmental changes.

Patterns that have been studied for invertebrate settling communities include what Odum (1971) calls "zonation" patterns and "coactive" patterns. Zonation patterns will be considered in Part II. Coactive patterns are those resulting from intraspecies interactions and include competition relationships. Connell (1961) studied the competition between the barnacle *Chthamalus stellatus* and another barnacle, *Balanus balanoides*. Harger (1972) studied populations of two intertidal mussels, *Mytilus edulis* and *M. californicus*. Harger concluded from this study that ". . . complete elimination of one species by the other is rare and transitory. . ." because the environment is so unstable, although one species can, at times, appear to be more successful than the other. Thus some changes in the composition of the community may be explained by an analysis of the species that are involved in intraspecies competition.

Changes in the community variables mentioned above can often be related to changes in the environmental parameters. The present study investigated the relationship of changes in salinity and temperature to properties of the sublittoral estuarine wood boring and fouling invertebrate community in Barnegat Bay, New Jersey. Different stations in the bay were selected which would represent a range in mean salinity and mean temperature conditions. The community was sampled by determining the number of individuals of each species which settled at each station during one-month periods. To determine if there were any differences in the community among the different stations, the community was analyzed in terms of the dominant species, community complexity and competition patterns.

II. Materials and Methods

A. Study Area

Barnegat Bay, New Jersey, is a shallow-water, enclosed estuary characterized by small tidal and wave actions. The location of the nine sampling stations used in the study are shown in Figure I-1. Based on salinity, the area studied is classified as upper to middle estuary (Carriker, 1967).

Barnegat Bay is heavily built up with residences and commercial docks along the shore and in man-made lagoons. With the exceptions of Forked River Intake and Oyster Creek Outfall stations, samples were all taken near the shore, off of shallow water docks or bulwarks. Sampling at the previously mentioned two stations was done near the intake and outfall pipes of coolant water used by a nuclear power plant. Estuary water is pumped up Forked River, used as a coolant by the nuclear power plant and dumped into Oyster Creek where it is diluted with cooler water before it returns to the bay. The Oyster Creek Outfall station was located near the outfall but above the dilution pipes.

B. Sampling Times

Consecutive one-month sampling was done throughout the year from October, 1971, through September, 1972, at the Waretown, Oyster Creek Mouth, Oyster Creek Marina, Forked River Mouth, and Forked River Bridge stations. Additional stations including Stouts Creek Mouth, Stouts Creek at Winthrop St., Forked River Intake, and Oyster Creek Outfall stations were all sampled in this manner after March, 1972. In addition, overlapping consecutive one-month samples and consecutive two-week samples were taken from mid-May, 1972, through mid-October, 1972, at all stations.

C. Sampling Materials

A "sample" is defined as two boards strung on a single rope and weighted by a brick. The boards used were 6 x 3 x 2 inch, knot-free, aged Douglas fir. The bottom board was tied just above the brick so that the board rested two to three inches above mudline, and the top board was suspended about two feet above the bottom board so that the top board remained just below the low tide line. The bottom boards at Forked River Intake and Oyster Creek Outfall were no more than three feet below the surface.

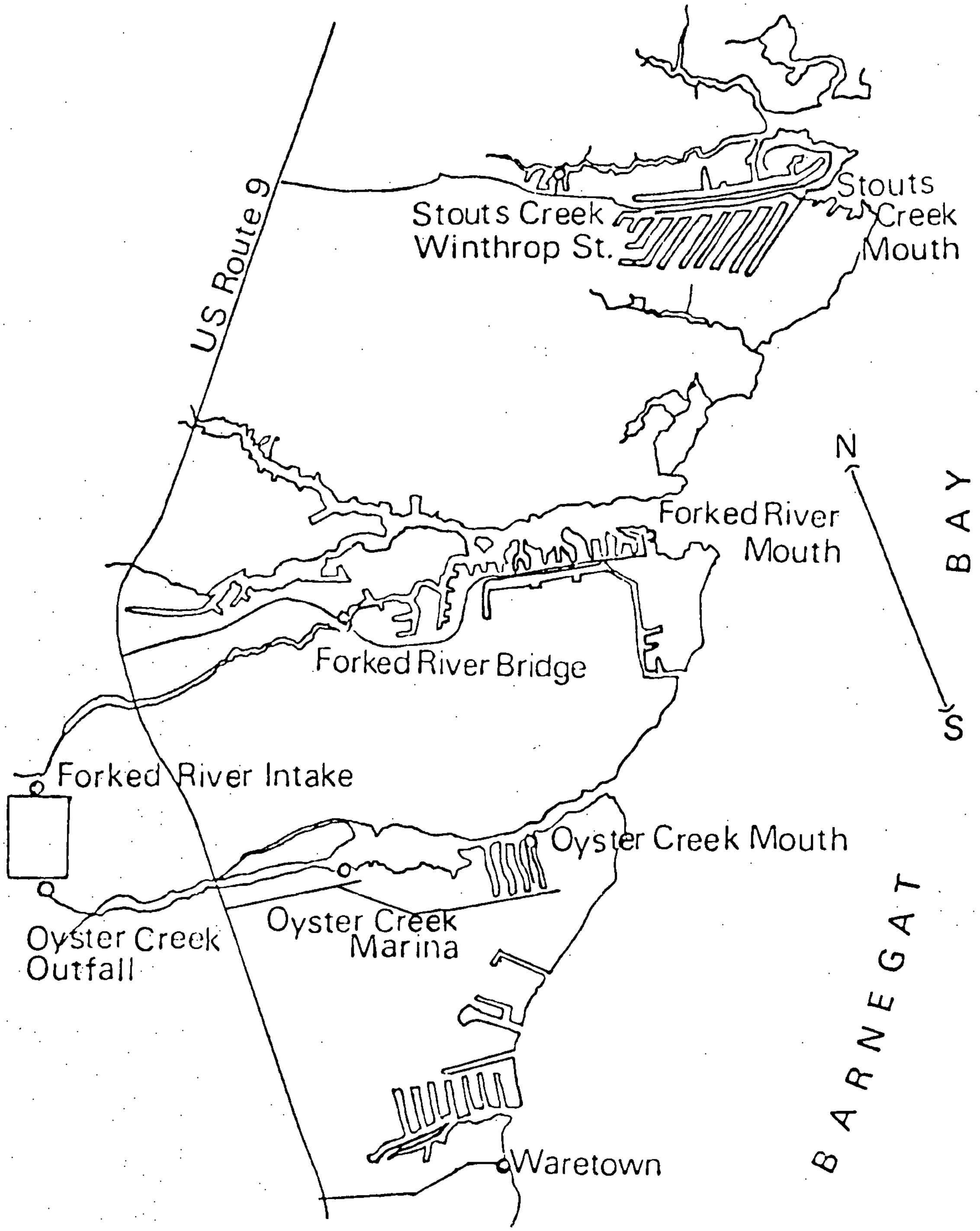
At the end of a sampling interval, the boards were returned to the laboratory in plastic bags and kept at a temperature of 7 C to keep the animals alive. The boards were examined under a dissecting microscope. Every invertebrate larger than 0.25 mm. was speciated and the number of individuals of each species per board was counted. Speciation was based on Gosner (1971), Loveland, Hendler and Newkirk (1969), Miner (1950), Smith (1964), and the "Taxonomic Keys and Checklists of Local

Flora and Fauna" produced by the Virginia Institute of Marine Sciences and the University of Delaware (not in publication).

Water salinity and temperature were taken at the beginning and the end of each sampling interval at all stations. Salinity and temperature were usually taken in the field with a Beckman RS - 5 salinometer, except for the last two dates when salinity was determined using the Knudsen technique (Knudsen, 1962; Oxner, 1962), and temperature was taken with a stem thermometer.

All analysis of variance calculations were done using A Multi-purpose Analaysis of Variance Fortran IV Computer Program" by Butler, Kamlet and Monty (1969).

Figure I-1: Map of Study Area showing locations of Sampling Stations.



US Route 9
Stouts Creek
Winthrop St.
Stouts
Creek
Mouth
N
S
BAY
Forked River
Mouth
Forked River Bridge
Forked River Intake
Oyster Creek Mouth
Oyster Creek
Outfall
Oyster Creek
Marina
BARNEGAT
Waretown

Figure I-1

III. Results

A. Hydrographic Data

There were significant differences among the nine stations with respect to mean temperature and mean salinity. The salinity and temperature data for March, 1972, through September, 1972, were examined over time and stations using a two-way factorial analysis of variance design.

Within-cell variance was obtained by using the measurements of salinity or temperature taken at the beginning and at the half-way point in a month. There were no significant interactions of time with station for either salinity or temperature. This means that the relative differences among stations did not change significantly through time.

Figure I-2 (A and B) shows the least significant intervals (LSI) around each station salinity or temperature mean (for March through September) which is superimposed on the total range of values observed at each station (for all the times that a station was sampled).

The graphs show that the Waretown and the Forked River Mouth stations had relatively high mean salinities. The Stouts Creek at Winthrop St. station had a low mean salinity. The Oyster Creek Mouth, Oyster Creek Marina, and Nuclear Power Plant Outfall in Oyster Creek stations all had significantly higher mean temperatures than the other stations. Thus, the stations can be distinguished from each other in a statistically meaningful way with regard to hydrography.

B. Dominant Species

The dominant species differed in settling seasons, in salinity and temperature limits, and in relative settling intensity at different stations.

The dominant species are assumed to be the ones that are the most important to the community. Since there has been little observation on interactions between members of the marine boring and fouling community, the present study uses only measures of abundance to define dominant members of the community. The measures of abundance include the mean number of individuals which settled per all samples, and the percentage of samples in which at least one individual of a species was found (sampling frequency).

Table I-1 gives the mean number of individuals per sample of each species, and the sampling frequency. The three ectoprocts and the chordate Botryllus schlosseri are all encrusting organisms. On a sample of wood, these species appear as sheets spreading out over the surface of the wood. For this reason, it is difficult to determine how many individual larvae initially settled to establish a colony. In

Figure I-2-A: Total Salinity Range at Each Station and Significance of Difference Between Mean Station Salinities. Stations are designated: WT = Waretown; OCM = Oyster Creek Mouth; OCMa = Oyster Creek Marina; FRM = Forked River Mouth; FRB = Forked River Bridge; SCM = Stouts Creek Mouth; SCW = Stouts Creek Winthrop St.; IN = Forked River Intake; OUT = Oyster Creek Outfall. Total salinity range represented by dotted line; station means with least significant interval ($p < 0.05$) represented by solid line.

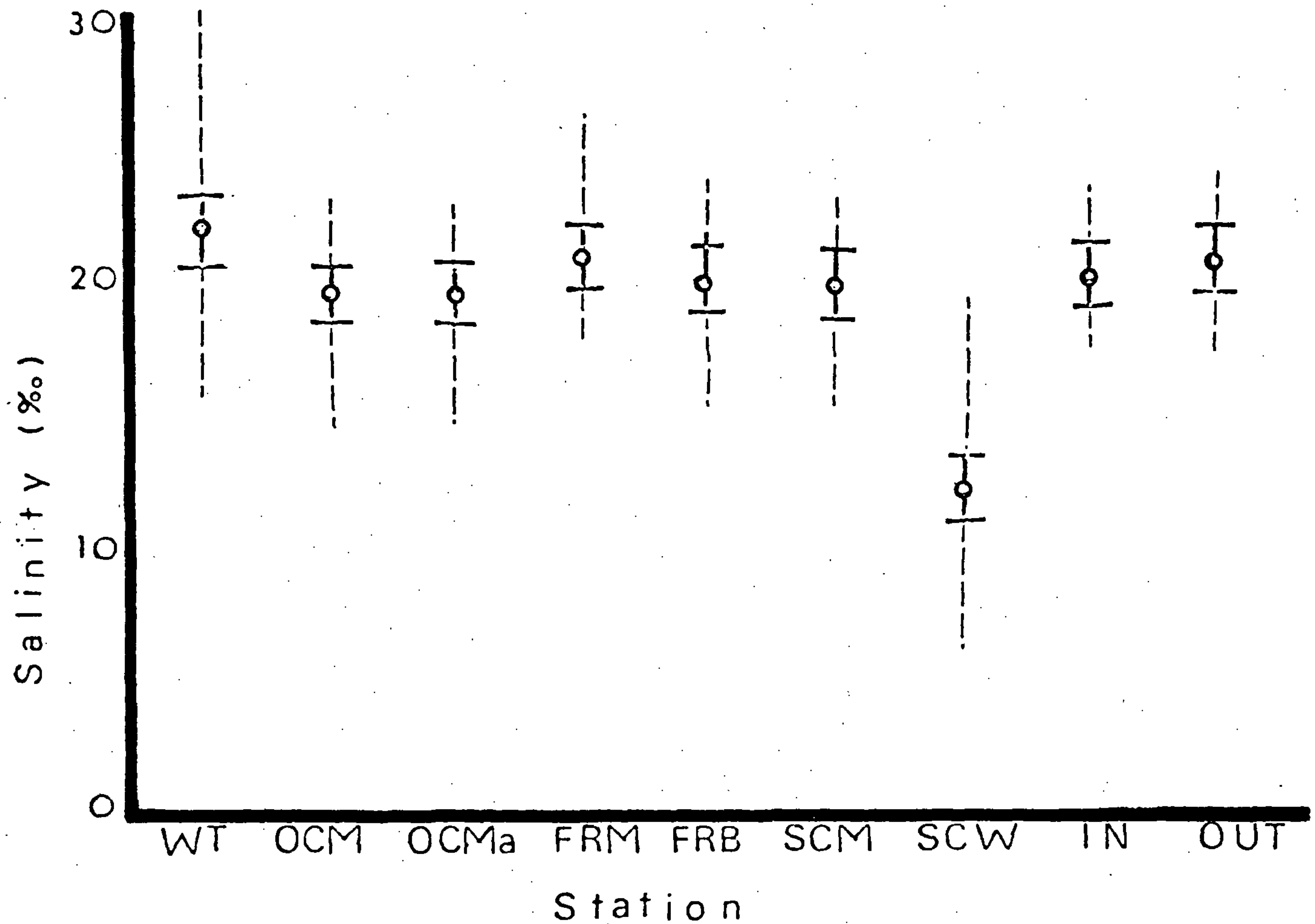


Figure I-2-A

Figure I-2-B: Total Temperature Range at Each Station and Significance of Difference Between Mean Station Temperatures. Stations are designated: WT = Waretown; OCM = Oyster Creek Mouth; OCMa = Oyster Creek Marina; FRM = Forked River Mouth; FRB = Forked River Bridge; SCM = Stouts Creek Mouth; SCW = Stouts Creek Winthrop St.; IN = Forked River Intake; OUT = Oyster Creek Outfall. Total Temperature Range represented by dotted line; station means with least Significant Interval ($p < 0.05$) represented by solid line.

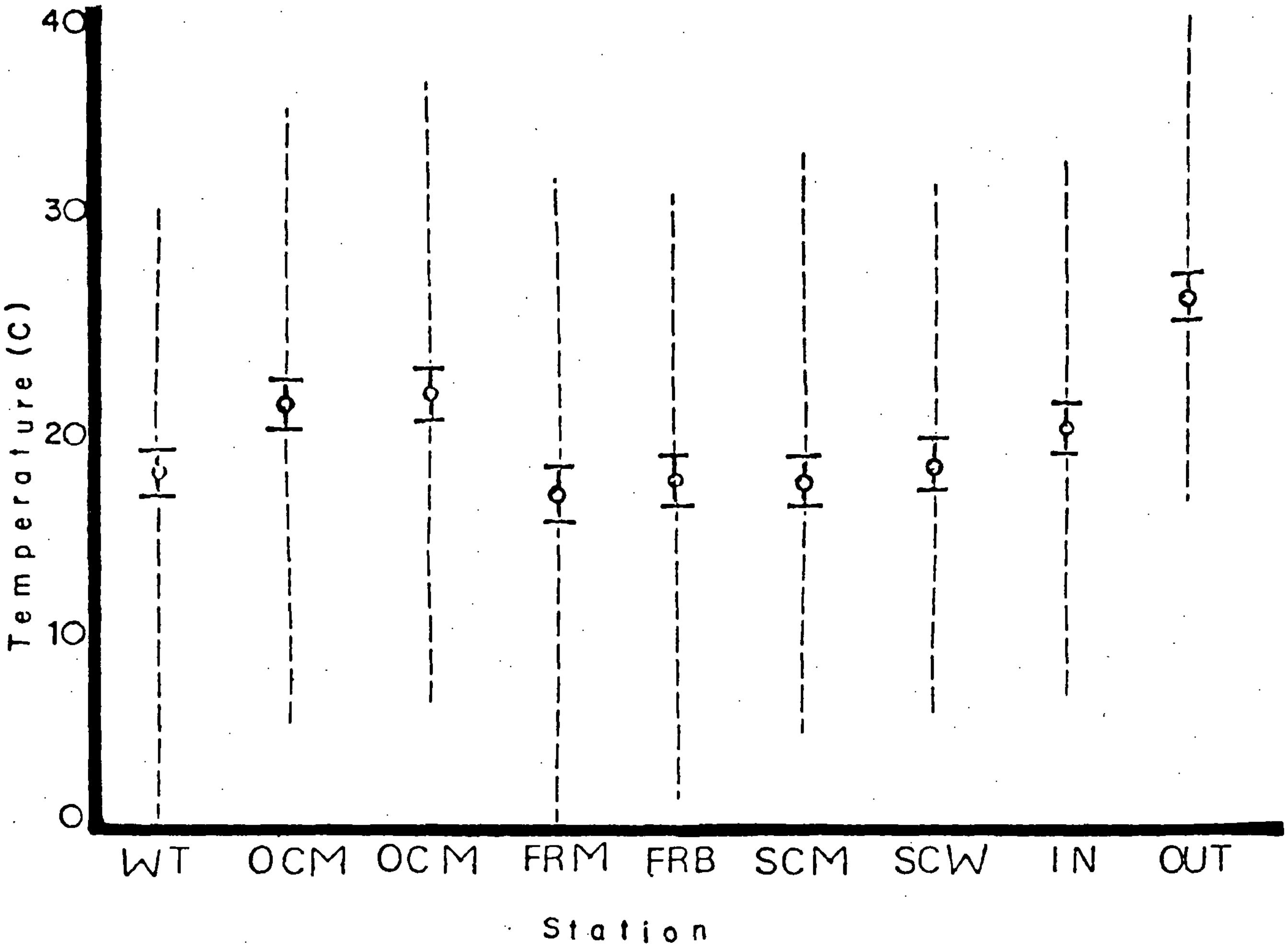

40
30
20
10
0
Temperature (C)
WT
OCM
OC M
FRM
FRB
SCM
SCW
IN
OUT
Station

Figure I-2-B

Table I-1: Abundance and Life Type of All Species. Measures of abundance include Frequency Sampled, which is the percentage of all 143 total samples in which a species was found; Number/Meter-squared/sample, which is the average number of individuals of the species found for all 143 samples (two-week sample data was adjusted to be proportional to one-month sample data). Life Type includes: E = Encrusting or Attached; T = Tube or burrow dwelling; M = Mobile.

*Value is the average percentage of board surface covered per sample.

Table I-1

PHYLUM	Species	Frequency Sampled (%)	Number/Meter^2/Sample	Life Type
PORIFERA				
	Haliclona canaliculata	3	0.51	E
CNIDARIA				
	Haliplanella luciae	7	2.96	E
	Diadumene leucolena	3	1.12	E
TURBELLARIA				
	Stylochus ellipticus	19	14.19	M
	Euplana gracilis	5	1.12	M
ANNELIDA				
	Capitella capitata	4	26.15	M
	Diopatra cuprea	1	0.10	T
	Eteone lactea	1	0.10	M
	Goniada maculata	1	0.41	M
	Hydroides dianthus	30	2456.88	T
	Nereis euccinea	41	35.14	M
	Phyllodocid sp.	1	0.20	M
	Polydora ligni	37	310.81	T
	Sabellaria vulgaris	4	2.86	T
ARTHROPODA				
	Ampelisca macrocephala	2	0.72	T
	Balanus eburneus	77	3155.30	E
	Caprella geometrica	6	35.14	M
	Callipallene brevirostris	4	12.36	M
	Cirolana concharum	1	0.10	M
	Corophium volutator	26	129.82	T
	Cyathura polita	2	7.66	M
	Erichsonella sp.	1	0.10	M
	Leptochelia savignyi	5	1.33	M
	Melita nitida	35	90.59	T
	Tendipedida sp.	4	21.76	M
MOLLUSCA				
	Bittium alternatum	9	2.15	M
	Doridella obscura	10	10.93	M
	Crepidula fornicata	12	22.88	M
	Mitrella lunata	6	2.25	M
	Nassarius obsoletus	1	0.10	M
	Bankia gouldi	20	366.48	T
	Mytilus edulis	3	0.51	E
	Solemya velum	1	0.20	M
	Tellina agilis	1	0.10	M
ECTOPROCTA				
	Bowerbankia gracilis	39	*12.80%	E
	Electra hastingsae	14	* 2.60%	E
	Membranipora sp.	49	* 4.20%	E
CHORDATA				
	Botryllus schlosseri	12	* 1.10%	E
	Molgula manhattensis	20	244.42	E

this study, the percent of the board surface which the colonies covered is assumed to be proportional to the numbers of individual larvae which settled. This assumption is necessary if these species are to be included in the community analyses which are made for this study. In Table I-1 the mean percent surface coverage per sample is given for these four species.

Table I-1 also gives the "life type" of each species. Life type is here defined as the degree to which the animal is sedentary. Thus "attached or encrusting" species are completely sedentary as adults and cannot move around on the settling surface. Except for the three anemones and Bowerbankia gracilis, all of which are relatively soft-bodied, the attached or encrusting species are all well protected by calcareous shells. "Tube dwelling" species are generally limited in their movements to reaching around the area immediately surrounding the tube opening. These species could not survive being removed from their tubes for very long, although Melita nitida and Corophium volutator were observed to completely leave and re-enter their tubes. "Mobile" species are those which do not live in tubes and are known to move around on the settling surface. Presumably, if they were displaced from the surface, they would be able to settle on another surface without undergoing much damage. Information on the life type of the complete list of species in Table I-1 is not available. Thus for the present study, species that were never observed in a tube or burrow are classified as "mobile".

The ten dominant species were selected from Table I-1. Selection was primarily done by taking those species with the highest mean number settling per sample. Table I-2 lists the dominant species with a brief description of their biology, as determined by observation. In addition, Table I-2 gives the sampling times when each species reached its maximum monthly settling rate at each station. As can be seen in Table I-1, these dominant species also had high sampling frequencies. Among the species which could not be analyzed in terms of the mean number which settled per sample, Bowerbankia gracilis and Membranipora sp. were found to have very high sampling frequencies, and for this reason they are included among the dominant species. Botryllus schlosseri is also included as a dominant because, when it was present, it had a potentially devastating effect on the rest of the community by completely covering and smothering the other animals.

All of the dominant species listed in Table I-2 are either encrusting, attached, or tube-dwelling organisms. Even though 21 of the 39 species which were observed are classified in Table I-1 as mobile, none of the dominant species are mobile organisms. Except for Corophium volutator and Melita nitida, if an adult of any of these dominant species were detached from the wood surface, it would probably not survive long. Thus the dominant species are fairly similar to each other in terms of life type.

The dominant species can, however, be differentiated in terms of seasonal cycles, temperature and salinity limits, and the absolute number of individuals which settled. In addition, subgroups of the dominant

SPECIES	DESCRIPTION	Station								
		WT	OCM	OCMa	FRM	FRB	SCM	SCW	IN	OUT
Balanus eburneus	Acorn barnacle; attached, with heavy calcareous shell	M/J	M/J	June	June	June	M/J	June	M/J	June
Bankia gouldi	Wood-boring clam; lives inside wood	M/J J/J	J/J	July	June	J/A		July		
Botryllus schlosseri	Colonial tunicate; forms fleshy sheets	A/S			Sept	S/O	Sept		Sept	
Bowerbankia gracilis	Colonial ectoproct; forms thin, connected stalks	S/O	July	July	A/S	Sept	S/O	Aug9	S/O	Sept
Corophium volutator	Amphipod; lives in mud-detrital burrows	May	M/J	June	M/J	J/J	M/J		M/J	M/J
Hydroides dianthus	Polychaete worm; forms calcareous tubes	June	S/O	A/S	July	J/J	July A/S	Aug	J/A	S/O
Melita nitida	Amphipod; lives in mud-detrital tubes	A/S	Aug	Sept	Aug	J/J	J/J	Aug	Sept	S/O
Membranipora sp.	Colonial ectoproct; froms calcarecus sheets	J/J	A/S	Sept	July	J/J	July	J/J	J/J	
Molgula manhattensis	Solitary, attached tunicate; fleshy body	July	Sept		A/S	Sept	Sept	S/O	Sept	
Polydora ligni	Polychaete worm; lives in mud-detrital burrows	July	July	July	Aug	July	May J/A	M/J J/A	July	M/J

TABLE I-2: Dominant Species with a Brief Biological Description and a Summary of Times of Maximum Monthly Settling Rate at each Station. (Samples that overlapped months are designated by the first initials of the two months.)

species can be defined in terms of the relative number of individuals which settled at the different stations.

1. Seasonal cycles, and Salinity and Temperature limits

Table I-2 indicates that each dominant species reached its maximum monthly settling rate at different times at the different stations. Several species, such as Balanus eburneus and Melita nitida, reached their maximum monthly settling rates at the different stations at approximately the same time, while other species, such as Hydroides dianthus and Bankia gouldi, reached their maximum settling rates four to six weeks later.

Figure I-3 (A-D) shows the monthly settling rate for each species during the year, averaged over all the stations that were sampled, using the one-month sample data. The figure indicates the length of the total settling season and the times when the mean monthly settling rate for all nine stations attained maximum value for each species.

The barnacle Balanus eburneus had the longest settling season, and the wood-boring clam Bankia gouldi had the shortest. For Bankia gouldi, the polychaete Hydroides dianthus, and the tunicate Molgula manhattensis, the mean monthly settling rate reached a maximum in the middle of July, 1972. All of the species except Bankia gouldi showed fluctuations in monthly settling rate which suggest that settling rates decreased due to higher summer temperatures, but increased again with the cooler fall temperatures. The Balanus eburneus monthly settling rate decreased when the settling rates of several other species were on the increase; Balanus eburneus again increased while Hydroides dianthus, Bankia gouldi, Membranipora sp., and the ectoproct Bowerbankia gracilis all suddenly decreased during early and mid-August, 1972.

Figure I-4 (A and E) shows the total range of salinity and temperature values under which each species was found in the bay. Balanus eburneus and Bowerbankia gracilis had the widest salinity ranges. Bankia gouldi and Hydroides dianthus had the narrowest salinity ranges. This data probably does not reflect upper salinity tolerances since none of the stations had salinities over 24 o/oo during the seasons when most of these species settled.

Balanus eburneus had the widest temperature range, and the polychaete Polydora ligni and the tunicate Botryllus schlosseri had the narrowest. Only two species, Bowerbankia gracilis and Balanus eburneus, were found at temperatures as high as 39.5°C. These data probably do not reflect upper temperature tolerances for Bowerbankia gracilis and Balanus eburneus since none of the stations had recorded temperatures over 39.5°C.

Figure I-3-A: Monthly Settling Rate in Barnegat Bay of *Bowerbankia gracilis*, *Botryllus schiosseri*, and *Membranipora sp.* for October, 1971, through October, 1972. Settling rate of a species for a given month was based on the average "percentage of board surface covered" at all nine stations after a one-month sampling period.

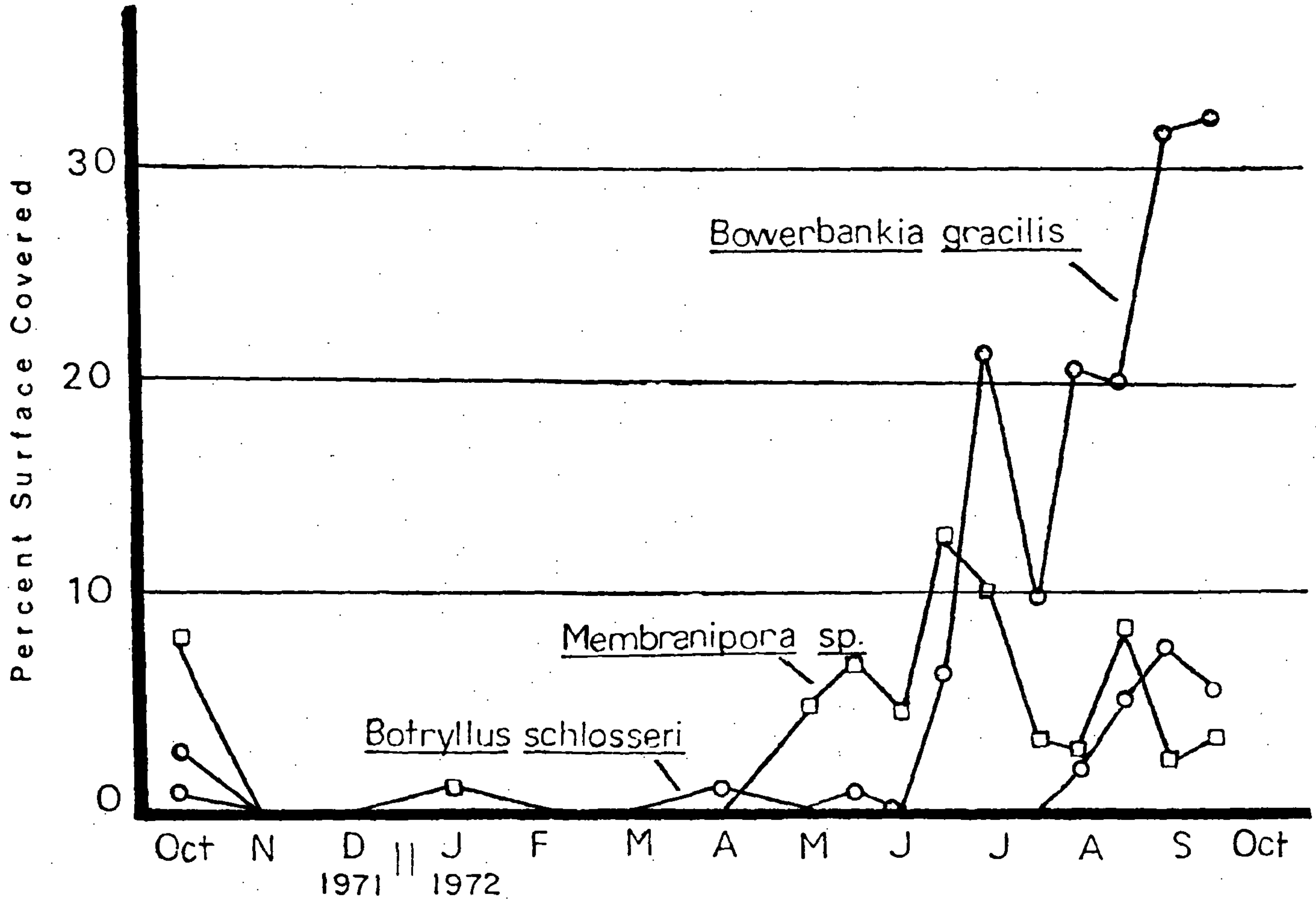

Percent Surface Covered
30
20
10
0
Bowerbankia gracilis
Membranipora sp.
Botryllus schlosseri
Oct
N
D
J
F
M
A
M
J
J
A
S
Oct
1971
1972

Figure I-3-A

Figure I-3-B: Monthly Settling Rate in Barnegat Bay of _Balanus eburneus_ and _Hydroides dianthus_ for October, 1971, through October, 1972. Settling rate is based on the average number of individuals which settled at all nine stations during a one-month sampling period.

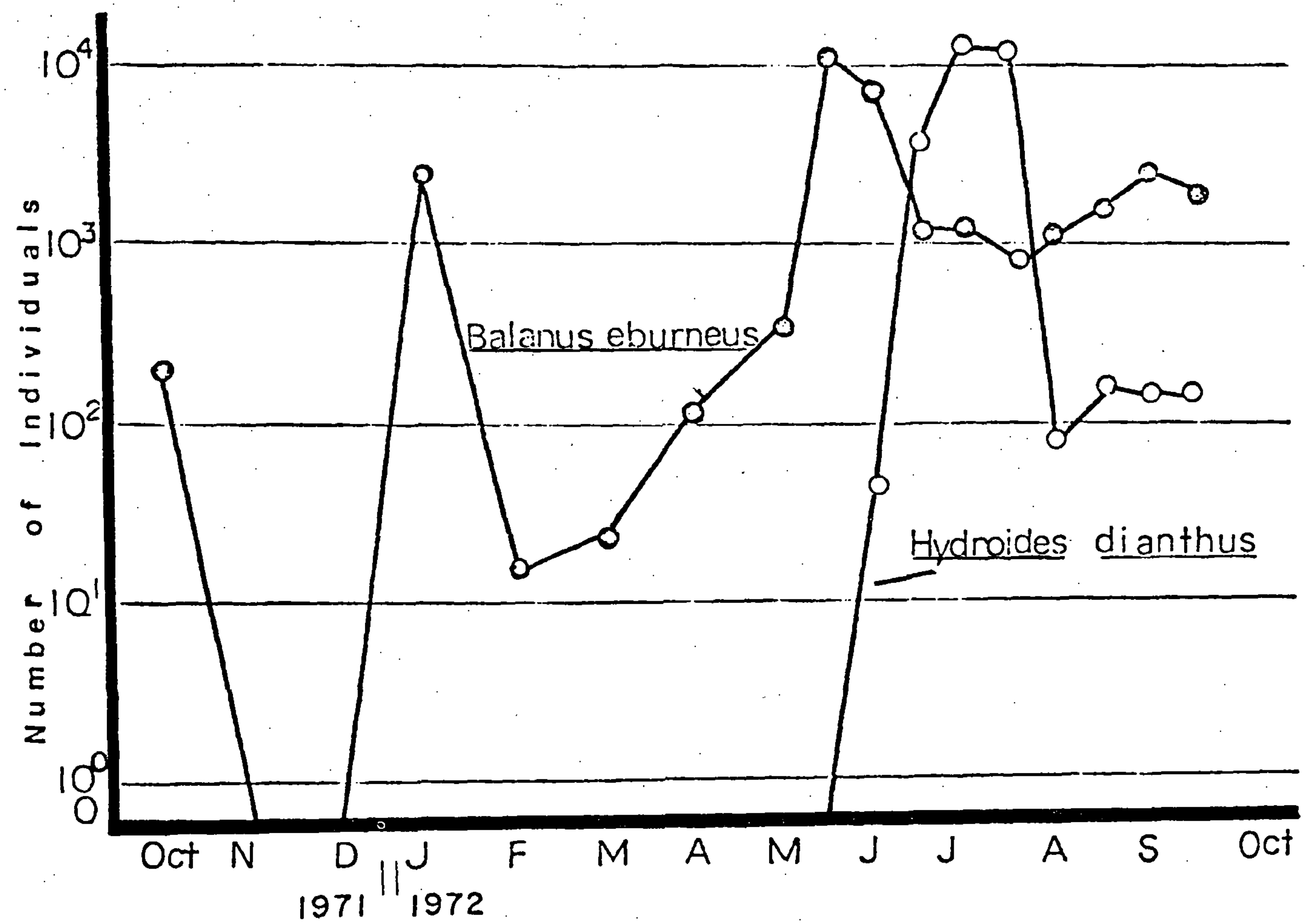

Number of Individuals
10⁴
10³
10²
10¹
10⁰
0
Balanus eburneus
Hydroides dianthus
Oct N D J F M A M J J A S Oct
1971 1972

Figure I-3-B

Figure I-3-C: Monthly Settling Rate in Barnegat Bay of *Bankia gouldi*, *Polydora ligoi*, and *Molgula manhattensis* for October, 1971, through October, 1972. Settling rate is based on the average number of individuals which settled at all nine stations during a one-month sampling period.

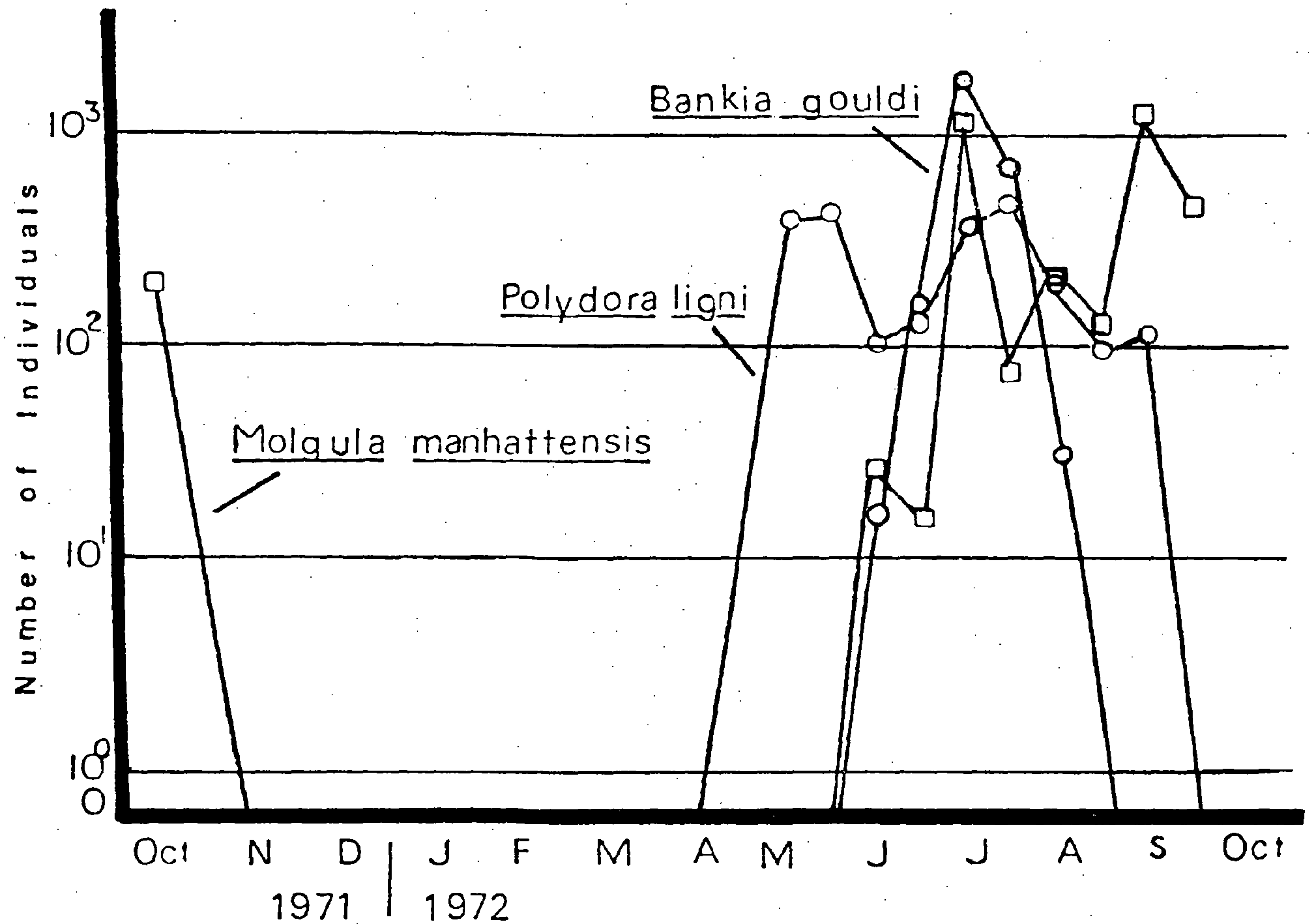

Number of Individuals
10^3
10^2
10^1
10^0
0
Bankia gouldi
Polydora ligni
Molgula manhattensis
Oct N D J F M A M J J A S Oct
1971 1972

Figure I-3-C

Figure I-3-D: Monthly Settling Rate in Barnegat Bay of *Corophium volutator* and *Melita nitida* for October, 1971, through October, 1972. Settling rate is based on the average number of individuals which settled at all nine stations during a one-month sampling period.

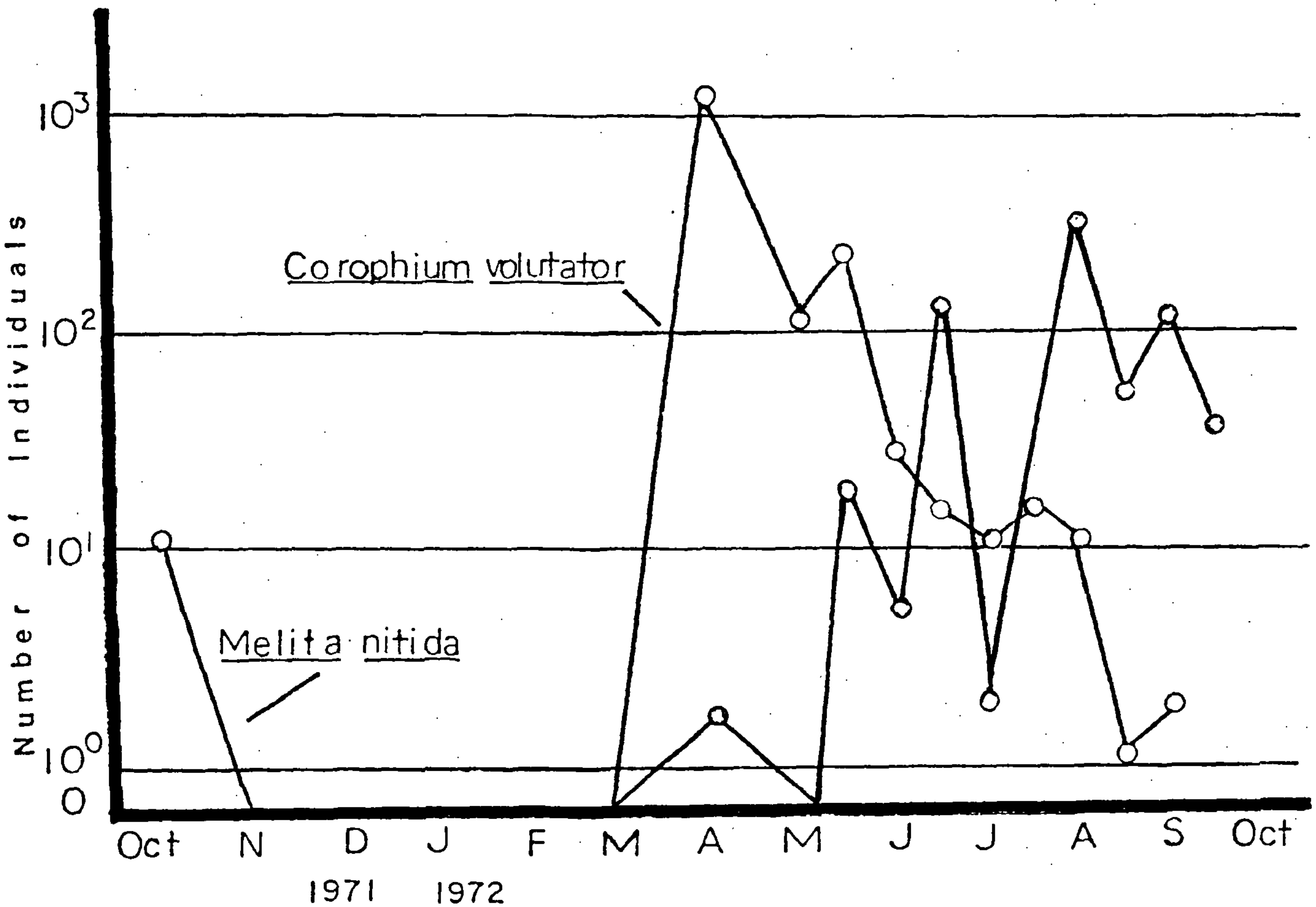

Number of Individuals
10^3
10^2
10^1
10^0
0
Corophium volutator
Melita nitida
Oct N D J F M A M J J A S Oct
1971 1972

Figure I-3-D

Figure I-4-A: Salinity RangefFor Each Dominant Species

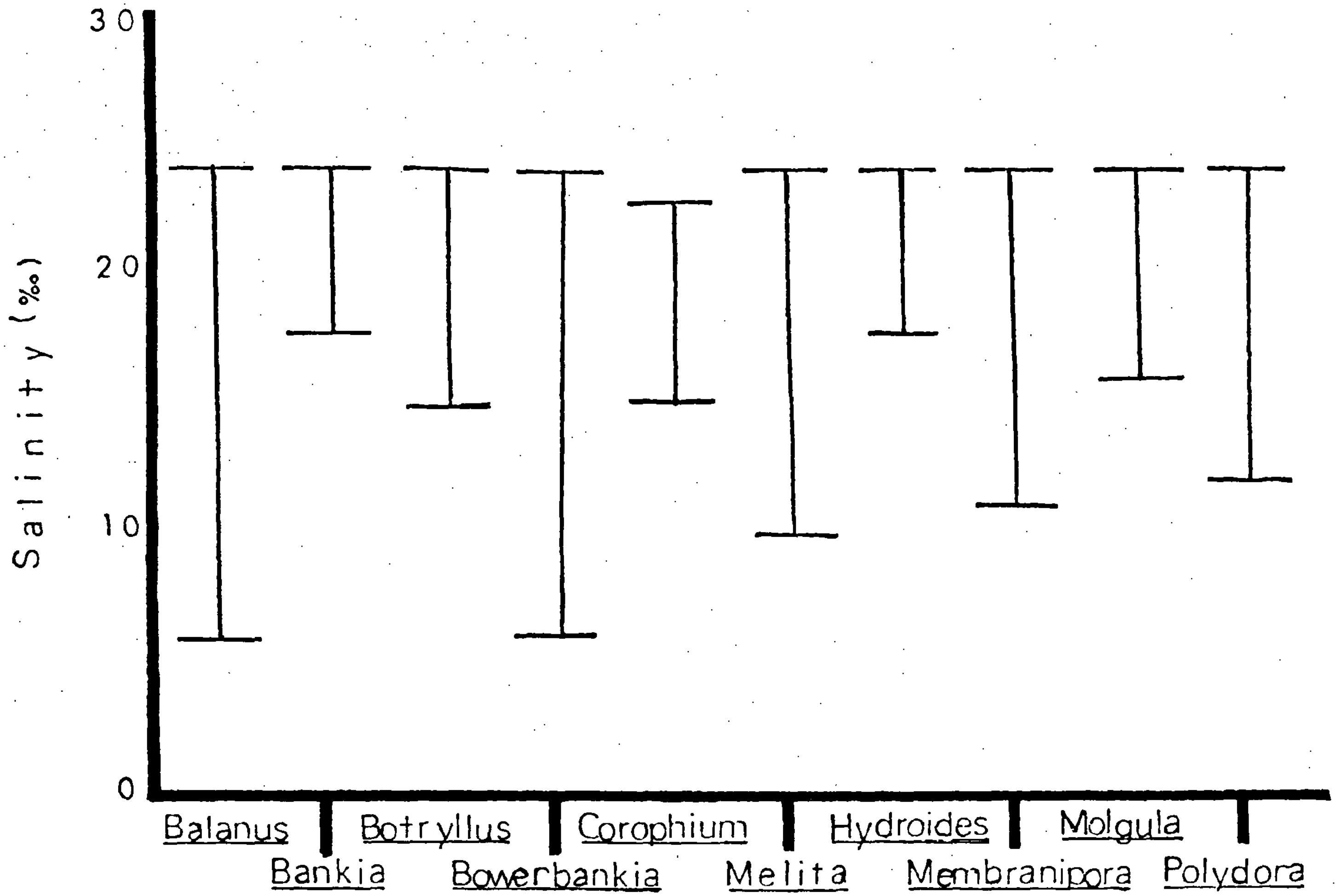

30
20
10
0
Salinity (‰)
Balanus
Bankia
Botryllus
Bowerbankia
Corophium
Melita
Hydroides
Membranipora
Molgula
Polydora

Figure I-4-A

Figure I-4-B: Temperature Range for Each Dominant Species.

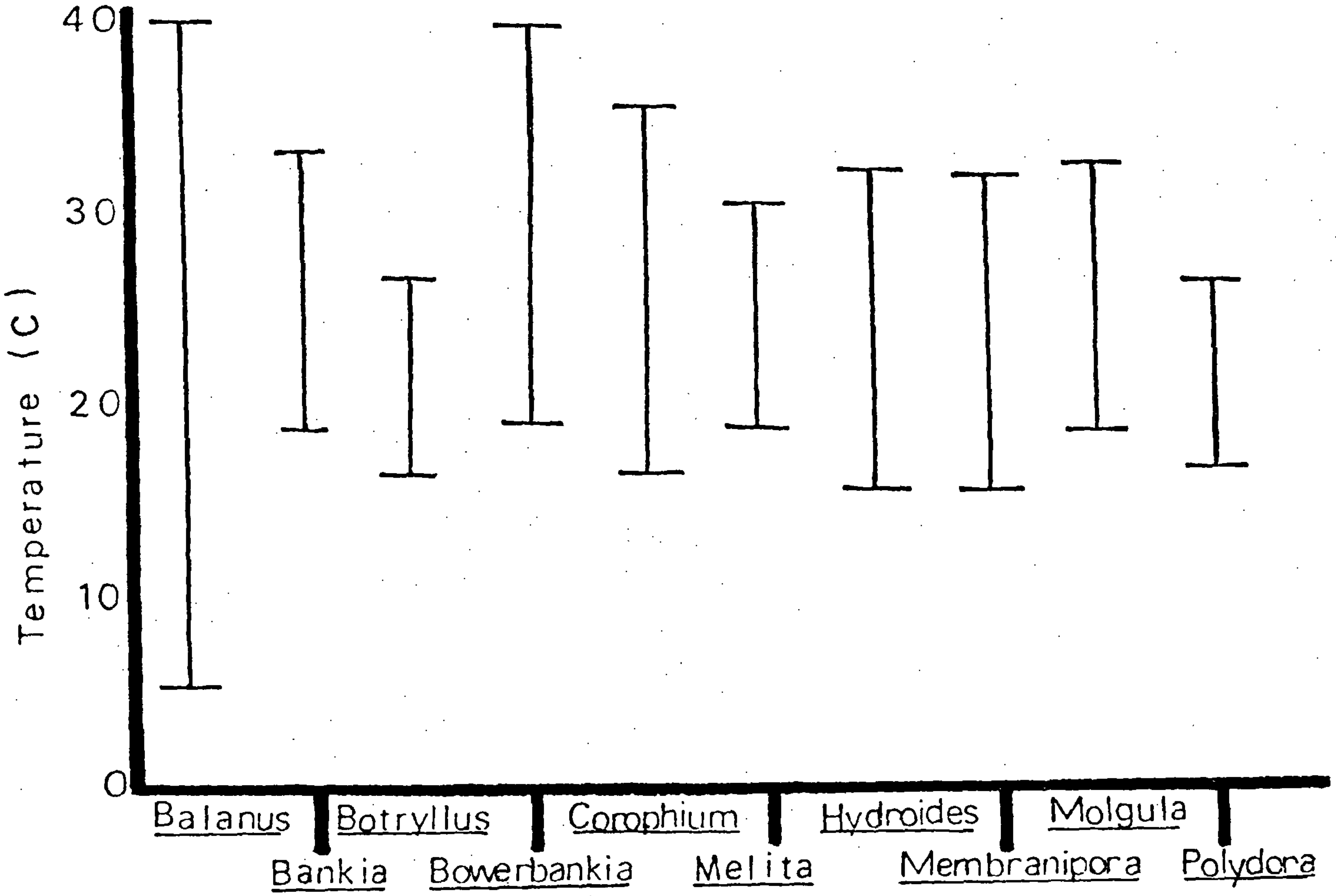

40
30
20
10
0
Temperature (C)
Balanus
Bankia
Botryllus
Bowerbankia
Corophium
Melita
Hydroides
Membranipora
Molgula
Polydora

Figure I-4-B

2. Settling profiles of the dominant species

Species are relatively similar or dissimilar to each other based on their relative settling intensity at the different stations. Figure I-5 shows the total number of individuals of a given species which settled at each of the stations. Each of these frequency histograms can be converted to a relative frequency distribution by converting the numbers of individuals of a given species which settled at each of the stations to percentages of the total number of individuals of that species which settled at all of the stations. The relative frequency distribution for a given species will be referred to in the following discussion as that species' "settling profile". Figure I-5 adequately illustrates settling profiles.

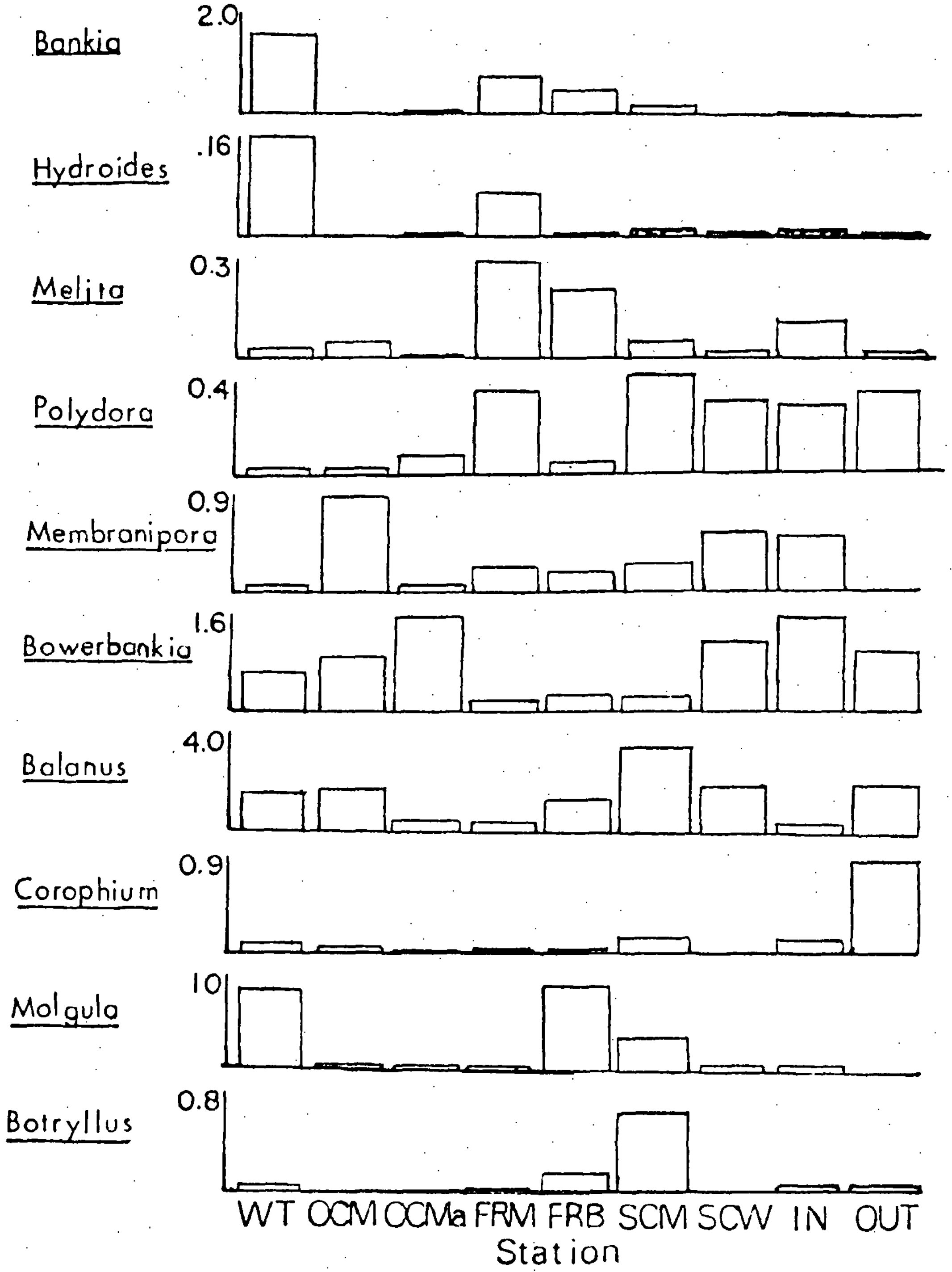
From Figure I-5, Hydroides dianthus and Bankia gouldi both settled relatively heavily at the Waretown station, which was then followed by Forked River Mouth and Bridge, and Stouts Creek Mouth stations. Molgula manhattensis and Botryllus schlosseri both settled relatively heavily at Forked River Bridge and Stouts Creek Mouth. Compared to other species, Balanus eburneus and Bowerbankia gracilis both settled fairly heavily at all of the stations, with high numbers at Oyster Creek Mouth, Stouts Creek at Winthrop St., and Forked River Intake stations.

If two species have exactly the same settling profile, they could be said to be positively associated. Presumably, as environmental parameters change from station to station, so would the relative number of individuals which settled of two associated species. Thus a systematic evaluation of associations of dominant species based on settling profiles could contribute to an understanding of the relationship between the relative number of individuals which settled and the changes in environmental parameters.

The data presented in Figure I-5 are analyzed for the relative association of each pair of dominant species. In order to analyze the association of species, it is useful to calculate a single value which reflects the relative association between two species. An index which represents the dissimilarity of species (or "distance between" species), based on their settling profiles, is the information radius (Jardine and Sibson, 1971). A matrix of information radius values which gives the dissimilarity between every pair of species was generated. Groups of species which were the least dissimilar (hence the most similar) were extracted from this matrix by means of Johnson's diameter method of hierarchical cluster analysis (Johnson, 1967).

The results of these analyses, showing the clustering of species at different levels of the clustering hierarchy, are shown in Figure I-6. Hydroides dianthus and Bankia gouldi had the most similar settling profiles resulting in the lowest information radius value; therefore

Figure I-5: Settling Profile of Each Dominant Species. The total number of individuals of each species which settled at each station from April, 1972, through September, 1972; the Y-axis gives the number of individuals x 10^3. Both two-week and one-month samples were included.



Bankia
2.0
Hydroides
.16
Melita
0.3
Polydora
0.4
Membranipora
0.9
Bowerbankia
1.6
Balanus
4.0
Corophium
0.9
Molgula
10
Botryllus
0.8
WT OCM OCMa FRM FRB SCM SCW IN OUT
Station

Figure I-5

Figure I-6: Dominant Species Clusters Based on Similarity of Settling Profiles. The number in a box indicates hierarchical level at which the species which are included within the perimeter of the box clustered together.

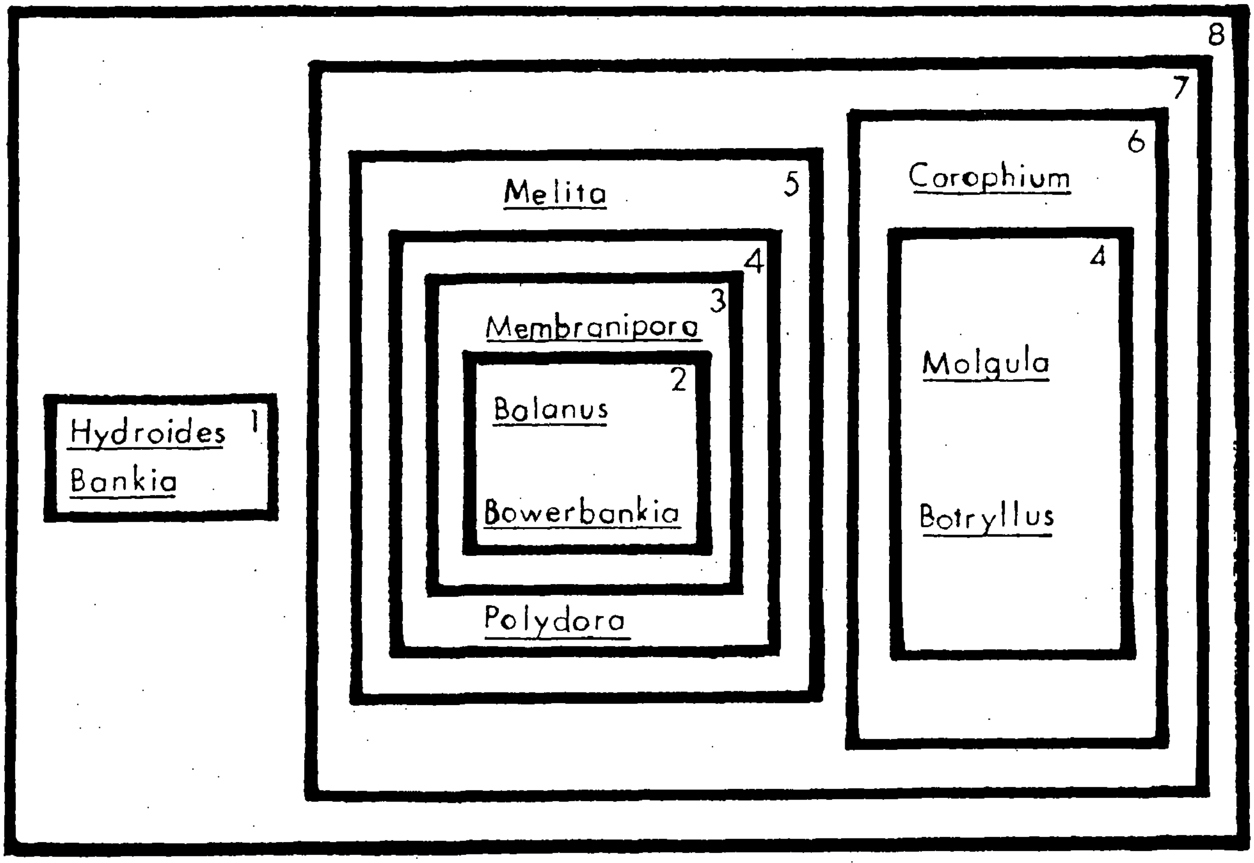

8
7
6
Corophium
5
Melita
4
3
Membranipora
2
Balanus
Bowerbankia
Polydora
1
Hydroides
Bankia
4
Molgula
Botryllus

Figure I-6

these two species formed the first cluster. They remained as a unit, separate (different) from all other species until the final (weakest) cluster level was reached. Balanus eburneus, Bowerbankia gracilis, and Membranipora sp. clustered at the third hierarchical level.

As seen in Figure I-5, Molgula manhattensis is fairly similar in settling profile to Bankia gouldi and Hydroides dianthus. But Molgula manhattensis never clustered with Hydroides dianthus and Bankia gouldi until the final level. This illustrates a fundamental problem in understanding results of a hierarchical cluster analysis. The clusters of species represent the largest, most highly inter-associated, non-overlapping groups that can be derived at a given hierarchical level. Thus the clusters build up from the most tightly associated pairs. Because, in the case above, Molgula manhattensis initially clustered with Botryllus schlosseri, and Botryllus schlosseri is relatively dissimilar in settling profile to Hydroides dianthus and Bankia gouldi, Molgula manhattensis does not cluster with Hydroides dianthus and Bankia gouldi until the final, weakest clustering level is reached.

3. Community profiles of stations

As suggested in the analysis above, each station may represent a different environment. Thus there may be changes in the total community from station to station, as well as changes in the settling of individual species. The environmental parameters responsible for community changes can be detected by first determining the relative similarity of stations based on some community property, and relating this to similarity of stations based on measured environmental parameters.

Station associations can be based on the relative intensity of settling of the dominant species at each station. Figure I-7 shows the total number of individuals of each species which settled at a given station. Each of these frequency histograms can be converted to relative frequency distributions by converting the number of individuals of a species which settled at a given station to the percentage of the total number of individuals of all the dominant species which settled at that station. The relative frequency distribution for a given station will be referred to in the following discussion as that station's "community profile". The graphs indicate that four of the species, Hydroides dianthus, Balanus eburneus, Membranipora sp., and Bowerbankia gracilis, are the most important species in defining a station's community profile. Oyster Creek Mouth and Stouts Creek Mouth stations appear to be similar because both had relatively high numbers of Bowerbankia gracilis, Balanus eburneus, and Membranipora sp.. Waretown and Forked River appear similar primarily because these stations had relatively high numbers of Hydroides dianthus.

Information radius was used to compare each pair of stations with respect to their community profiles. Groups of similar stations were extracted from the complete matrix of information radius values by means of cluster analysis (Johnson, 1964). The results are illustrated in Figure I-8.

Figure I-7: Community Profile of each Station. The total number of individuals of each dominant species which settled at a station are given: th Y-axis gives the number of individuals x 10^3. Species include: BAL = _Balanus eburneus_, BAN = _Bankia gouldi_, BOT = _Botryllus schlosseri_, BOW = _Bowerbankia gracilis_, COR = _Corophium volutator_, MEL = _Melita Nitida_, HYD = _Hydroides dianthus_, MEM = _Membranipora sp._, MOL = _Molgula manhattensis_, and POL = _Polydora ligni_.

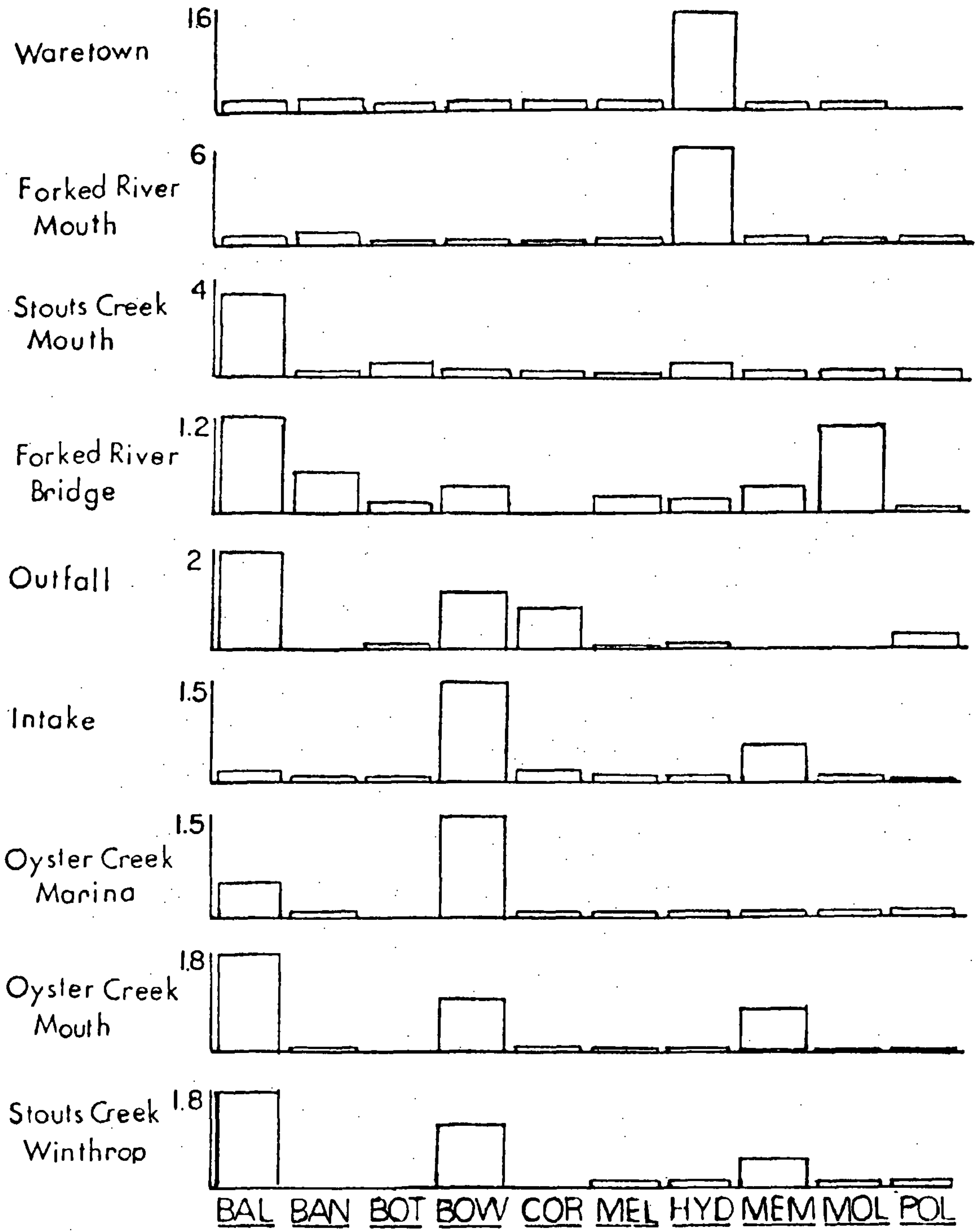

16
Waretown
6
Forked River
Mouth
4
Stouts Creek
Mouth
1.2
Forked River
Bridge
2
Outfall
1.5
Intake
1.5
Oyster Creek
Marina
1.8
Oyster Creek
Mouth
1.8
Stouts Creek
Winthrop
BAL
BAN
BOT
BOW
COR
MEL
HYD
MEM
MOL
POL

Figure I-7

Figure I-8-A: Station Clusters Based on Similarity of Community Profiles. The number in a box indicates hierarchical level at which the stations included within the perimeter of the box clustered together.

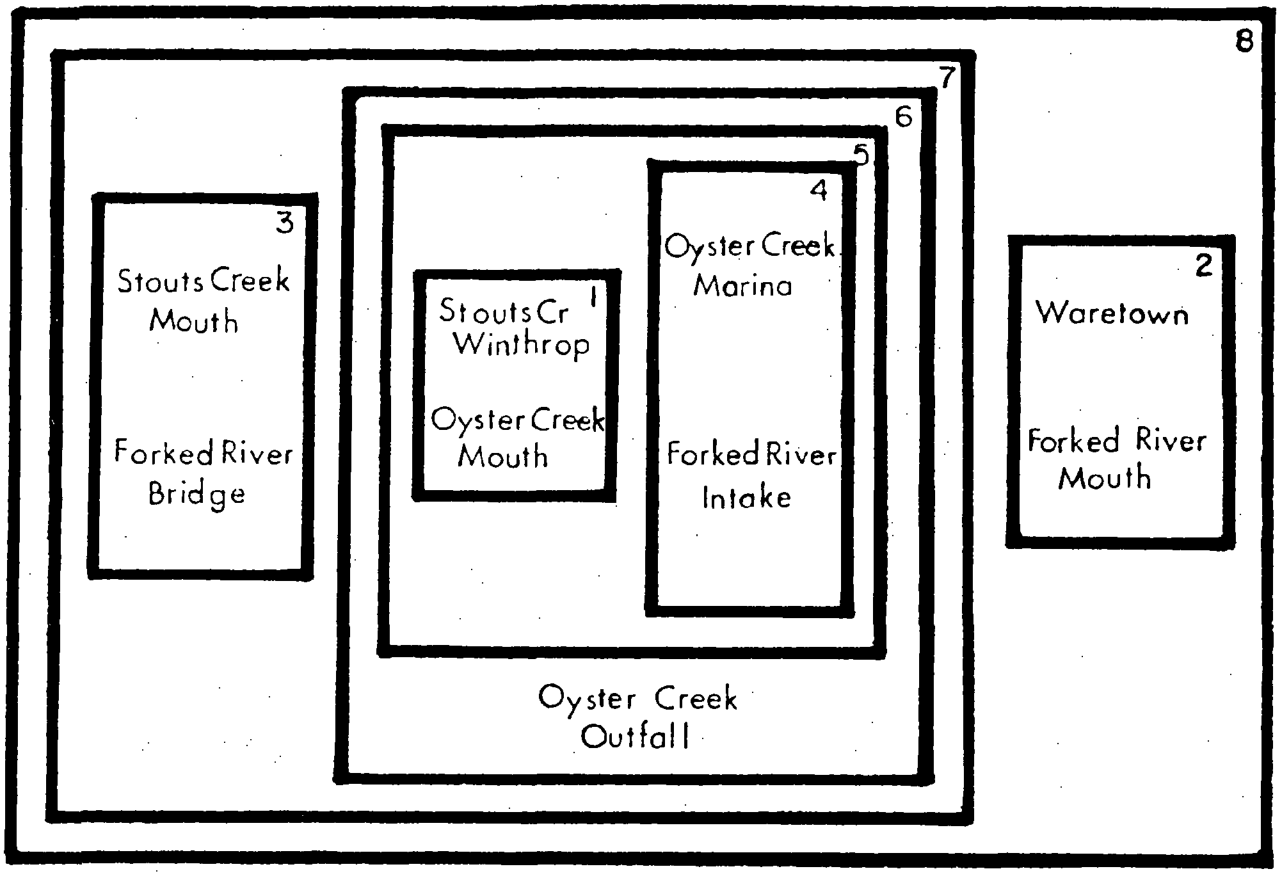

8
7
6
5
4
3
Stouts Creek
Mouth
Forked River
Bridge
1
Stouts Cr
Winthrop
Oyster Creek
Mouth
Oyster Creek
Marina
Forked River
Intake
Oyster Creek
Outfall
2
Waretown
Forked River
Mouth

Figure I-8-A

Figure I-8-B: Map of Final Two Station Clusters Based on Similarity of Community Profiles.

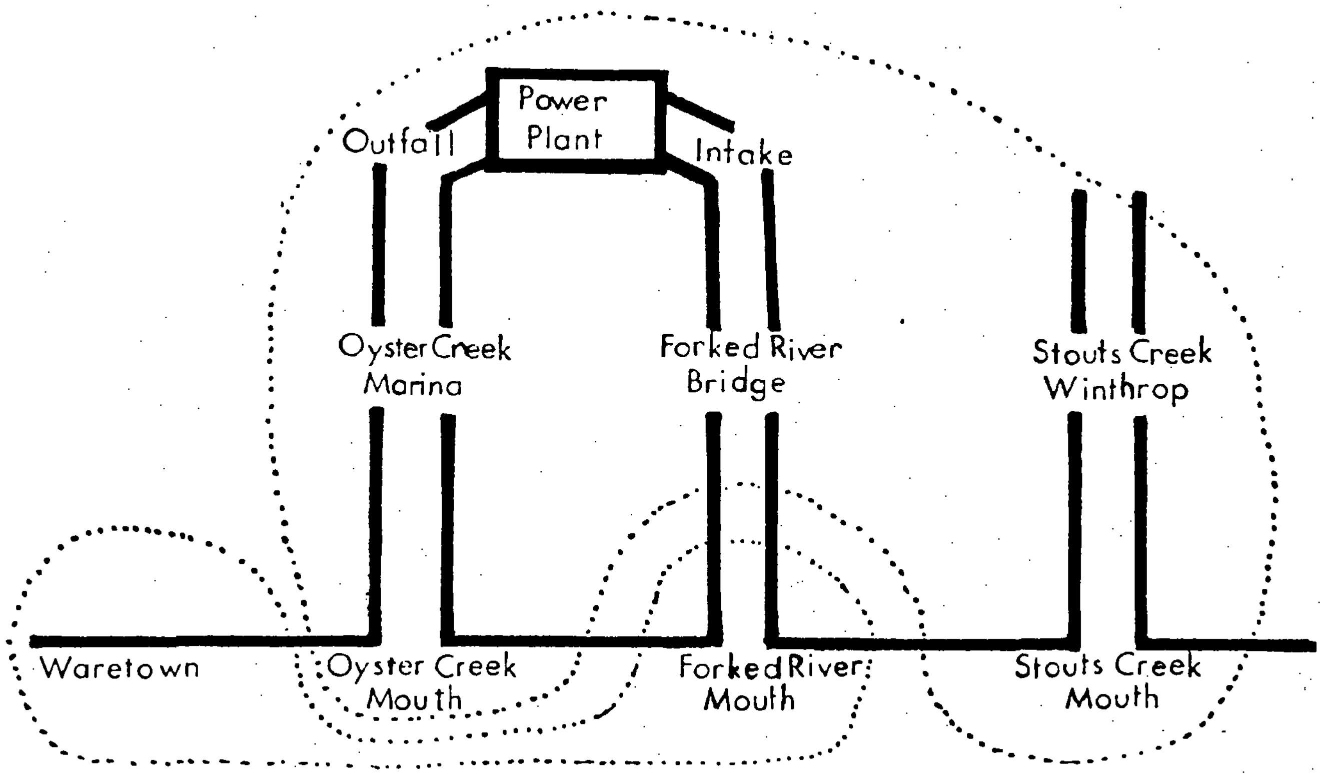

Power Plant
Outfall
Intake
Oyster Creek Marina
Forked River Bridge
Stouts Creek Winthrop
Waretown
Oyster Creek Mouth
Forked River Mouth
Stouts Creek Mouth

Figure I-8-B

Figure I-8-A shows the clusters that occured at each hierarchical level. Figure I-8-B shows the two largest clusters before the final hierarchical level. The figures show that, as a pair, Waretown and Forked River Mouth stations are very different from the other stations with regard to community profiles and are very similar to one another.

C. Community complexity

The stations differed from each other in the total number of different species which settled. The particular species which comprised the community also varied from station to station. In addition, the mean Diversity Index (Margalef, 1958), a commonly used measure of community complexity, varied from station to station.

1. Total numbers of species

The more species that settle at a given station, then presumably the better or more generalized the environment is for the total community. Table I-3 shows the invertebrate species that occurred at each station after March, 1972, and the total number of species which occured at each station during that time. Forked River Mouth and Forked River Intake stations had the highest numbers of invertebrate species. Oyster Creek Outfall, Oyster Creek Marina and Stouts Creek at Winthrop St. stations had the lowest numbers.

2. Species in common

As in the analysis of dominant species, (section B-3), station similarity can be examined using characteristic species. Rather than use the relative importance of a few species, though, this analysis determined station similarities based on presence or absence of each of the 39 species. That is, the more species that two stations have in common, (present or absent at both stations) the more similar those stations are in "community composition". From Table I-3, a matrix of numbers of speices in common (present or absent) for each pair of stations was generated. The results of a hierarchical cluster analysis (Johnson, 1967) performed on this matrix are shown in Figure I-9. Oyster Creek Outfall, Oyster Creek Marina, and Stouts Creek at Winthrop St. stations are very similar to each other in terms of community composition. Waretown was the least similar to any other station in community composition, and was therefore the last to cluster with any other station.

3. Species diversity index

Even if two stations have the same community composition the community structure may be different since the relative number of individuals of species can vary. Using the entire community, it is possible to generate a single value, the Species Diversity Index. H', (Margalef, 1958) which reflects the total number of species found and the relative predominance of those species within a sample.

Table I-3: All Species that Settled at Each Station.
"X" indicates that a given species was found at a given station. The total number of species that settled at each station is also given.

Table I-3

PHYLUM	Species	Station								
		OCM	FRB	SCM	WT	FRM	IN	OUT	OCMa	SCW
PORIFERA										
	Haliclona canaliculata		X	X						
CNIDARIA										
	Haliplanella luciae		X	X		X	X	X		
	Diadumone leucolena			X		X	X			
TURBELLARIA										
	Stylochus ellipticus	X	X	X	X	X	X		X	X
	Euplana gracilis	X	X	X	X	X				
ANNELIDA										
	Capitella capitata	X	X	X						X
	Diopatra cuprea						X			
	Eteone lactea				X					
	Goniada maculata		X			X				
	Hydroides dianthus	X	X	X	X	X	X	X	X	X
	Nereis succinea	X	X	X	X	X	X	X	X	X
	Phyllodocid sp.					X	X			
	Sabellaria vulgaris				X		X			
ARTHROPODA										
	Ampelisca macrocephala				X		X	X		
	Balanus eburneus	X	X	X	X	X	X	X	X	X
	Caprella geometrica					X	X	X	X	
	Callipallene brevirostris				X	X	X	X		X
	Cirolana concharum	X								
	Corophium volutator	X	X	X	X	X	X	X	X	
	Cyathura polita					X	X			
	Erichsonella sp.	X								
	Leptochelia savignyi	X	X			X	X			
	Melita nitida	X	X	X	X	X	X	X	X	X
	Tendipedida sp.					X				X
MOLLUSCA										
	Bittium alternatum	X	X	X	X	X				
	Doridella obscura	X	X	X	X	X				
	Crepidula fornicata	X	X	X	X	X			X	
	Mitrella lunata	X	X	X	X	X	X			
	Nassarius obsoletus					X				
	Bankia gouldi	X	X	X	X	X	X		X	
	Mytilus edulis		X		X	X	X			
	Solemya velum					X				
	Tellina agilis				X					
ECTOPROCTA										
	Bowerbankia gracilis	X	X	X	X	X	X	X	X	X
	Electra hastingsae	X	X	X	X	X	X			X
	Membranipora sp.	X	X	X	X	X	X	X	X	X
CHORDATA										
	Botryllus schlosseri		X	X	X	X	X	X		
	Molgula manhattensis	X	X	X	X	X	X		X	X
TOTAL NUMBER OF SPECIES		21	24	22	24	30	25	13	13	13

Figure I-9-A: Station Clusters Based on Species in Common. The number in a box indicates the hierarchical level at which the stations included within the perimeter of the box clustered together.

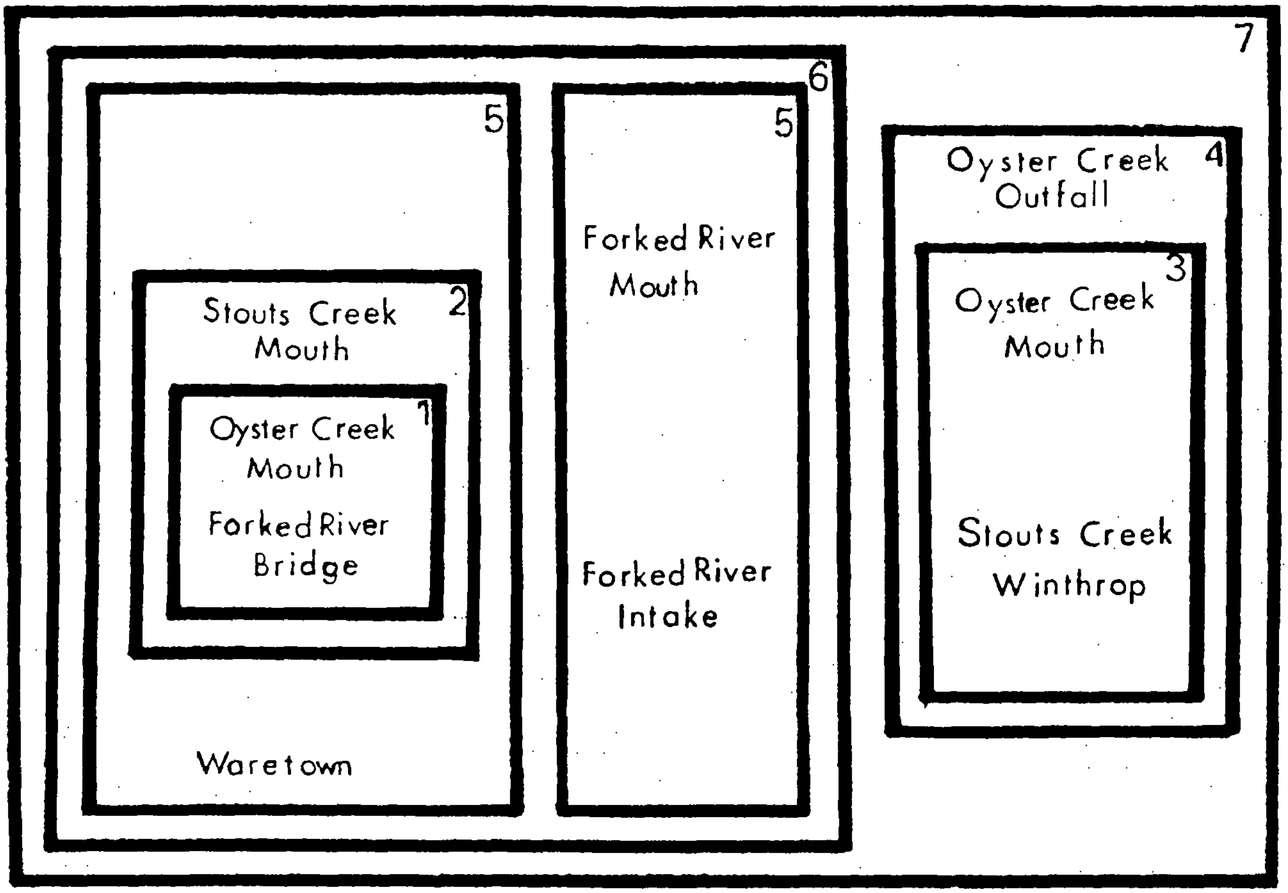

7
6
5
5
Oyster Creek Outfall
4
Forked River Mouth
Stouts Creek Mouth
2
3
Oyster Creek Mouth
1
Oyster Creek Mouth
Forked River Bridge
Stouts Creek Winthrop
Forked River Intake
Waretown

Figure I-9-A

Figure I-9-B: Map of Final Two Station Clusters Based on Species in Common.

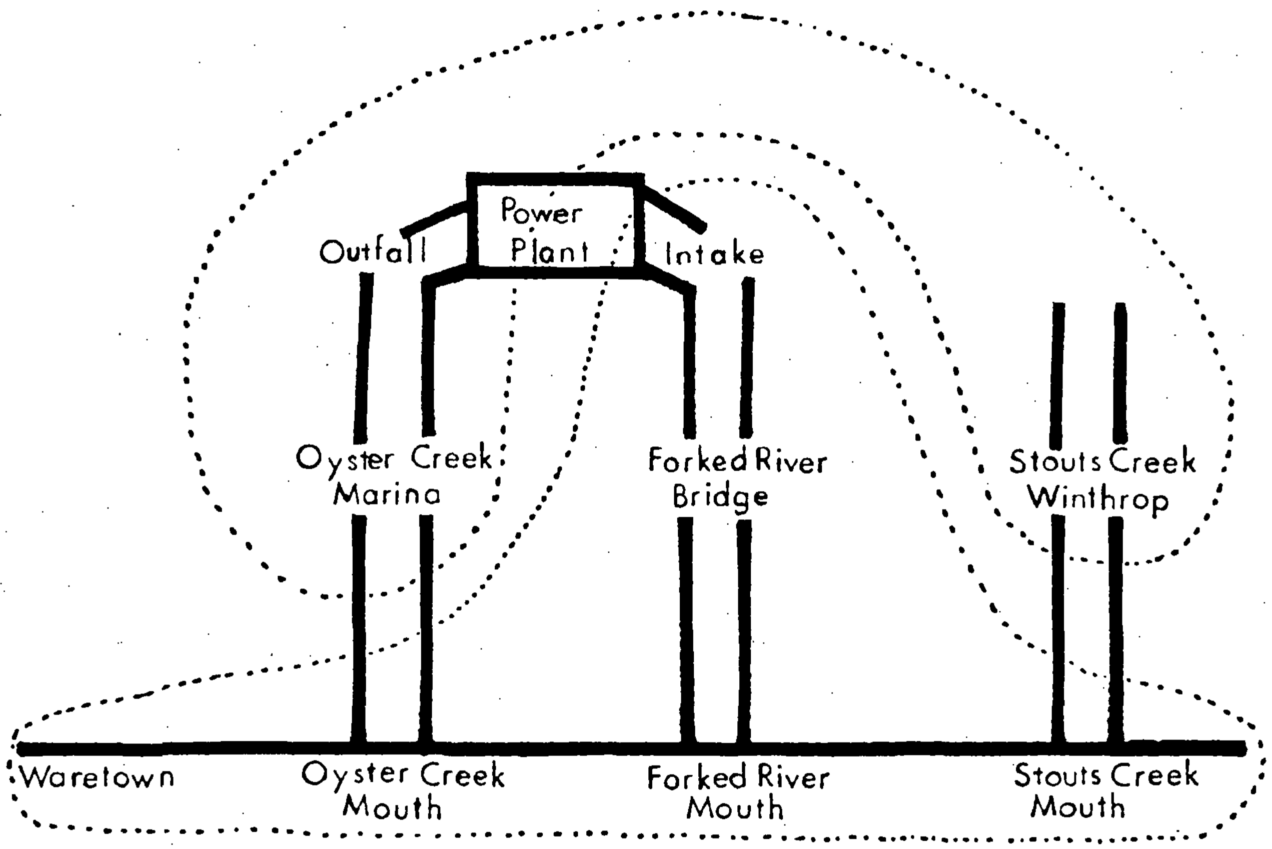

Power Plant
Outfall
Intake
Oyster Creek Marina
Forked River Bridge
Stouts Creek Winthrop
Waretown
Oyster Creek Mouth
Forked River Mouth
Stouts Creek Mouth

Figure I-9-B

Specifically:

$$H' = -p\ (i) \sum \log p\ (i)$$

where: $p\ (i) = n\ (i)\ /N$

$n\ (i)$ = the number of individuals of the "ith" species

N = the total number of individuals of all species.

Generally, the more species present in a sample, the higher the value of H'. For samples with a given number of species, however, when one species becomes proportionately more numerous than the other species, the value of H' decreases. H' is thus a function of the number of species and the evenness with which the total number of individuals is distributed among the species. If the number of species increases over time, but H' decreases, then it can be concluded that the number of individuals is being distributed more and more unevenly among the species. That is, one (or a few) species is becoming proportionately more and more dominant.

Figure I-10 (A-I) shows the number of species and the value of H' at each station for every time that station was sampled using one-month interval samples. The number of species which settled during a month reached its maximum at all stations around August. The number of species and the value of H' generally paralleled each other, with a few exceptions such as early June at Forked River Intake, when H' decreased while the number of species increased.

To evaluate the community properties responsible for a given value of H', an Evenness value (Pielou, 1966) can be calculated:

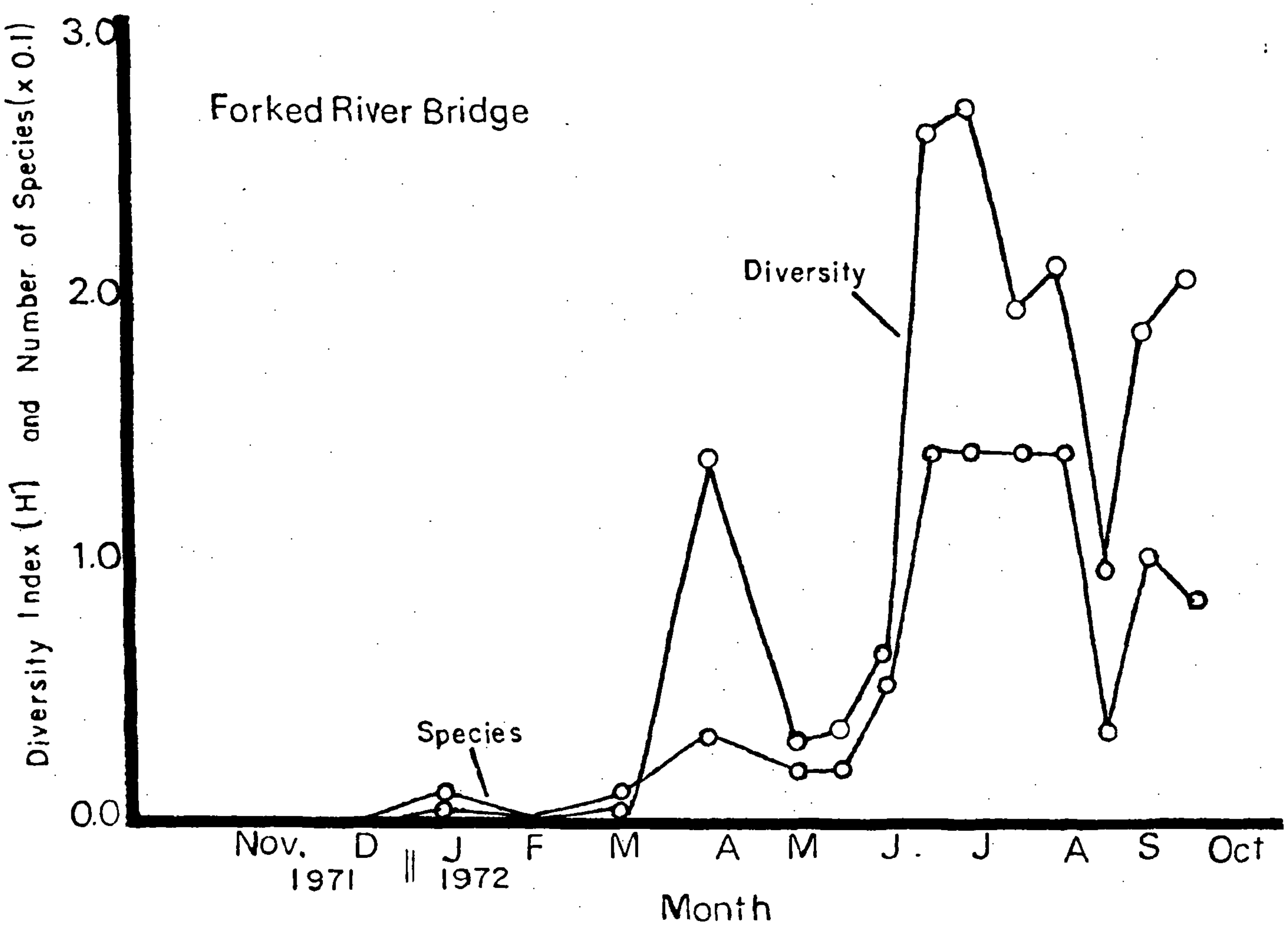
$$\text{Evenness} = H' / \log N.$$

Evenness represents the relative abundance of dominant species compared to non-dominant species. This indicates, in absolute terms, how close a sample is to maximun diversity. Maximum diversity occurs when the total number of individuals is distributed evenly among all the species. A low Evenness implies that a few species heavily dominate the sample.

It appears from Figure I-10 that stations may differ in mean number of species and in mean H' value. This was tested statistically by analysis of variance of the number of species, H', and Evenness were done using three different sets of data which covered the period from June through September, 1972, for the nine stations.

Figure I-11 (A-C) Shows the results of the analysis of variance calculations, with the least significant intervals (LSI) around the station means. There were significant ($p<0.05$) differences among stations in the number of species and in H' using all three data sets. There were significant differences among stations in Evenness using Data Sets A and B. Data Set C was not significant due to larger variance, but showed a similar pattern of mean station values. All three Oyster Creek stations and, for the most part, the Stouts Creek at Winthrop St. station, were low in number of species, H', and Evenness. The Forked River Intake station is high in number of species and in H', but low in Evenness.

Figure I-10-A: The Number of Species and H' for Each One-month Sample at Forked River Bridge.



Forked River Bridge
Diversity Index (H) and Number of Species (x 0.1)
3.0
2.0
1.0
0.0
Diversity
Species
Nov. 1971
D
J 1972
F
M
A
M
J.
J
A
S
Oct
Month

Figure I-10-A

Figure I-10-B: The number of Species and H' for Each One-month Sample at Forked River Intake.

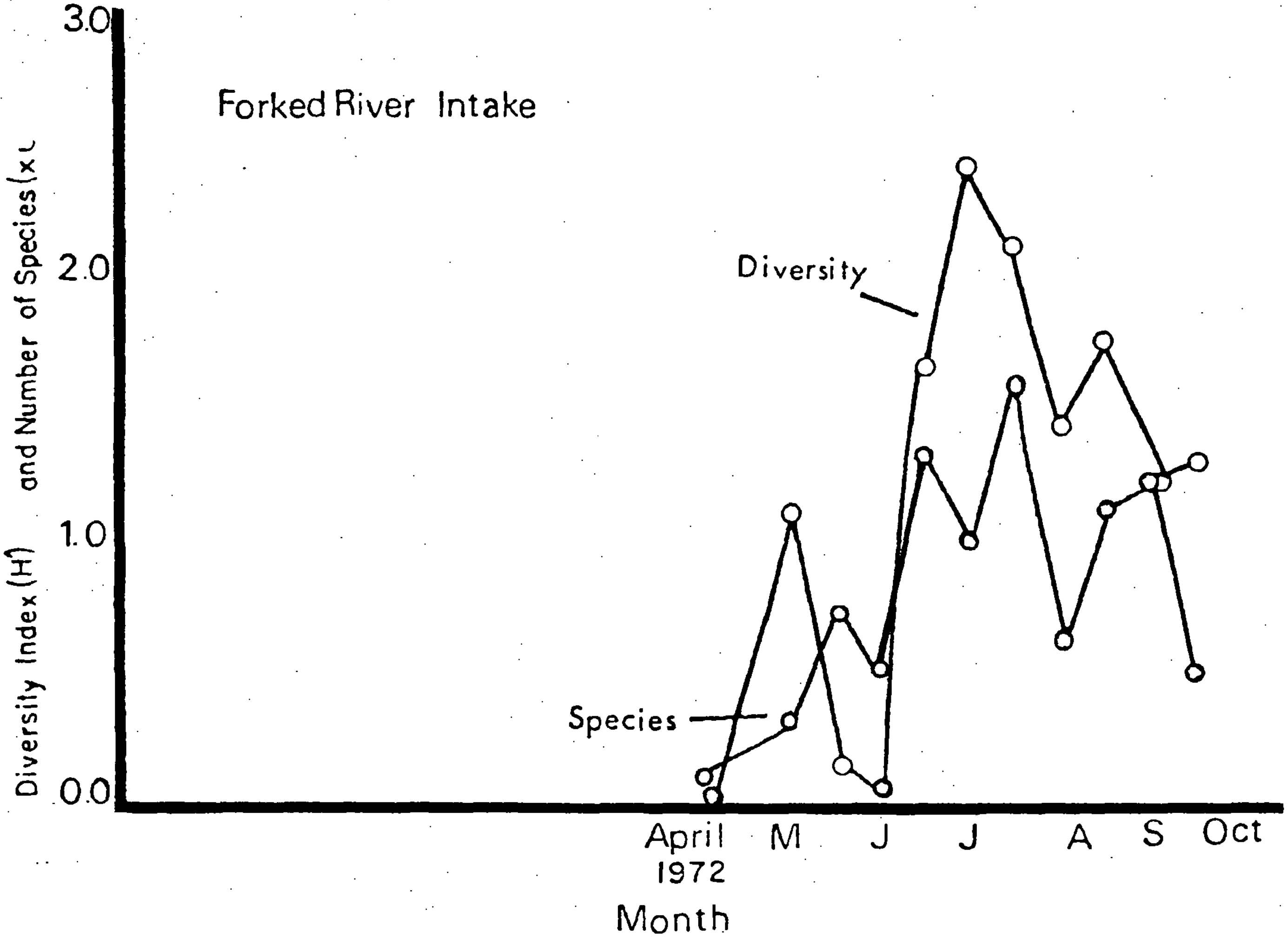

Forked River Intake
Diversity
Species
Diversity Index (H) and Number of Species (x
3.0
2.0
1.0
0.0
April 1972
M
J
J
A
S
Oct
Month

Figure I-10-B

Figure I-10-C: The Number of Species and H' for Each One-month Sample at Forked River Mouth.

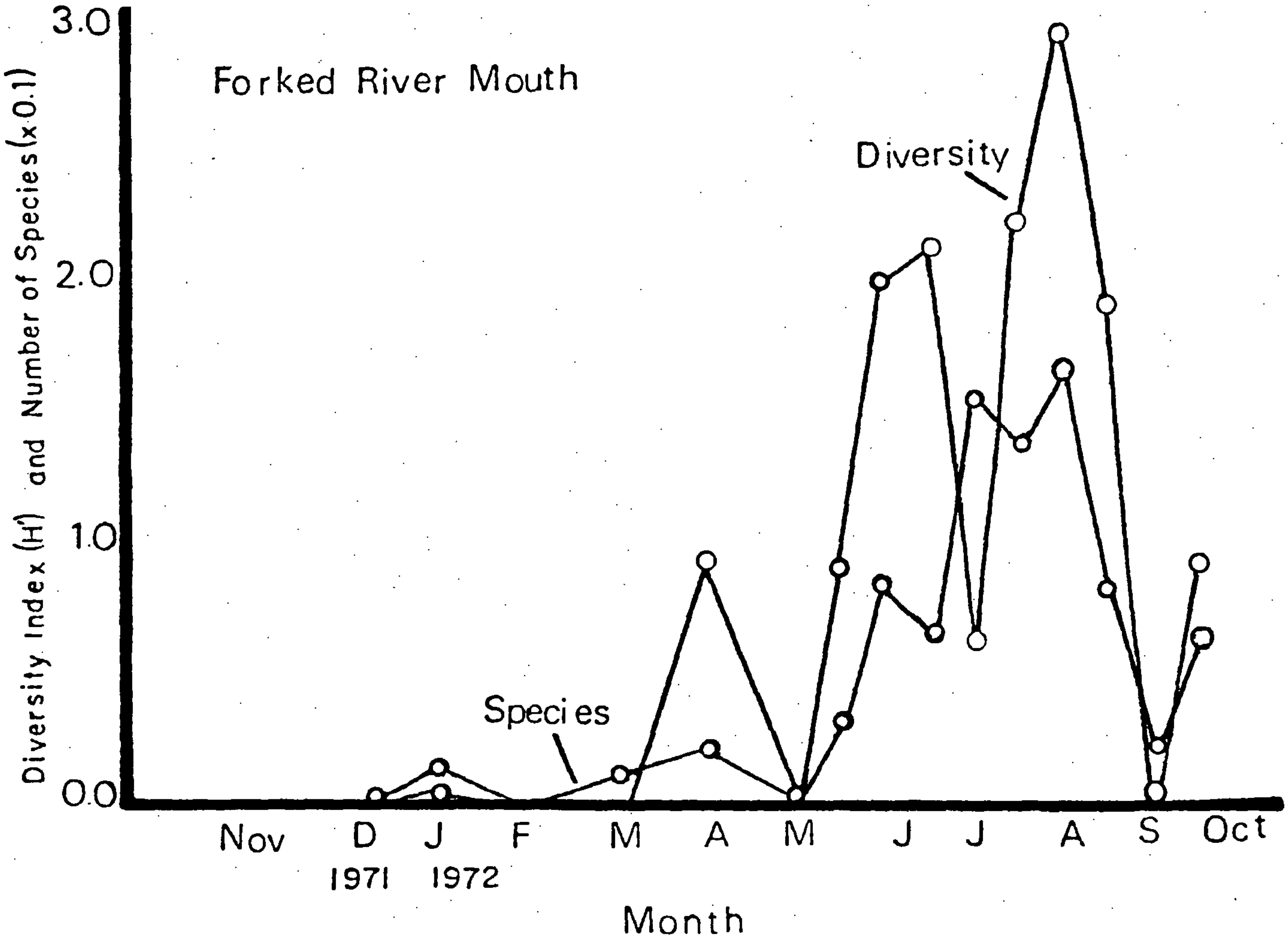
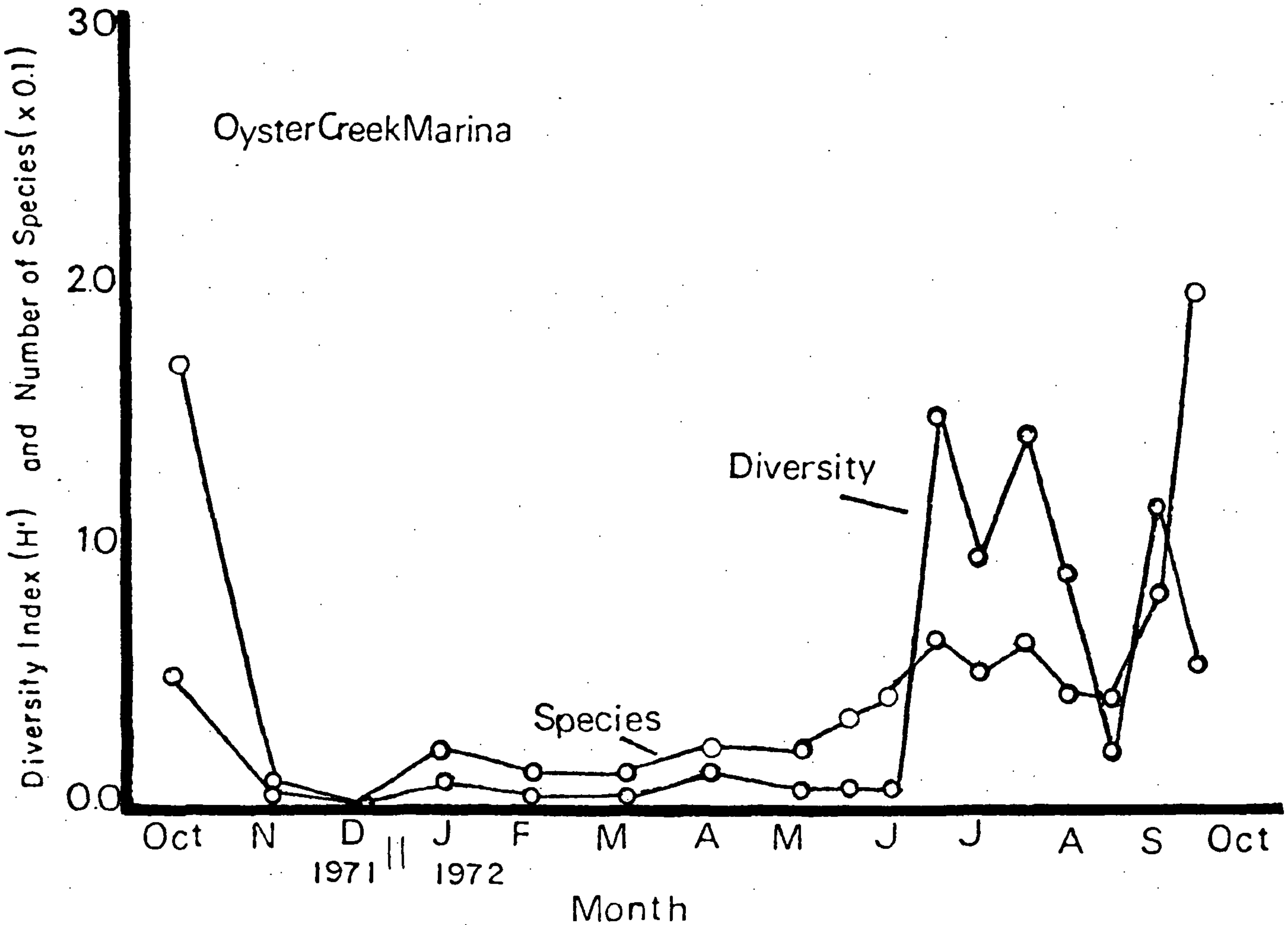

3.0
2.0
1.0
0.0
Forked River Mouth
Diversity
Species
Diversity Index (H') and Number of Species (x 0.1)
Nov
D
J
F
M
A
M
J
J
A
S
Oct
1971
1972
Month

Figure I-10-C

Figure I-10-D: The Number of Species and H' for Each One-month Sample at Oyster Creek Marina.



Oyster Creek Marina
Diversity Index (H') and Number of Species (x 0.1)
3.0
2.0
1.0
0.0
Diversity
Species
Oct
N
D
J
F
M
A
M
J
J
A
S
Oct
1971
1972
Month

Figure I-10-D

Figure I-10-E: The Number of Species and H' for Each One-month Sample at Oyster Creek Mouth.

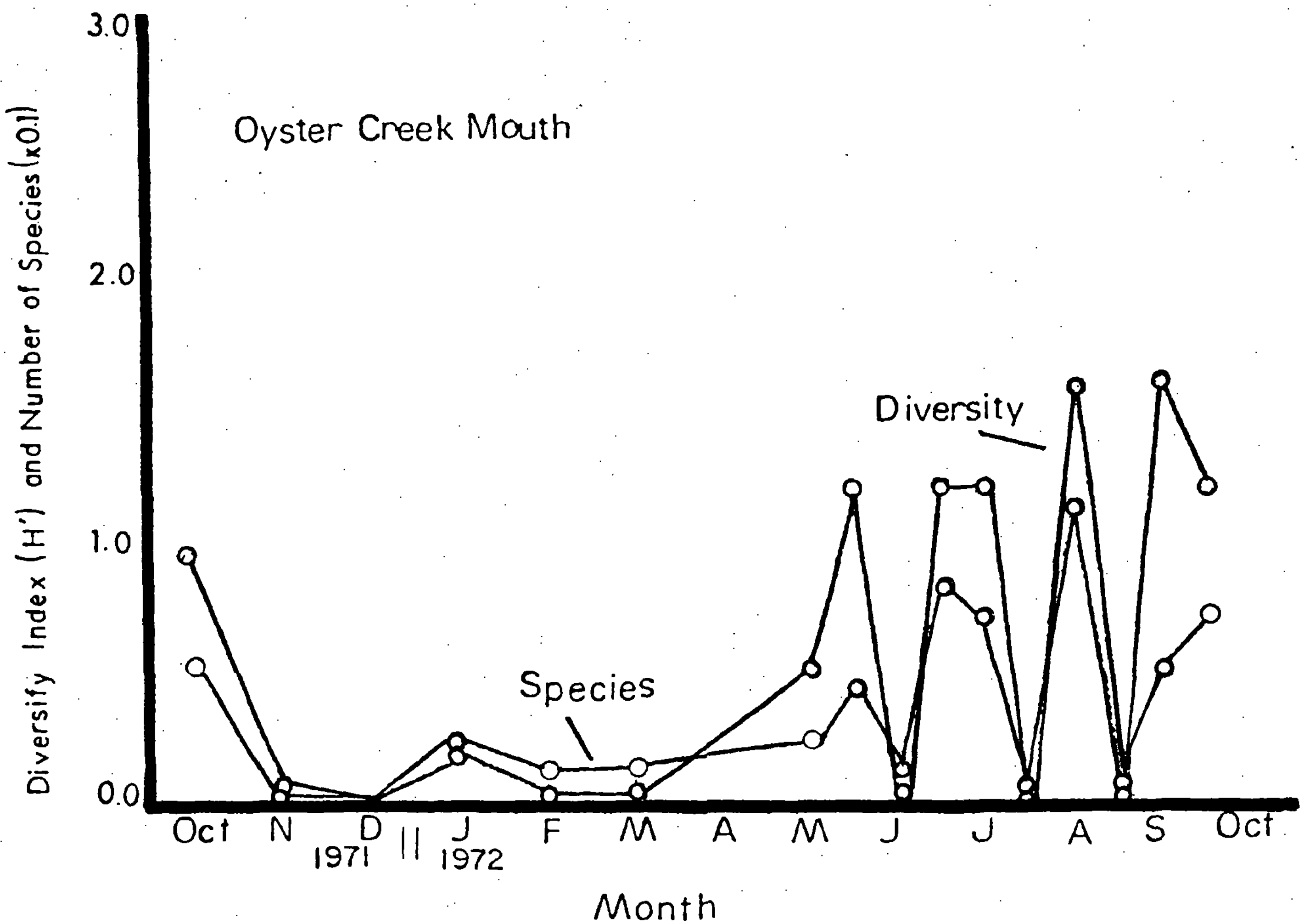

Oyster Creek Mouth
Diversity
Species
Diversity Index (H') and Number of Species (x0.1)
3.0
2.0
1.0
0.0
Oct
N
D
1971
J
1972
F
M
A
M
J
J
A
S
Oct
Month

Figure I-10-E

Figure I-10-F: The Number of Species and H' for Each One-month Sample at Oyster Creek Outfall.

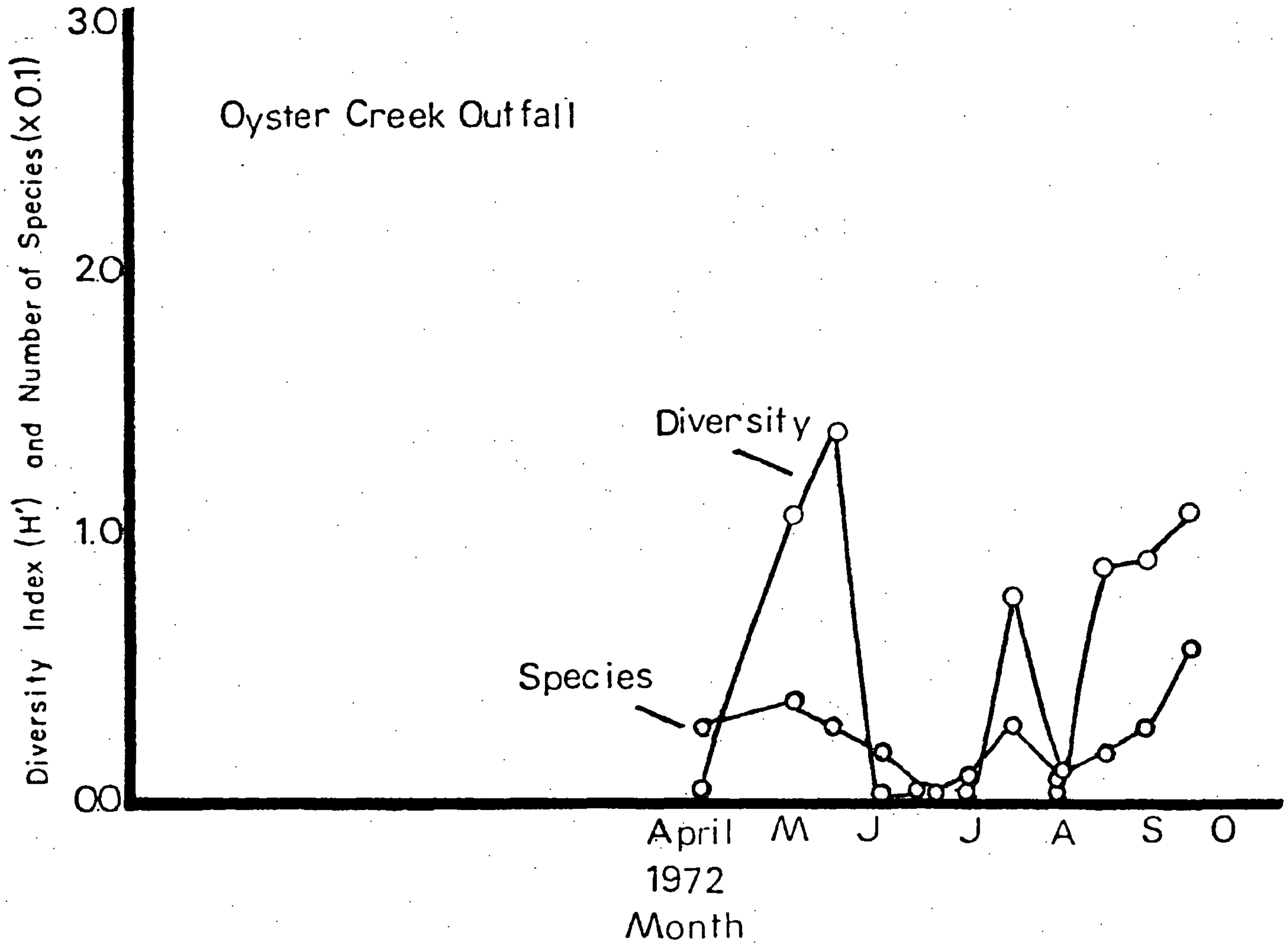

Oyster Creek Outfall
Diversity Index (H') and Number of Species (x 0.1)
3.0
2.0
1.0
0.0
Diversity
Species
April
M
J
J
A
S
O
1972
Month

Figure I-10-F

Figure I-10-G: The Number of Species and H' for Each One-month Sample at Stouts Creek Mouth.

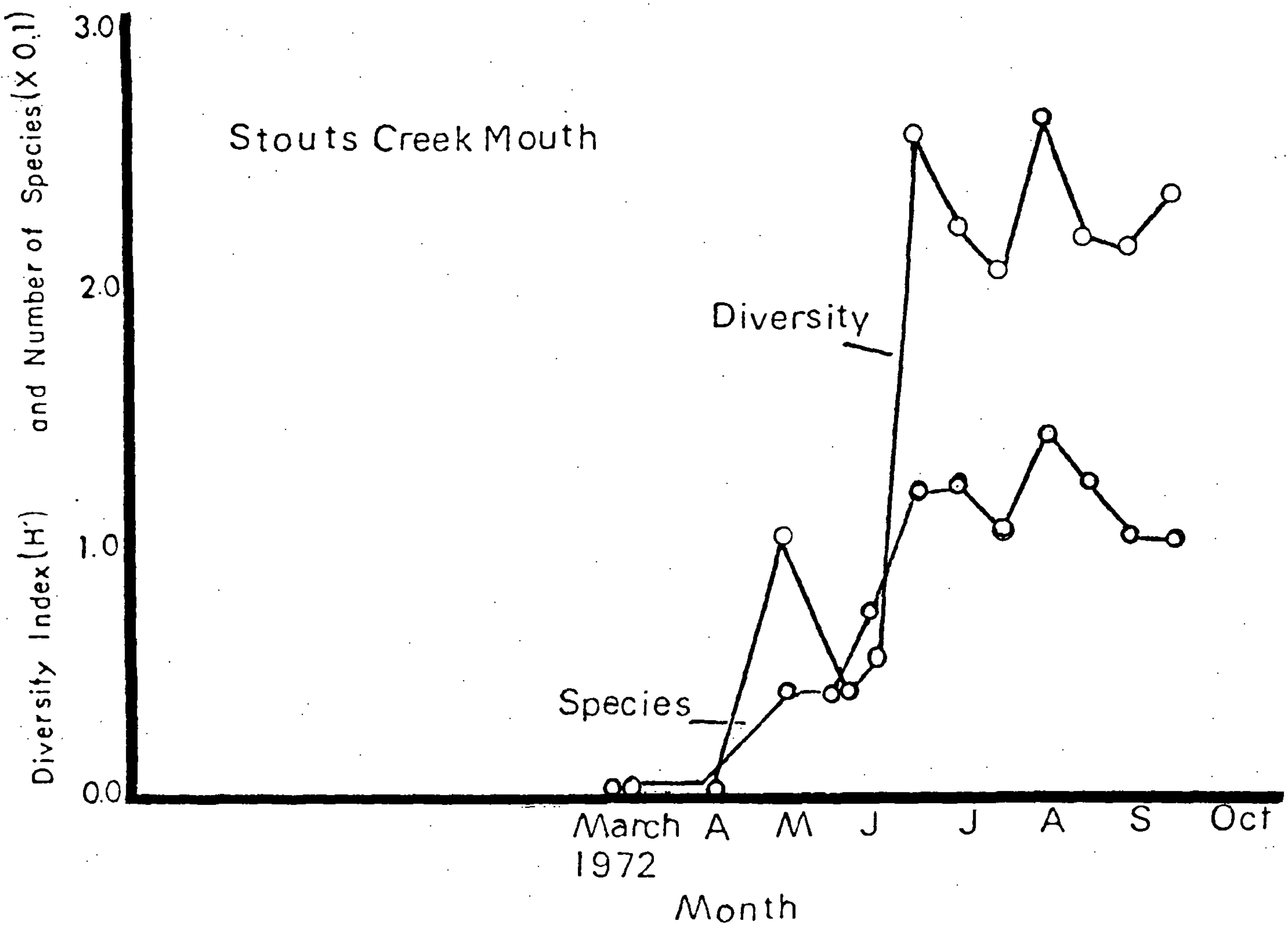

Stouts Creek Mouth
Diversity Index (H') and Number of Species (X 0.1)
3.0
2.0
1.0
0.0
Diversity
Species
March 1972
A
M
J
J
A
S
Oct
Month

Figure I-10-G

Figure I-10-H: The Number of Species and H' for Each One-month Sample at Stouts Creek, Winthrop St.

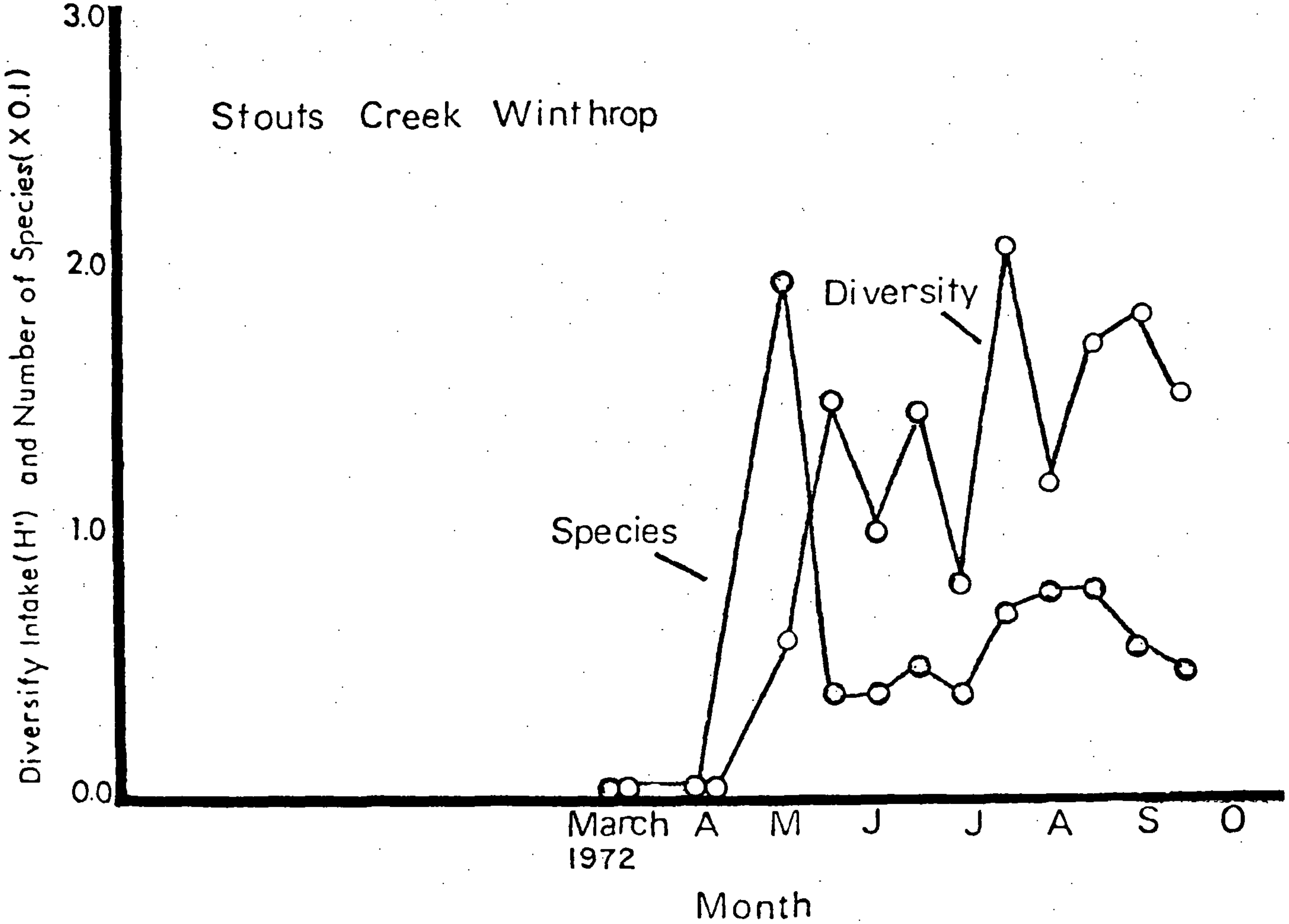

Stouts Creek Winthrop
Diversify Intake (H') and Number of Species (X 0.1)
3.0
2.0
1.0
0.0
Diversity
Species
March 1972
A
M
J
J
A
S
O
Month

Figure I-10-H

Figure I-10-I: The Number of Species and H' for Each One-month Sample at Waretown.

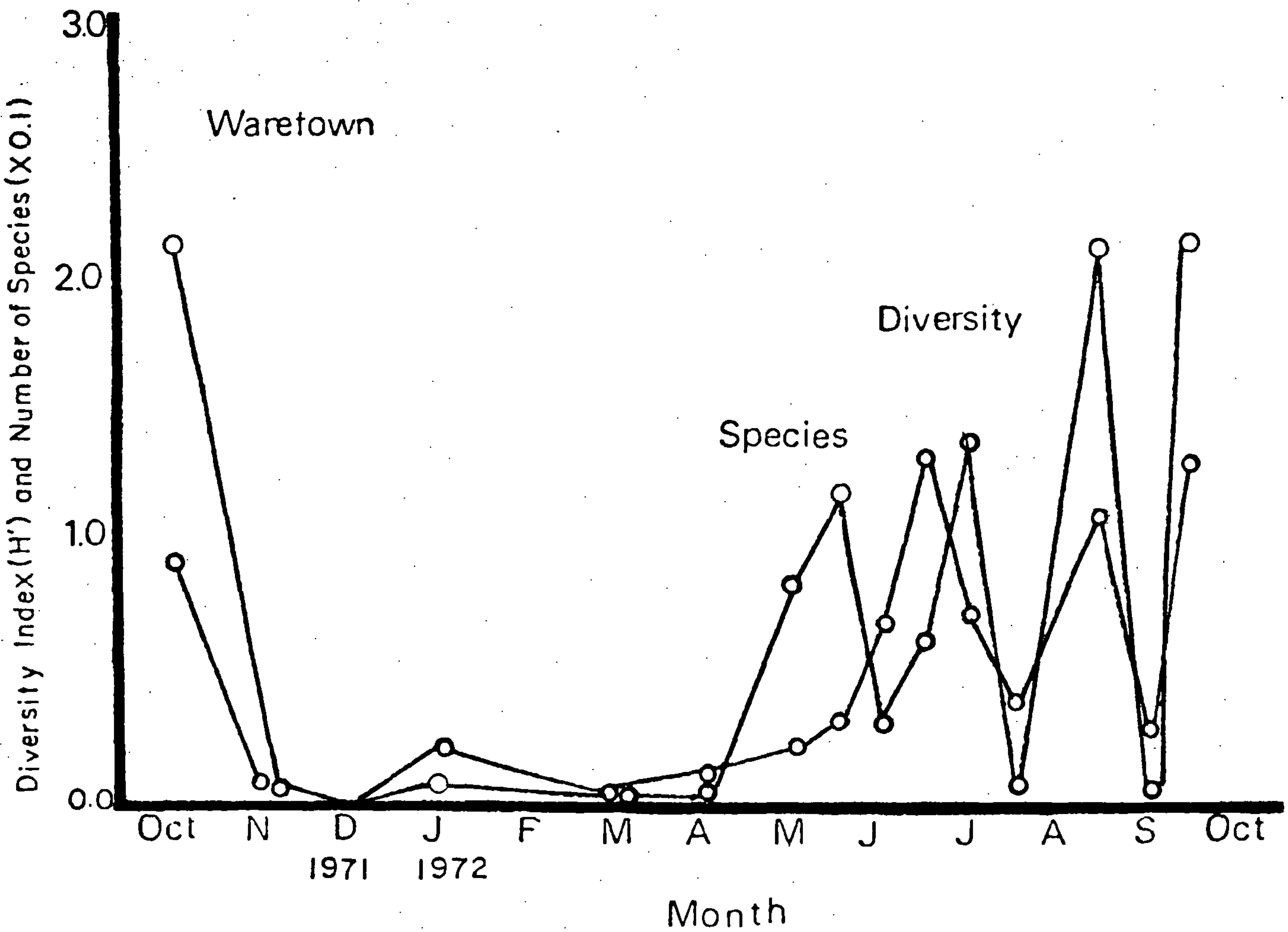

Waretown
Diversity
Species
3.0
2.0
1.0
0.0
Diversity Index (H') and Number of Species (X 0.1)
Oct
N
D
J
F
M
A
M
J
J
A
S
Oct
1971
1972
Month

Figure I-10-I

Figure I-11-A: Mean Diversity Index (H'), Number of Species, and Evenness at Each Station for Data Set A. Stations are WT = Waretown, OCM = Oyster Creek Mouth, OCMa= Oyster Creek Marina, FRM = Forked River Mouth, SCM = Stouts Creek Mouth, SCW = Stouts Creek Winthrop, IN = Forked River Intake, OUT = Oyster Creek Outfall.

A. Data Set A

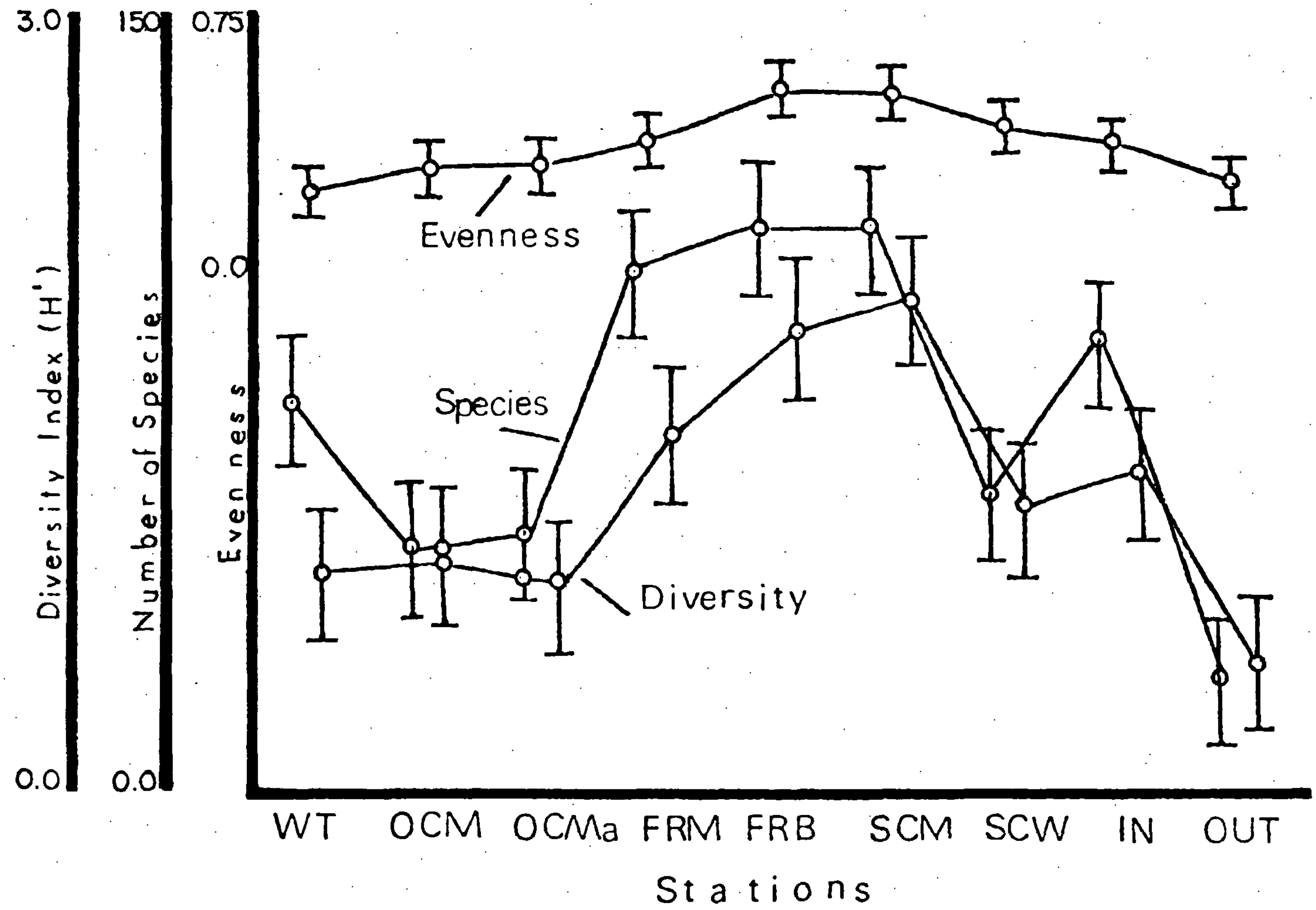


Figure I-11-A

Figure I-11-B: Mean Diversity Index (H'), Number of Species, and Evenness at Each Station for Data Set B. Stations are WT = Waretown, OCM = Oyster Creek Mouth, OCMa = Oyster Creek Marina, FRM = Forked River Mouth, SCM - Stouts Creek Mouth, FRB = Forked River Bridge, SCW = Stouts Creek Winthrop, IN = Forked River Intake, OUT = Oyster Creek Outfall.

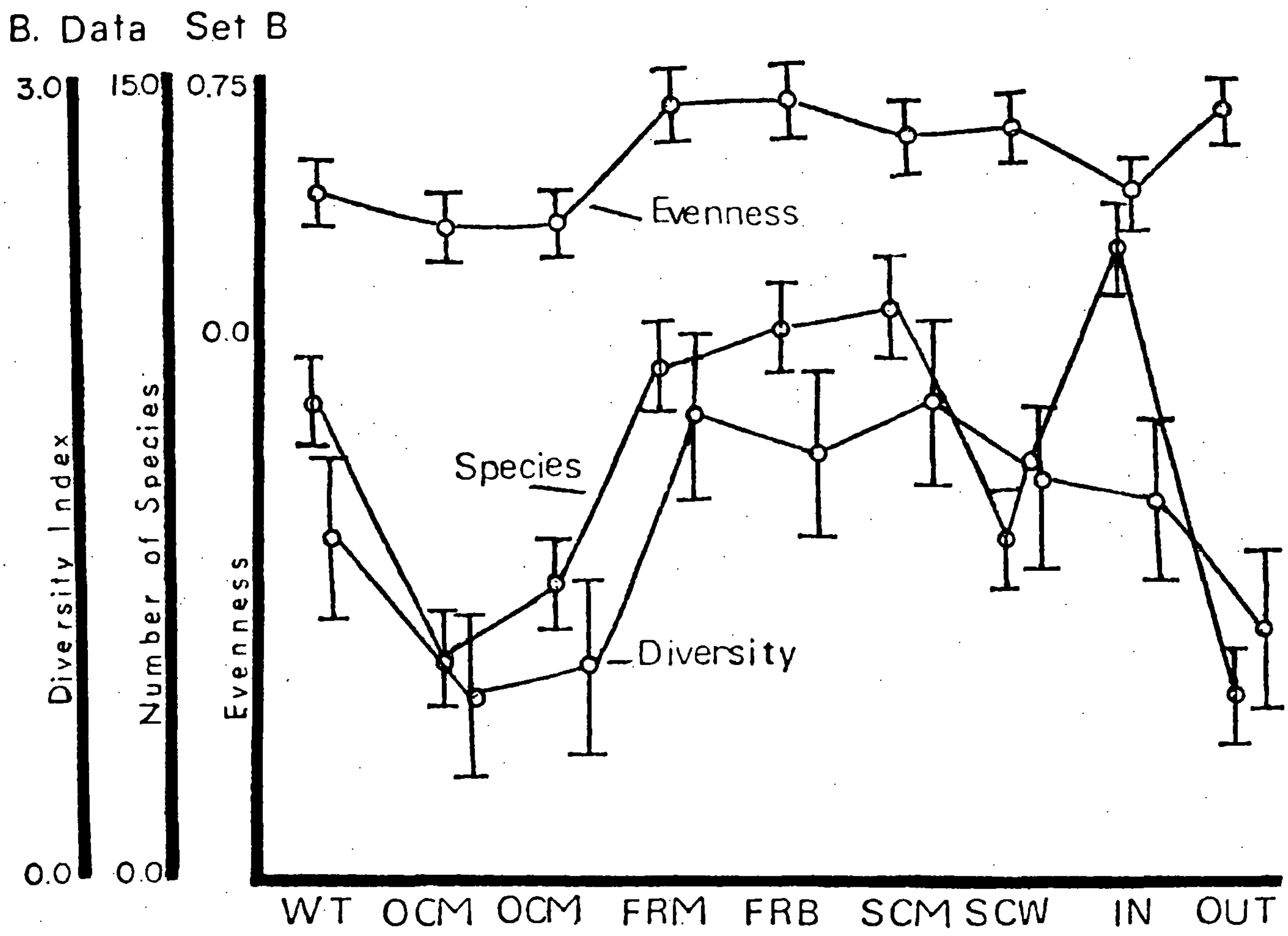

B. Data Set B
3.0
0.0
Diversity Index
15.0
0.0
Number of Species
0.75
0.0
Evenness
Evenness
Species
Diversity
WT
OCM
OCM
FRM
FRB
SCM
SCW
IN
OUT

Figure I-11-B

Figure I-11-C: Mean Diversity Index (H'), Number of Species, and Evenness at Each Station for Data Set C. Station are WT = Waretown, OCM = Oyster Creek Mouth, OCMa = Oyster Creek Marina, FRB = Forked River Bridge, FRM = Forked River Mouth, SCM = Stouts Creek Mouth, SCW = Stouts Creek Winthrop, IN = Forked River Intake, OUT = Oyster Creek Outfall.

C. Data Set C

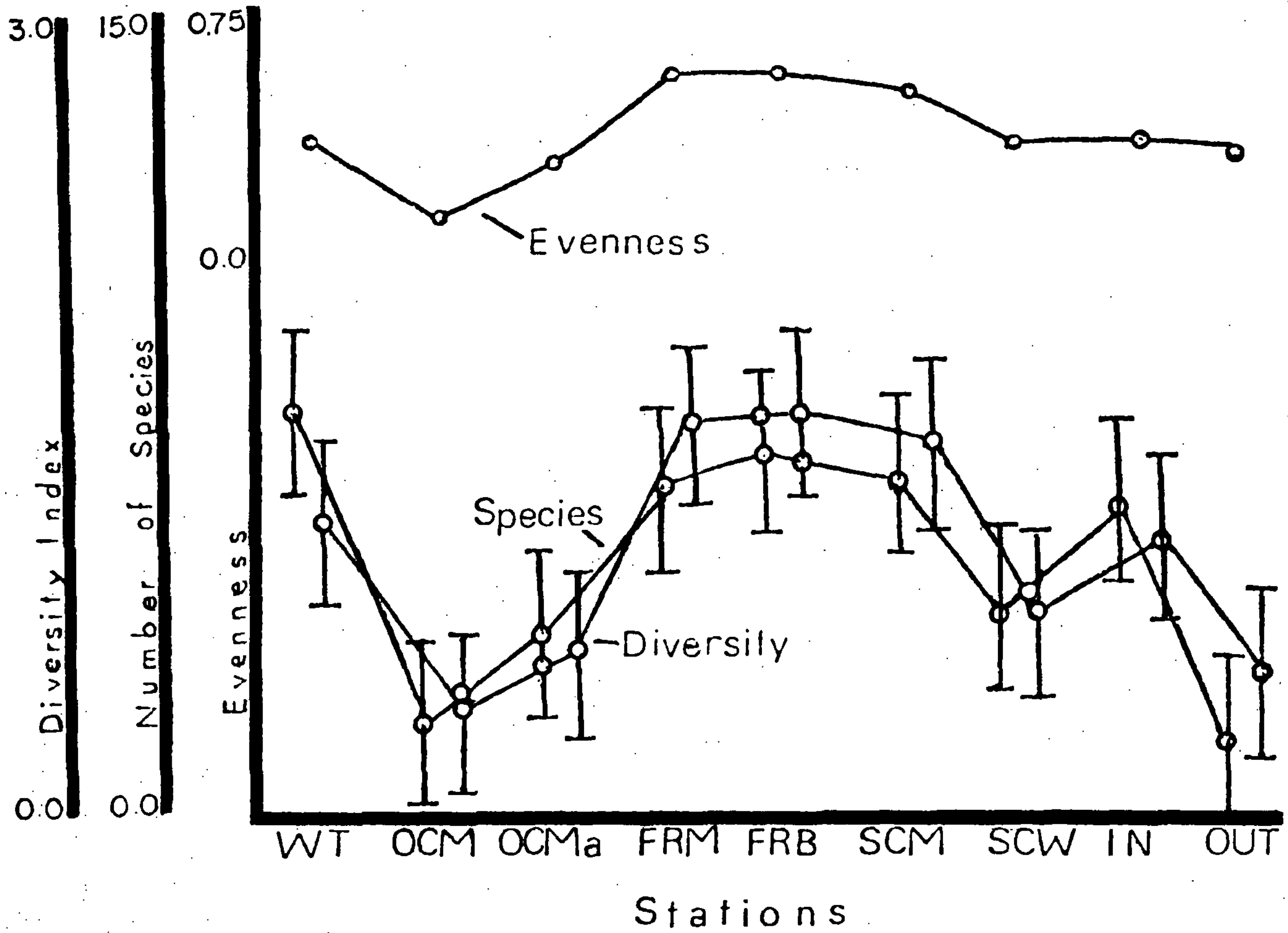


Figure I-11-C

IV. Discussion

Estuarine ecological studies generally assume that if all the hydrographic variables (salinity, temperature, dissolved oxygen pH, etc.) were precisely measured, the geographic distribution of any species could be theoretically understood (Kinne, 1967). Usually salinity is considered to be the most important variable (Moore, 1964). In the present study, several stations were significantly different with respect to mean salinity or mean temperature.

The three Oyster Creek stations were significantly higher in mean temperature than the other stations. Water from Forked River is used as a coolant for the nuclear power plant and is usually heated 10 - 12 C above the ambient temperature of Forked River water. Therefore, planktonic larvae are subjected to a sudden large heat shock. In the process of going through the coolant pipes, however, the larvae are also subjected to increased chlorinity (1 o/oo) and water turbulence. These factors could also affect larval survival or perhaps settling behavior. Thus differences among the settling communities at Oyster Creek stations and at Forked River stations may not be simply due to the higher temperatures in Oyster Creek, but may also be due to increased chlorinity and water turbulence.

Other studies of the effect of coolant water on invertebrate communities have shown that the use of water as a coolant did not necessarily decrease the number of individuals of a species which settled. A literature review is given by Coutant (1968), and a bibliography is given by Kennedy and Mihursky (1967). Naylor (1965) concluded that sublittoral species are less tolerant than littoral species to temperature increases of this nature. He noted, however, that several sublittoral species such as the tunicate *Botryllus schlosseri* have been observed to respond with a prolonged breeding season. The shipworm *Teredo navalis*, the barnacle *Elminius modesta*, and the mussel *Mytilus edulis*, all showed increased settling densities due to "slight heating" of the water at a power plant (Pannell, *et al*., 1962). It will be shown later, however, that coolant water in Oyster Creek does deleteriously affect the settling of many species.

The Stouts Creek stations had relatively low H' values and relatively few species. This may have been due to the significantly lower mean salinity at these two stations. The Stouts Creek stations are on dredged canals, as are the Forked River and Oyster Creek stations. The higher salinity bay water is not pumped into Stouts Creek as it is for the other creeks so that fresh water land drainage lowers the Stouts Creek salinity. Because the water is not pumped, Stouts Creek water is quieter and these two stations could also differ from the others in the amount of flushing by bay water, and thus perhaps differ in concentrations of pollutants. There are, however, fewer people living along Stouts Creek compared to the other creeks. Therefore the present study concludes that salinity was the important hydrographic variable for distinguishing Stouts Creek stations from the others.

Waretown and Forked River Mouth stations had relatively high numbers of species and H' values. This may have been due to the mean salinities at these stations which were higher than at other stations. Waretown had a relatively high mean salinity because it is the station that was nearest to the Barnegat Bay Inlet, which is the only passage from the bay into the ocean. The Waretown station and the Forked River Mouth station are exposed to the open bay where wave action can be heavy. Thus, differences between the settling community at these two stations and at the other stations may be due to this difference in wave action, as well as differences in salinity.

Kinne (1963) discussed general types of abiotic and biotic factors which determine distribution patterns of marine organisms. But he, like others (Moore, 1964) concluded that the abiotic are the more important, and that salinity first and then temperature are the most important factors in estuaries. Thus the field data on salinity and temperature tolerances of dominant species that are presented in this study should be useful in predicting where a species will be found. As is always the case with field work, it is difficult to test extremes of conditions and findings of this nature are not always conclusive.

For example, based on the results of several different studies, it is difficult to generalize about salinity tolerances of the shipworm, Bankia qouldi.Scheltema and Truitt (1954) studied the distribution of this species in Chesapeake Bay. They found that Bankia gouldi settled when temperatures were 19-20 C, and when mean salinity was as low as 9‰. Bankia gouldi which had been taken from Newport Estuary, North Carolina, released gametes into the water at temperatures of 17.5-30 C (salinity of 30‰), and larvae still developed at salinities of 10‰ (Culliney, 1970). The present study found that Bankia gouldi settled in Barnegat Bay at temperatures of 19.5-33.5 C and at salinities of 17.5 to at least 24‰.

Although the temperature ranges found in Scheltema and Truitt (1954), Culliney (1970) and the present study are all fairly similar, the salinity ranges are dissimilar. For example, the results from Scheltema and Truitt (1954) and Culliney (1970) suggest that Bankia gouldi should have been found at Stouts Creek at Winthrop St. That station had a low salinity compared to the other stations, but the mean salinity from March through September was 12‰, and salinity reached a high of 19.3‰. If Bankia gouldi does not settle at that station, then this must among the populations studied in Barnegat Bay, Chesapeake Bay and Newport Estuary.
If a species is tolerant to a relatively wide salinity range and a wide temperature range, compared to other species, then it would probably have a high sampling frequency for the whole bay and be one of the more dominant species in the general community. This was certainly true for Balanus eburneus which had the highest sampling frequency, the highest mean number of individuals per sample, and the widest salinity and temperature tolerances of any other species. Botryllus schlosseri had low salinity and low temperature ranges and, additionally, had a low sampling frequency.

These wide hydrographic tolerances, however, were not essential for dominance. Hydroides dianthus had the second highest mean number of individuals per sample. Many times its calcareous tubes completely covered boards and were stacked three or four deep after only a month.

Hydroides dianthus was clearly an important member of the Barnegat Bay fouling community, yet it had the smallest salinity range, a medium temperature range, and a medium sampling frequency. Similarly, Bankia gouldi had the third highest mean number of individuals per sample. It sometimes settled so heavily that after one month a board was almost disintegrating from the shipworms' burrows. Bankia gouldi was also an important species, yet its hydrographic tolerances were similar to those of Hydroides dianthus.

It is not possible, then, to relate consistently the hydrographic tolerances of each dominant species to its absolute dominance when dominance is based on summarized data for the whole bay (i.e., all nine stations). It seems probable though, that for each dominant species, the relative differences in the number of individuals which settled at the different stations, i.e., the species' settling profile, would show a relationship to the differences in hydrography at those stations.

Bankia gouldi and *Hydroides dianthus* had similar settling profiles. These species settled most heavily where the mean salinity was high, i.e., Waretown and Forked River Mouth. *Polydora ligni*, however, settled most heavily at the Stouts Creek stations, where the mean salinity was low, and at the Forked River Mouth station where mean salinity was relatively high. Thus, the settling profile of a given species cannot be fully explained in terms of the differences in mean salinity at the different stations.

Fortunately, the settling profile of a species could be analyzed independently of mean station salinity by means of cluster analysis. Cluster analysis helped to determine which species were most similar to each other with respect to their settling profiles.

The results of the cluster analysis indicate that there are three major groups of species. These three groups happen to coincide with species which grouped based on lower salinity tolerances and include: 1) those found settling only at salinities above 17.5‰ (*Hydroides dianthus* and *Bankia gouldi*); 2) those found settling only at salinities above 15‰ (*Molgula manhattensis*, *Botryllus schlosseri*, and *Corophium volutator*); and, 3) those found settling at salinities below 15‰ (*Balanus eburneus*, *Bowerbankia gracilis*, *Membranipora sp.*, *Polydora ligni* and *Melita nitida*). Thus there probably is a relationship between the salinity tolerances and the settling profile of a species although the direct relationship is not clear.

It seems reasonable, then, that once the range in salinity at a station is known, it should be possible to predict which of the dominant species will characterize that station. Identifying species by their settling profiles, however, does not necessarily give information as to the relative abundance of those species at a station (i.e., the community profile).

For example, Waretown and Forked River Mouth stations had similar community profiles; these stations had high salinities and were characterized by proportionately high numbers of *Hydroides dianthus* and *Bankia gouldi*. As discussed before, those species settled only at the higher salinities. Thus, in this case, similarity of community profile was related to mean station salinity and furthermore was related to the salinity tolerances of the most abundant species at those stations.

Oyster Creek Mouth and Forked River Intake had fairly similar community profiles. These stations had moderate mean salinity and temperature conditions. They were characterized by heavy *Bowerbankia gracilis* settling. As discussed earlier, *Bowerbankia gracilis* settled under a wide range of salinity and temperature conditions. Thus, in this case, station similarity can be related somewhat to hydrography, but the hydrographic tolerances of the most abundant species do not predict that that species will necessarily be important at these stations.

None of the other groupings of stations, based on similarity of community profiles, can be explained by a knowledge of the settling profiles or the hydrographic tolerances of the most abundant species. Thus, having autocological information that allows one to predict the relative importance of different environments to a species does not necessarily allow predictions of what the total community structure will be in relation to that species under given environmental conditions.

There appear to be some general principles describing the types of species which are to be found under low salinity or high temperature conditions. The stations with low mean salinity or high mean temperature represent extreme estuarine environments where only a few species were able to live. Most of the species that were present under these extremes were also found under more moderate conditions, but these species have a lift type that shields them from the adverse conditions. It is not at all clear why the species which were found at low salinities were also found at high temperatures. Apparently the species found under low salinity and high temperature conditions in Barnegat Bay have general hardiness to both extreme conditions.

Salinity tolerances of the dominant species indicate that there were fewer and fewer species that settled at lower and lower salinities. As Carriker (1967) pointed out, there is usually a decrease in numbers of species in the gradient from marine to freshwater. Thus the highest salinity station (Waretown) should have had more species than the lowest salinity station (Stouts Creek at Winthrop St.), with a gradient in between. This was true to some extent when data summarized the total community (i.e., all 39 species) for most of the settling season. The Oyster Creek stations, however, despite high mean salinities, had low total numbers of species; as previously discussed, this was probably an effect of the heated power plant effluent which is dumped into Oyster Creek.

The results of the hierarchical cluster analysis of station similarity based on the number of species in common during the settling season indicate that stations with low total numbers of species had similar species. And stations with high total numbers of species had similar species. The species that Stouts Creek Winthrop St. (low salinity), and Oyster Creek Marina and Oyster Creek Outfall (high temperature) had in common included Nereis succinea and six of the ten dominant species. Only seven of the twenty species which occurred at any of these three stations were classified as "mobile".

For the two stations with the highest total number of species, Forked River Mouth and Forked River Intake, 17 of the 33 species which occurred at either of the two stations were mobile species. The species that occurred at other stations but were never present at the three stations with low numbers of species (Stouts Creek Winthrop St., Oyster Creek Marina, and Oyster Creek Outfall) included nine species which are mobile, and four species which are non-mobile. Thus the additional species that appeared under moderate mean salinity and temperature conditions included a higher proportion of mobile species.

Kinne (1967) listed escape, reduction of contact with the environment, and physiological regulation (ion, volume or osmo-regulation) as mechanisms available to estuarine invertebrates for dealing with adverse salinity or temperature conditions. The species that are mobile can leave an area which has a low salinity or a high temperature. Species that live in tubes or in calcareous tests (e.g., Membranipora sp. and Balanus eburneus) can partially protect themselves from temporary low salinity. The few soft-bodies species that are present must be able to respond physiologically in order to tolerate low salinity. One of the seven mobile species found under adverse salinity conditions was Nereis succinea. It may be physiologically similar to Nereis diversicolor which is able to live under low salinity conditions by altering its volume (Kinne, 1967).

Thus in this study, the species found under adverse salinity or temperature conditions primarily included attached species with shells, tube-dwelling species, and only a few mobile species.

Evaluating changes in the community over time at each station can also yield information which relates the community structure to the hydrography of those stations. Changes that occurred in the relative dominance of certain species at certain stations are indicated by changes that occurred in the Diversity Index (H') at those stations. Changes in the Diversity Index at certain stations during the summer may have been due to a competition interaction of Hydroides dianthus with Balanus eburneus for settling space.

It is apparent that for the most part, changes in H' at different times reflected changes in the number of species at those times. The higher the number of species, the higher H'. There were specific instances at particular times and stations, however, when H' was affected by the settling rates of certain species. When these species reached their maxima in numbers settling, they also predominated in the community, thus lowering the H' at that time and station. Table I-4 gives stations and times when sudden decreases in H' of this nature took place; the table also gives the dominant species which simultaneously had reached their maximum in numbers settling at those stations.

From Table I-4, Balanus eburneus and Hydroides dianthus were the two species most commonly associated with drops in H'. These were also the species with the highest mean number of individuals settling per sample. At most stations, Balanus eburneus reached a maximum in monthly settling rate about six weeks before Hydroides dianthus reached its maximum. This relation also held when it was based on the monthly settling rates summed for all nine stations.

The decrease in Balanus eburneus during the summer months could have been due to the higher summer temperatures. Balanus eburneus, however, settled at extremely high temperatures (39.5 C). The Oyster Creek Outfall station had the second highest total number of individuals of Balanus eburneus, and that station also had the highest mean temperature. Therefore it seems unlikely that the reduction in the monthly settling rate of Balanus eburneus was caused solely by the higher summer temperatures.

The summer reduction in the monthly settling rate of Balanus eburneus could have been due to the presence of other species competing for settling space during those months. Balanus eburneus reached its minimum summer monthly settling rate in the bay when Hydroides dianthus reached its maximum. If Hydroides dianthus competed effectively against Balanus eburneus for space, then at those stations where Hydroides dianthus was prevented from settling due to low salinity, (e.g., Stouts Creek Winthrop St.), Balanus eburneus would increasingly dominate the community during the summer months and thus lower H'.

STATION	MONTH WHEN H' DECREASED WHILE NUMBER OF SPECIES INCREASED	DOMINANT SPECIES WHICH MAXIMIZED IN MONTHLY SETTLING RATE
Forked River Intake	early June	*Balanus eburneus* *Corophium volutator*
	July/August	*Hydroides dianthus*
Forked River Mouth	July	*Hydroides dianthus* *Membranipora sp.*
Forked River Bridge	July/August	*Polydora ligni* *Bankia gouldi*
Oyster Creek Marina	August/September	*Hydroides dianthus*
Stouts Creek Mouth	May/June	*Balanus eburneus* *Corophium volutator*
	July	*Hydroides dianthus* *Membranipora sp.*
Stouts Creek Winthrop St.	June	*Balanus eburneus*
	August	*Hydroides dianthus* *Melita nitida* *Bowerbankia gracilis*

TABLE I-4: Stations and times when species Diversity Index (H') decreased in value while the number of species increased in value. Also given are the dominant species which had reached their maximum monthly settling rates at those given stations and times.

At stations where salinity was more moderate, (e.g., Stouts Creek Mouth), both Hydroides dianthus and Balanus eburneus would have settled relatively heavily, and H' would have increased during the summer months because dominance would have been divided more evenly between two species. At stations where salinity was high, (e.g., Waretown), Hydroides dianthus would have settled heavily during the summer months, and H' would have dropped because the heavy settling of Hydroides dianthus would have inhibited the settling of Balanus eburneus.

These expectations are confirmed by the various observations on changes in the number of species and H' over time at each station, the settling profiles of the dominant species, the times of the maximum monthly settling rate of each dominant species at each station, and the monthly settling rates of each dominant species during the year for the whole bay. Hydroides dianthus may not have been the only species responsible for inhibiting the settling of Balanus eburneus during the summer, but because Hydroides dianthus was the second most important species in terms of mean number of individuals per sample, it was probably the most responsible. Therefore, the observed summer decrease in monthly settling rate of Balanus eburneus may have been due to a competition for settling space between Hydroides dianthus and Balanus eburneus.

Separate analyses of variance for number of species, H' and Evenness Index for each station over the summer months show that, for the most part, differences in the station means for H' reflect differences in the mean number of species. This indicates that the number of species which settled determined the diversity of the community, and presumably there was little change in community structure in terms of relative species dominance. Evenness also reflected H', however. Thus a high number of species was accompanied by a proportionately more even distribution of the number of individuals over all the species.

Forked River Intake was an exception to this general rule. Forked River Intake had a high number of species, hence a high H', but a fairly low Evenness. In this case, despite the high number of species, a few species occurred in such great numbers that they still heavily dominated the community. The community profile for Forked River Intake indicates that the high numbers of Bowerbankia gracilis which settled may have caused the low Evenness at that station.

Moskovitz (1971) analyzed benthic invertebrate species diversity in Barnegat Bay. The data used was for benthic species at stations comparable to the ones used in the present study, although Moskovitz's study did not include a Waretown station or a Stouts Creek at Winthrop St. station. Moskovitz's analysis showed that there was a low mean number of species, a low mean H', and a low mean Evenness at the Oyster Creek stations, and a high mean number of species, a high mean H', but a low mean Evenness at a Forked River (at Route 9) station. Dense populations of two dominant species, Mulinia lateralis and Pectinaria gouldii, were considered to be responsible for the low Evenness in Forked River. Forked River has a fairly fast current of bay water pumped through it. At Forked River Intake, the current increases as the water is channeled into intake pipes at the power plant. The fast current may be particularly conducive to survival or settling of just a few species, and these would then be excessively abundant at that station, as compared to the other Forked River stations. Thus in both studies, individuals of many species settled as they did at all Forked River stations, but a few species disproportionately benefited from the fast water current at the Forked River Intake station. This possible effect of water current was not quantified for this study. As the above suggests, though, a quantitative study of water currents may lead to predictive information on changes in community structure.

For the most part, those stations that were low in numbers of species also had a low diversity because of a high predominance of a few species, e.g., the Oyster Creek stations and to some extent Stouts Creek Winthrop St. station. This generalization concurs with the analysis of station similarity based on the species that any two stations had in common during most of the settling season. In that analysis, the Oyster Creek Marina, Oyster Creek Outfall, and Stouts Creek Winthrop St. stations all had low total numbers of species and clustered together based on species in common. Thus, again, community structure was similar and simplest (low numbers of species and heavy dominance of only a few species) under adverse environmental conditions. Bowerbankia gracilis and Balanus eburneus were especially abundant at these three stations. These two species predominated probably because other dominant species were unsuccessful under these adverse conditions, not necessarily because these conditions were conducive to these two species.

PART II: SPECIFIC COMMUNITY STRUCTURE

PATTERNS OF DIFFERENTIAL SETTLING OF DOMINANT SPECIES AS A FUNCTION OF DEPTH AND SURFACE ORIENTATION

I. Introduction

There is a wide variety of settling surfaces available to a member of the sublittoral wood boring and fouling invertebrate community. Depth and spatial orientation are important in defining the settling surfaces available. In the present study, the ten dominant invertebrate species of the wood boring and fouling community of Barnegat Bay, New Jersey, were examined for differences in the relative number of individuals which settled as a function of depth and/or spatial orientation of settling surfaces. If different species prove to have distinctive settling patterns, then those species may have species-specific mechanisms for maintaining their characteristic settling patterns.

These settling patterns are conceptually related to the notion of zonation, although zonation generally means segregation of populations along a single environmental gradient (Odum, 1971). For the present study, depth could be considered to be this type of gradient.

Most of the work done on marine zonation has been done on intertidal zonation. A zone is theoretically defined by the physical environment, but zones are often only identified by the organisms which characterize them (Moore, 1964). Using the latter characterization, there has been a considerable amount of work describing the intertidal community in terms of invertebrate and algal zonation (Hedgepeth, 1954; Moore, 1964).

The primary cause of intertidal zonation is considered to be the tide (Moore, 1964). Universal classification of zones is made possible by using Extreme High and Low Spring tides as reference points (Stephenson and Stephenson, 1933). Thus intertidal zones can be defined precisely using a physical gradient.

The association of a particular species with a particular zone has been explained in terms of the species' tolerance to submergence or desiccation. For example, Broekhuysen (1940) showed that differences among certain gastropod species in resistance to death from desiccation could account for the tidal levels at which they were found. For five out of six species, the lower the amount of body desiccation necessary to cause death in a species, the lower the tidal level at which that species was found. In the simplest form, a given species will be found in a zone which is perpendicular to wave and/or tidal action and limited in size by the amount of time that that area is submerged by water.

Another approach used to explain the zonation of an intertidal species is to determine where its planktonic form settles. It is generally accepted that planktonic larvae have some control over where they settle (Thorson, 1950). This control may depend on responses to changes in light, temperature, salinity, or substrate. Thus a zone can still be defined by physical gradients, but several parameters must be considered.

For example, the penetration of marine larvae into brackish water estuaries can be influenced by light: decreased light facilitates penetration (Friedrich, 1961). Thorson (1964) summarized studies of estuarine species and demonstrated that the photic responses characteristic of a species can determine where it will eventually settle. Most larvae are photopositive at first, probably to facilitate dispersal in the upper, faster water currents. Larvae need not remain photopositive, however, The barnacle _Balanus oburneus_ remains photopositive until it settles, at which time it becomes photonegative and begins crawling (McDougall, 1943). This larval behavior could place adults on shaded areas of objects that are near the water surface.

Temperature effects on general temporal and geographic locations of benthic organisms have been discussed by Kinne (1963, 1967), Naylor (1965), and Thorson (1950). Kinne (1963) suggested that changes in water viscosity due to changes in temperature could affect vertical distribution of planktonic larvae. This has implications for zonation of fouling organisms (e.g., along a very deep piling). There is some evidence that temperature affects photic responses of larvae. Ryland (1962) found that higher temperature accelerated the change from photopositive to photonegative behavior of the polyzoan _Cryptosula pallasiana_.

Kinne (1967) also discussed the effect of salinity on behavior of planktonic larvae. Salinity may affect zonation by influencing the photic responses of larvae. Haskin (1964) showed "that gradually increasing salinities will stimulate older stage larvae to swim and that with decreasing salinities the larvae tend to remain quiescent on the bottom. . . Light intensity and spectral quality are important in the behavior of the larvae."

Substrate selection during settling has been discussed by Crisp (1964). He suggested that chemicals dissolved in the water could play an important role in identifying a substrate for larvae. Larvae of the barnacle _Balanus balanoides_ settled most heavily where adults were already present (Grave and Nicholl, 1940). This settling preference occurred even if only remnants of adult shells were present. Since barnacle fertilization is internal, it is necessary that barnacles settle near each other for successful reproduction to take place. Zonation of a species of this type could be strongly influenced by the population's previous settling history.

In general, light is probably the most important physical variable influencing where larvae settle. Temperature and salinity are important in determining geographical distribution of estuarine species; they influence zonation, however, mainly through their effect on photic responses. Substrate sometimes can be as important as light, and within a given substrate, zonation of some gregarious species can be affected by the settling histories of the species.

Explaining intertidal zonation of a species in terms of adult desiccation resistance or larvael settling behavior probably requires analysis of each individual species (and possibly local populations) for these properties. This seems to be necessary if there is to be a precise explanation of why a given species is found in a given zone.

The purpose of the present study is to determine if species of the sublittoral wood settling community have characteristic settling zones as defined by both the depth and the spatial orientation of the settling surface. The sampling technique used in this study provided a total of six positions on wood blocks from which a given larva could "choose" to settle on one. The positions included upper (horizontal), side (vertical), and lower (horizontal) surfaces of two boards which were placed at different depths. If a given species appears to have any "preferences" for certain positions, this is evaluated in terms of any similarity of that species' preferences to those of other species, and in terms of the known species biology and larval behaviors.

II. Materials and Methods

Study area, sampling materials, and collection of hydrographic data were as per PART I. Sampling time for this study includes all collection times from July 19, 1972, through October 15, 1972. All boards were analyzed on every surface. These surface analyses included the species present and the number of individuals of each species.

Analysis of variance was performed by means of "A multi-purpose analysis of variance Fortran IV computer program" (Butler, Kamlet and Ponty, 1969).

III. Results

The dominant invertebrate species differed from one another in their settling patterns, i.e., relative numbers of individuals which settled at each depth and spatial orientation of the settling surface. The characteristic settling pattern of a species remained fairly constant over time and station, with some exceptions which are discussed below. (Dominant species used in this study were selected as described in Results, PART I.)

All of the data collected from mid-June through mid-October, 1972, are summarized in Table II-1. The table gives the number of individuals and the percentage of the total number of individuals of a species which settled on any given position, i.e., depth and surface orientation. These values have been corrected for differences in the area available on each settling surface.

An analysis of variance was used to determine the significance of settling patterns for depth and surface orientation, and also to test the consistency of these patterns over time and stations.

Because of the sampling strategy used, available data could be arranged three different ways while still obtaining an estimate of sampling variance within a month's time. The settling pattern of each species is analyzed three times, using the three different data sets. For two of the data sets, sampling variance within a month was determined by adding consecutive two-week samples and considering that sum to be an independent replicate of the parallel one-month sample.

It is possible that sampling over a one-month period could have a positive (e.g., gregarious settling) or negative (e.g., crowding) effect on the settling of animals as the community builds up. Therefore, t-tests were used to compare the means and variances of one-month data with added two-week data for all of the dominant species. There were no significant differences between the sets of data for any of the species. Thus, the summed two-week sets can be considered as replicates of the one-month sets.

For each of the nine dominant species, the three different data sets were analyzed in a four-way factorial analysis of variance design. The four factors were Station, Time, Depth, and Surface Orientation. Since the sampling unit was a single board, Surface Orientation was treated as a within-units factor. The results of the analysis of variance, summarized in Table II-2, indicate that the effects related to settling patterns which are discussed below were significant at $p < 0.05$.

Balanus eburneus settled most heavily on the top board rather than the bottom board, and on the lower surface rather than the upper or

SPECIES	TOTAL SAMPLE SIZE (No. of Individuals)	POSITION--DEPTH and SURFACE (% Total Number Settled)						DEPTH (% Settled)		SURFACE (% Settled)		
		Top Board			Bottom Board							
		Upper	Side	Lower	Upper	Side	Lower	Top	Bottom	Upper	Side	Lower
Balanus eburneus	16,055	9	20	26	8	17	21	55	45	17	47	37
Bankia gouldi	5,990	6	9	14	21	17	33	29	71	27	26	47
Botryllus schlosseri	1,011	0.1	13	26	4	32	26	39	61	4	45	52
Bowerbankia gracilis	11,843	17	14	21	17	13	18	52	48	34	27	39
Corophium volutator	70	29	3	4	37	14	13	36	64	66	17	17
Melita nitida	904	21	6	17	34	11	12	44	56	54	17	29
Hydroides dianthus	34,913	2	5	32	3	15	44	39	61	5	20	76
Membranipora sp.	3,025	14	16	25	11	14	20	55	45	25	30	45
Molgula manhattensis	2,308	6	3	28	4	35	25	37	63	10	38	53
Polydora ligni	2,082	20	6	8	44	9	14	34	66	64	15	22

TABLE II-1: Percent of Total Number of Individuals which settled on each Position, Board Depth, and Board Surface, for each Dominant Species

SPECIES	DATA SET	DEPTH F	DEPTH d.f.	DEPTH p<	SURFACE F	SURFACE d.f.	SURFACE p<	DEPTH X SURFACE F	DEPTH X SURFACE d.f.	DEPTH X SURFACE p<	TIME X SURFACE F	TIME X SURFACE d.f.	TIME X SURFACE p<	STATION X SURFACE F	STATION X SURFACE d.f.	STATION X SURFACE p<
Balanus	A	1.307	1,48	n.s.	20.306	2,96	.001	1.242	2,96	n.s.	5.202	4,96	.001	3.007	14,96	.005
eburnous	B	0.296	1,32	n.s.	17.449	2,64	.001	0.583	2,64	n.s.	9.069	2,64	.001	2.063	14,64	.05
	C	0.465	1,48	n.s.	9.718	2,96	.001	2.052	2,96	n.s.	2.168	4,96	n.s	0.875	14,96	n.s.
Bankia	A	3.071	1,48	n.s.	13.298	2,96	.001	0.949	2,96	n.s.	12.935	4,96	.001	4.894	14,96	.001
gouldi	B	8.139	1,32	.01	2.478	2,64	n.s.	0.523	2,64	n.s.	2.465	2,64	n.s.	1.713	14,64	n.s.
	C	2.183	1,48	n.s.	4.039	2,96	.025	0.615	2,96	n.s.	3.861	4,96	.01	1.752	14,96	n.s.
Botryllus	A	1.629	1.48	n.s.	5.225	2,96	.01	0.700	2,96	n.s.	3.535	4,96	.025	4.385	14.96	.001
schlosseri	B	0.636	1.32	n.s.	3.373	2,64	.05	0.370	2,64	n.s.	3.373	2,64	.05	2.427	14.64	.01
	C	0.833	1.48	n.s.	4.954	2,96	.01	0.066	2,96	n.s.	4.577	4,96	.005	4.649	14.96	.001
Bowsrbankia	A	0.025	1,54	n.s.	15.345	2,108	.001	1.131	2,108	n.s.	0.349	4,108	n.s.	1.933	16,108	n.s.
gracilis	B	1.843	1,36	n.s.	9.588	2,72	.001	1.059	2,72	n.s.	0.658	2,72	n.s.	1.262	16,72	n.s.
	C	1.843	1,54	n.s.	6.958	2,108	.003	0.227	2,108	n.s.	0.248	4,108	n.s.	0.954	16,108	n.s.
Melita	A	1.066	1,48	n.s.	2.147	2,96	n.s.	3.540	2,96	.05	0.798	4,96	n.s.	0.426	14,96	n.s.
nitida	B	1.511	1,32	n.s.	3.103	2,64	.05	2.174	2,64	n.s.	2.067	2,64	n.s.	1.241	14,64	n.s.
	C	0.999	1,48	n.s.	2.860	2,96	n.s.	2.240	2,96	n.s.	2.339	4,96	n.s.	1.072	14,96	n.s.
Hydroides	A	0.412	1,48	n.s.	2.213	2,96	n.s.	0.310	2,96	n.s.	2.066	4,96	n.s.	0.959	14.96	n.s.
dianthus	B	0.842	1,32	n.s.	1.189	2,64	n.s.	0.857	2,64	n.s.	0.875	2,64	n.s.	1.026	14.64	n.s.
	C	2.237	1,48	n.s.	4.734	2,96	.025	2.091	2,96	n.s.	1.534	4,96	n.s.	1.811	14.64	n.s.
Membranipora	A	0.399	1,48	n.s.	6.811	2,96	.005	0.391	2,96	n.s.	3.286	4,96	.025	1.426	14,96	n.s.
sp.	B	0.128	1,32	n.s.	5.351	2,64	.01	1.135	2,64	n.s.	1.516	2,64	n.s.	0.893	14,64	n.s.
	C	0.039	1,48	n.s.	5.744	2,96	.001	1.173	2,96	n.s.	3.168	4,96	.025	0.822	14,96	n.s.
Molgula	A	0.270	1,48	n.s.	0.796	2,96	n.s.	0.902	2,96	n.s.	1.896	4,96	n.s.	1.519	14,96	n.s.
manhattensis	B	0.003	1,32	n.s.	2.484	2,64	n.s.	0.159	2,64	n.s.	0.330	2,64	n.s.	1.445	14,64	n.s.
	C	0.018	1,48	n.s.	5.065	2,96	.01	0.173	2,96	n.s.	1.613	4,96	n.s.	1.498	14,96	n.s.
Polydora	A	4.097	1,48	.05	8.871	2,96	.001	1.536	2,96	n.s.	2.579	4,96	.05	3.646	14,96	.001
ligni	B	2.359	1,32	n.s.	6.829	2,64	.005	1.898	2,64	n.s.	1.069	2,64	n.s.	2.082	14,64	.05
	C	1.496	1,48	n.s.	5.505	2,96	.01	1.308	2,96	n.s.	1.669	4,96	n.s.	2.114	14,96	.05

TABLE II-2: Brief Summary of Major Analysis of Variance Results for Time, Station, Depth and Surface on Number of Individuals of each Dominant Species using Three Different Data Sets. ("n.s." means "not significant" at p<o0.05.)

side surfaces. Table II-1 shows that 55% of the total number which settled were on the top board; 47% of the total number which settled were on the lower surface. The four most heavily settled positions were ranked as follows in terms of total numbers of individuals settling: lower surface, top board; lower surface, bottom board; side surface, top board; side surface, bottom board. Analysis of variance results are summarized in Table II-2 and Figure II-1 (A-C). There is no significant depth effect. There is a significant surface effect in all three data sets. For Data Sets A and C, the lower surface is significantly higher than the upper or side surfaces (Figure II-1-A(1,3)). For Data Set B, the lower surface is significantly higher than the upper surface (Figure II-1-A(2)). trend of decreasing numbers from lower to side to upper surfaces is also indicated in Data Sets A and C. Al-1 three data sets show a significant interaction effect of time with surface which appears to be due to relatively heavy settling of Balanus eburneus on the side surfaces at Stouts Creek at Winthrop St. (Figure II-1-A(1-3)).

Bankia gouldi settled most heavily on the bottom board and on the lower surface. Table II-1 shows that 71% of the total number were on the bottom board; 47% of the total were on the lower surface. The three most heavily settled positions were ranked as follows: lower surface, bottom board; side surface, bottom board; upper surface, bottom board. Analysis of variance results are summarized in Table II-2 and Figure II-2 (A-C). Although mean values were consistently higher for the bottom board than for the top board, only Data Set B showed a statistically significant depth effect. This data set included only those time periods when Bankia gouldi was actually settling at most stations (late July through early September), whereas Data Sets A and C included early July and late September, when settling of Bankia gouldi was often low or non-existent. Thus the failure to get a significant depth effect with Data Sets A and C may have been due to high sample variance in those two sets. Surface effect was significant in Data Sets A and C, though, with highest numbers on the lower surface of the bottom board. It is not clear why surface effect was not significant using Data Set B. Significant interaction effects of time with surface which appeared from Data Sets A and C are, again, probably due to very high sample variance; as shown in the graphs, there were very low numbers which settled in late September. The significant interaction of station and surface was probably due to the relatively high numbers which settled on the upper surface at Forked River Bridge.

Figure II-1-A: Mean Number of Individual of _Balanus eburneus_ Which Settled for Each Surface Orientation (Upper, Side, or Lower) at Each Depth (Top or Bottom). Least significant intervals for Surface Orientation are given (if $p < 0.05$) from analysis of variance of (1) Data Set A, (2) Data Set B, (3) Data Set C.

A. <u>Balanus</u> <u>eburneus</u>: Depth x Surface Orientation

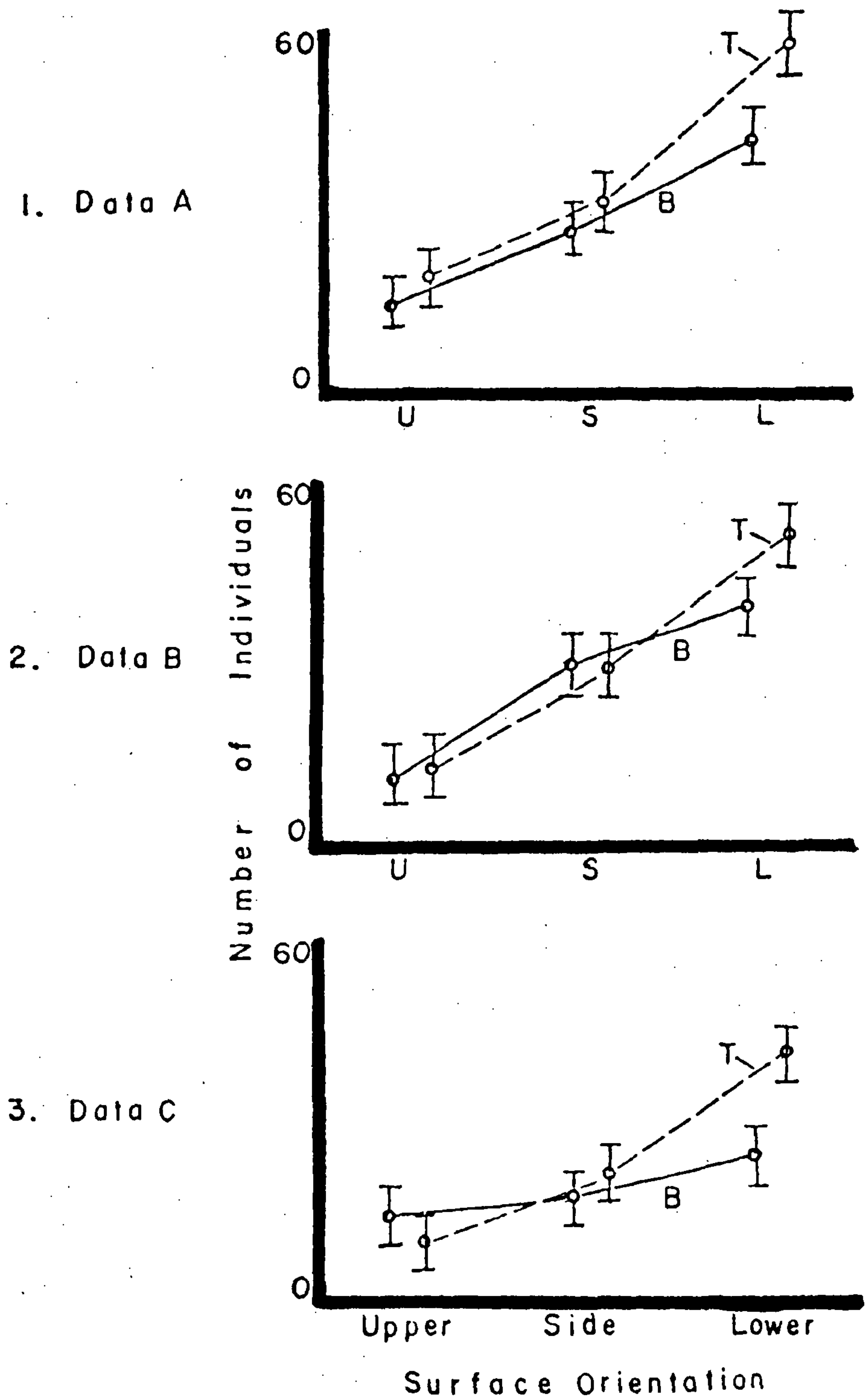


Figure I-1-A

Figure II-1-B: Mean (as generated from analysis of variance) Number of Individuals of <u>Balanus eburneus</u> Which Settled for Each Surface Orientation (Upper, Lower, or Side) during Each Month (July, August, or September) for (1) Data Set A, (2) Data Set B, (3) Data Set C are given.

B. Balanus eburneus: Month X Surface Orientation

1. Data A

2. Data B

3. Data C

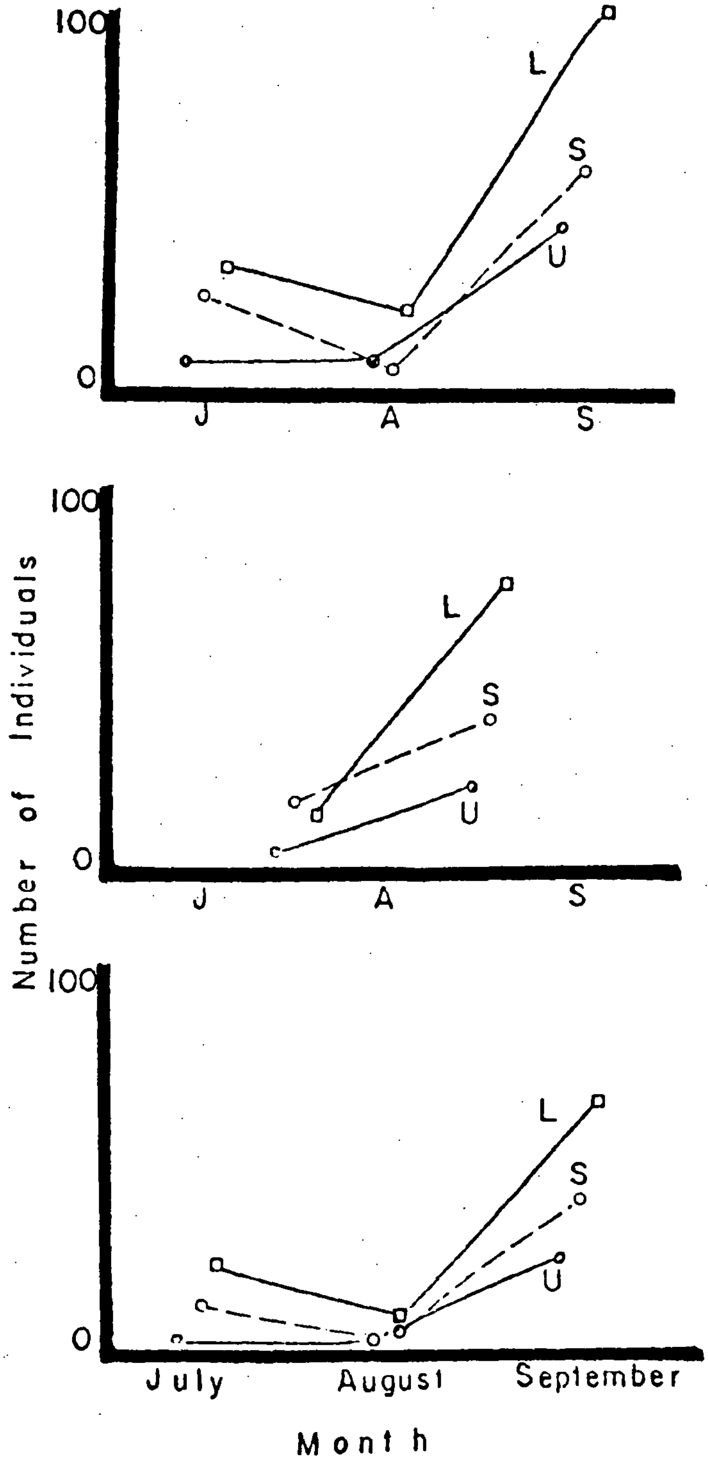


Figure II-1-B

Figure II-1-C: Mean (as generated from analysis of variance) Number of Individuals of *Balanus eburneus* which Settled for Each Surface Orientation (Upper, Side, or Lower) at each Station for (1) Data Set A, (2) Data Set B, (3) Data Set C. The stations are: WT = Waretown; OCM = Oyster Creek Mouth; OCMa = Oyster Creek Marina; FRM = Forked River Mouth; FRB = Forked River Bridge; SCM = stouts Creek Mouth; SCW = Stouts Creek, Winthrop St.; IN = Forked River Intake.

C. *Balanus eburneus*: Station X Surface Orientation

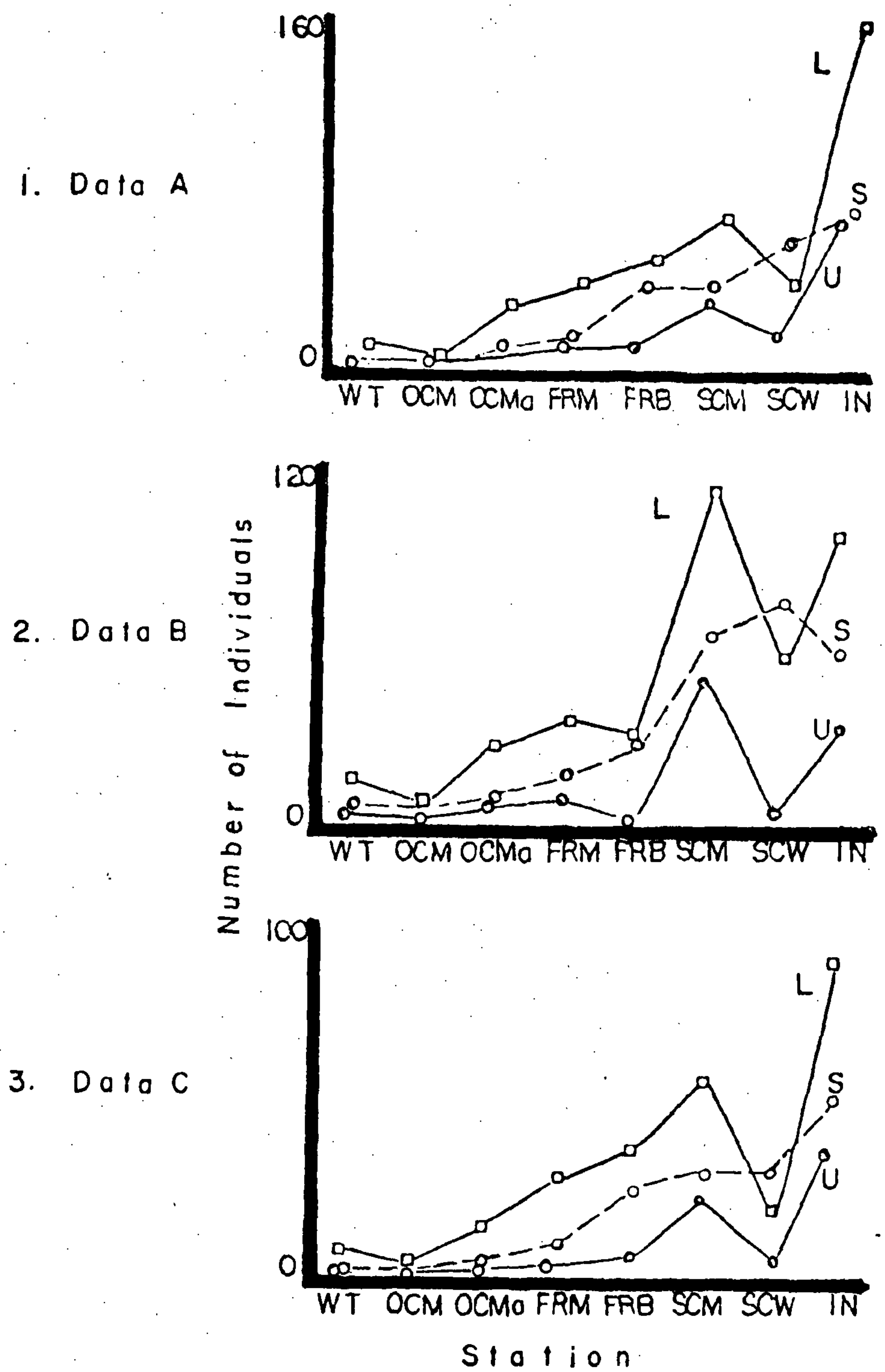


Figure II-I-C

Figure II-2A: Mean Number of Individuals of Bankia gouldi Which Settled for Each Surface Orientation (Upper, Side or Lower) at Each Depth (Top or Bottom). Least significant intervals for Surface Orientation are given (if $p < 0.05$) from (1) Data Set A, (2) Data Set B, (3) Data Set C.

A. Bankia gouldi: Depth X Surface Orientation

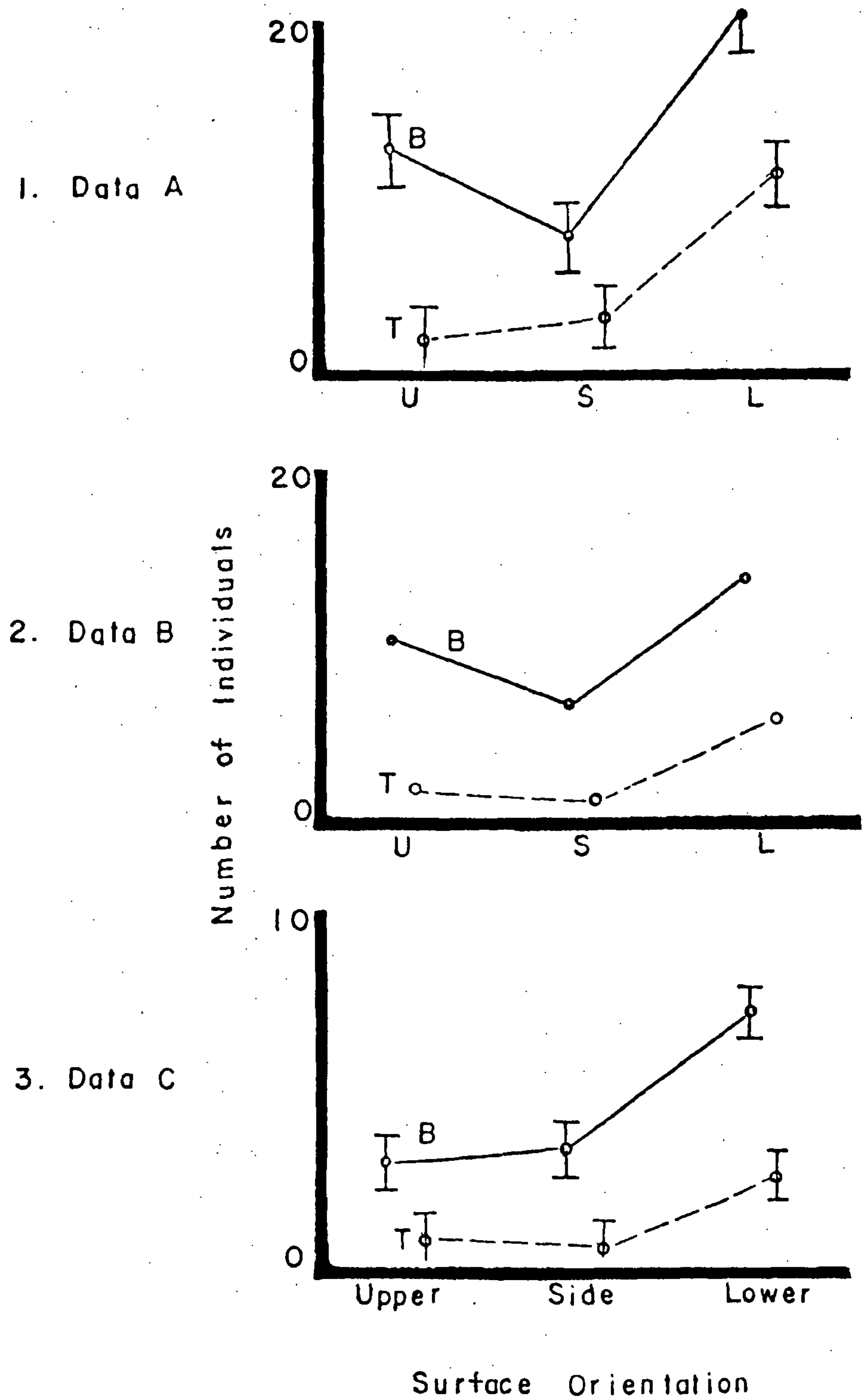


Figure II-2-A

Figure II-2-B: Mean (as generated from analysis of variance) Number of Individuals of *Bankia gouldi* Which Settled for Each Surface Orientation (Upper, Side, or Lower) during each Month (July, August, or September) for (1) Data Set A, (2) Data Set B, and (3) Data Set C.

B. Bankia gouldi: Month X Surface Orientation

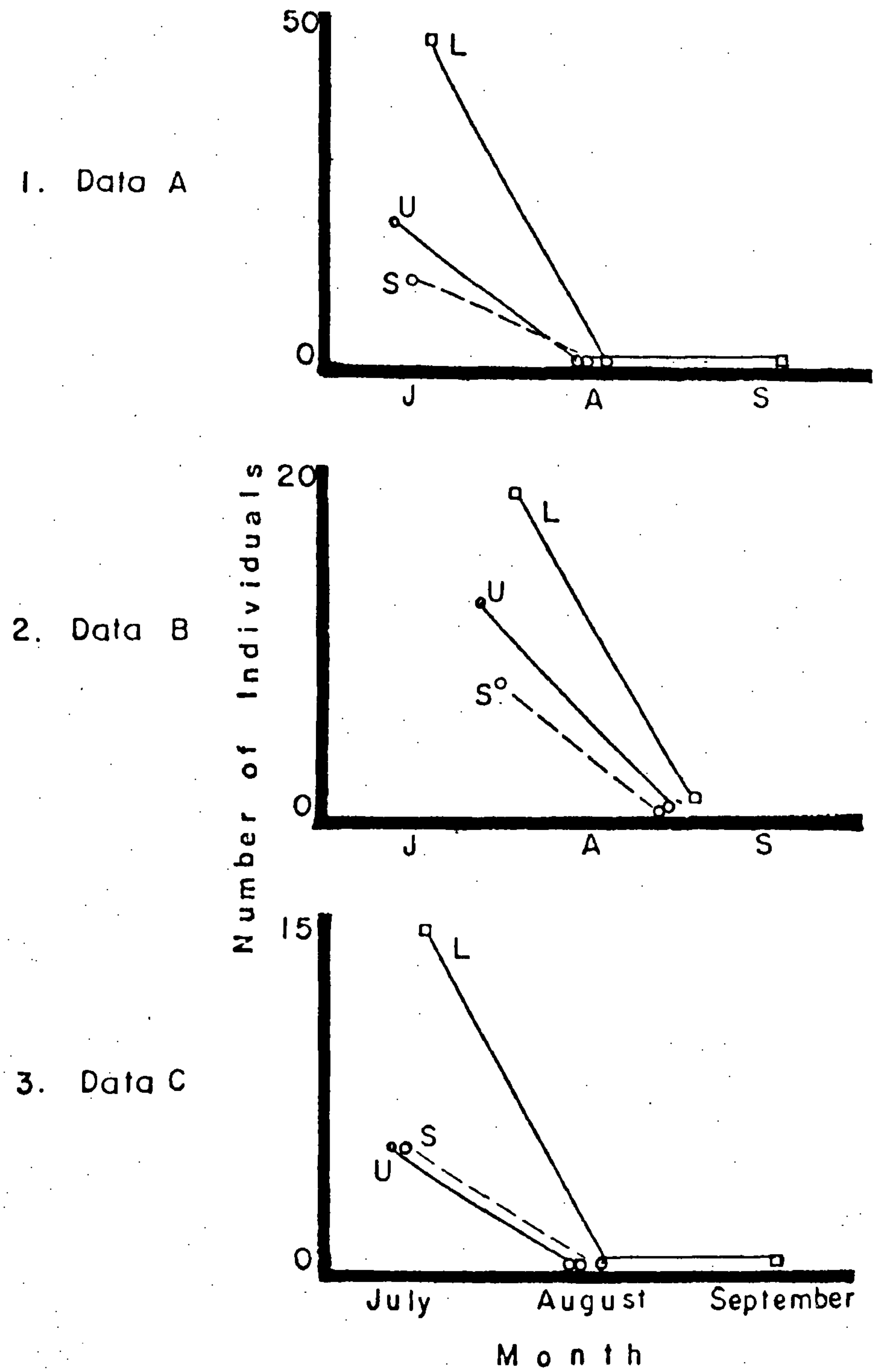


Figure II-2-B

Figure II-2-C: Mean (as generated from analysis of variance) Number of Individuals of Bankia gouldi which settled for each Surface Orientation (Upper, Side, or Lower) at Each Station for (1) Data Set A, (2) Data Set B, (3) Data Set C. The stations are: WT=Waretown; OCM=Oyster Creek Mouth; OCMa=Oyster Creek Marina; FRM-Forked River Mouth; FRB=Forked River Bridge; SCM=Stouts Creek Mouth; SCW=Stouts Creek, Winthrop St.; IN=Forked River Intake.

C. Bankia gouldi: Station x Surface Orientation

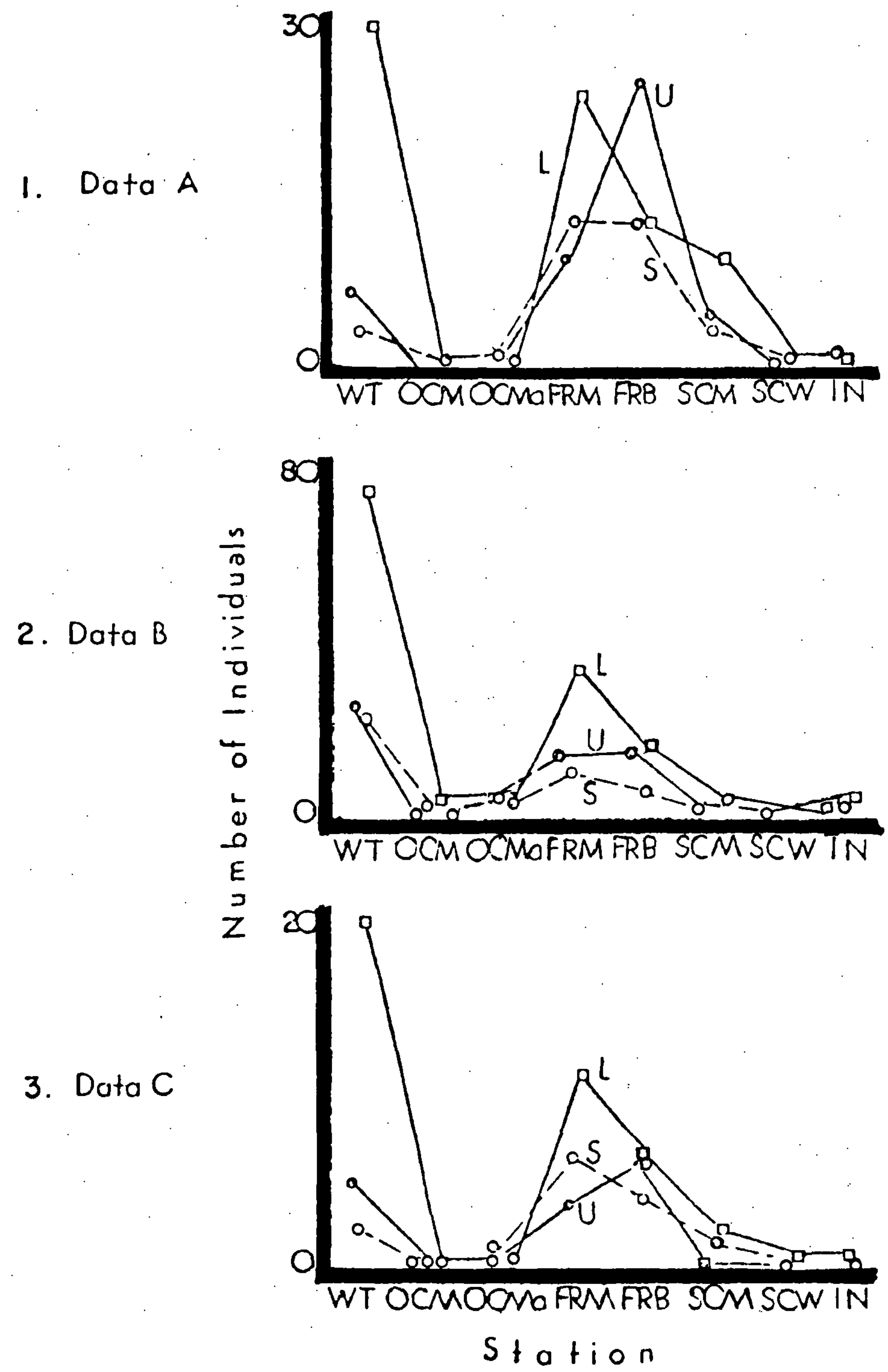


Figure II-2-C

Botryllus schlosseri settled most heavily on the bottom board and on the lower surface. Table II-I shows that 61% of the total number were on the bottom board; 52% of the total were on the lower surface. Analysis of variance results are summarized in Table II-2 and Figure II-3 (A-C). None of the three data sets indicated that there was a significant depth effect. There was a significant surface effect in all three data sets. The lower surface was significantly higher than the upper or side surfaces. Significant interaction effects of surface with time (Figure II-3-B), and surface with station (Figure II-3-C) were probably due to very low numbers of individuals which settled during July and August, and the very low numbers at a few of the stations. One specific interaction of surface orientation with station appears in the graph for Data Set A (Figure II-3-C-(1)). At Forked River Bridge the side surface had the highest mean number of individuals settling. This effect appears to be due to one sample taken in September when settling of Potryllus schlosseri was heaviest on the two side surfaces.

Bowerbankia gracilis settled more heavily on the top board and on the lower surface. Table II-1 shows that 52% of the total number were on the bottom board; 39% of the total were on the lower surface. The four most heavily settled positions were ranked as follows: lower surface, top board; lower surface, bottom board; upper surface, top board; upper surface, bottom board. Analysis of variance results are summarized in Table II-2 and Figure II-4. There was no significant depth effect in any of the data sets. There was a significant surface orientation effect in all three data sets; the side surface was significantly lower in numbers which settled than the upper or lower surfaces. There was apparently little difference between upper and lower surfaces.

Corophium volutator settled most heavily on the bottom board (64%), and on the upper surfaces (66%). Table II-1 shows that the four most heavily settled positions were ranked as follows: upper surface, bottom board; upper surface, top board; side surface, bottom board; lower surface, bottom board. There was insufficient data to test the significance of any of these effects, although the heavy settling on upper surfaces did seem pronounced, even with such a small sample size.

Figure II-3-A: Mean Number of Individuals of _Botryllus schlosseri_ Which Settled for Each Surface Orientation (Upper, Side, or Lower) at Each Depth (Top or Bottom). Least significant intervals for Surface Orientation are given (if 0.05) from analysis of variance results for (1) Data Set A, (2) Data Set B, (3) Data Set C.

A. *Botryllus schlosseri*: Depth X Surface Orientation

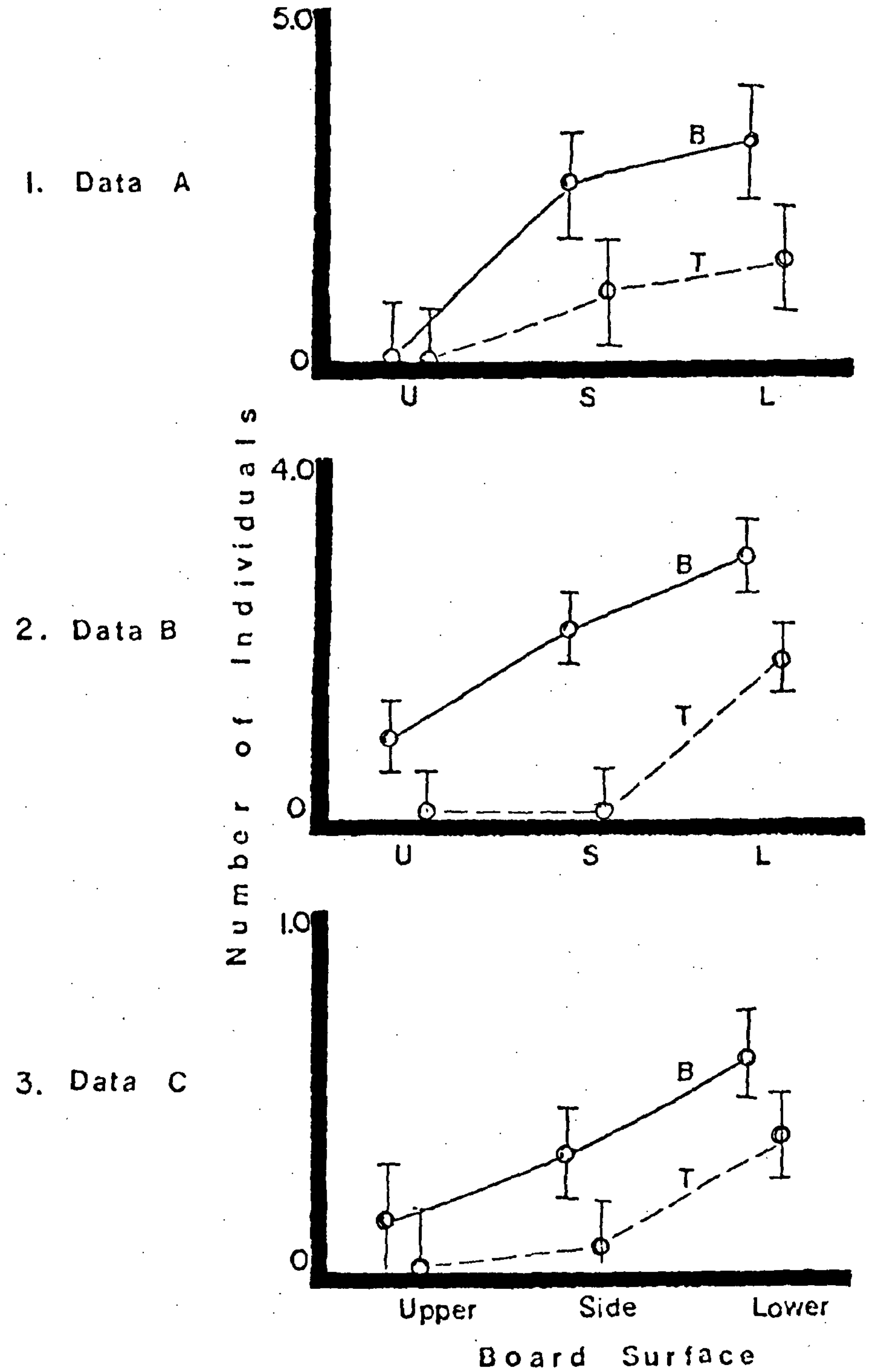


Figure II-3-A

Figure II-3-B: Mean (as generated from analysis of variance) Number of Individuals of *Botryllus schlosseri* Which Settled for Each Surface Orientation (Upper, Side or Lower) during Each Month (July, August, or September) for (1) Data Set A, (2) Data Set B, (3) Data Set C.

B. Botryllus schlosseri: Month X Surface Orientation

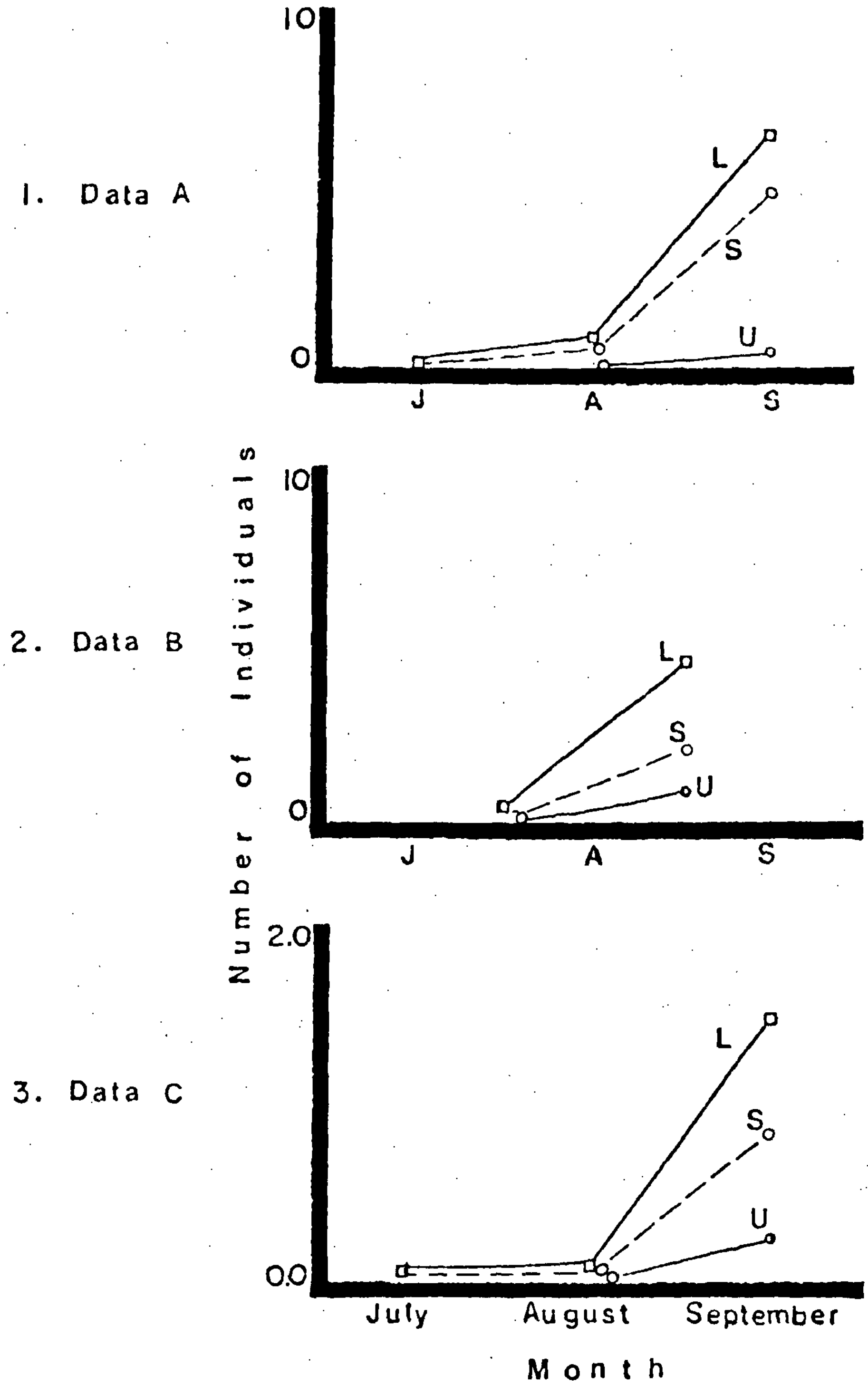


Figure II-3-B

Figure II-3-C: Mean (as generated from analysis of varfance) Number of Individuals of Botryllus schlosseri which Settled for Each Surface Orientation (Upper, Side, or Lower) at each Station for (1) Data Set A, (2) Data Set B, (3) Data Set C. The stations are: WT=Waretown; OCM=Oyster Creek Mouth; OCMa=Oyster Creek Marina; FRM=Forked River Mouth; FRB=Forked River Bridge; SCM=Stouts Creek Mouth; SCW=Stouts Creek, Winthrop St.; IN=Forked River Intake;

C. Botryllus schlosseri: Station x Surface Orientation

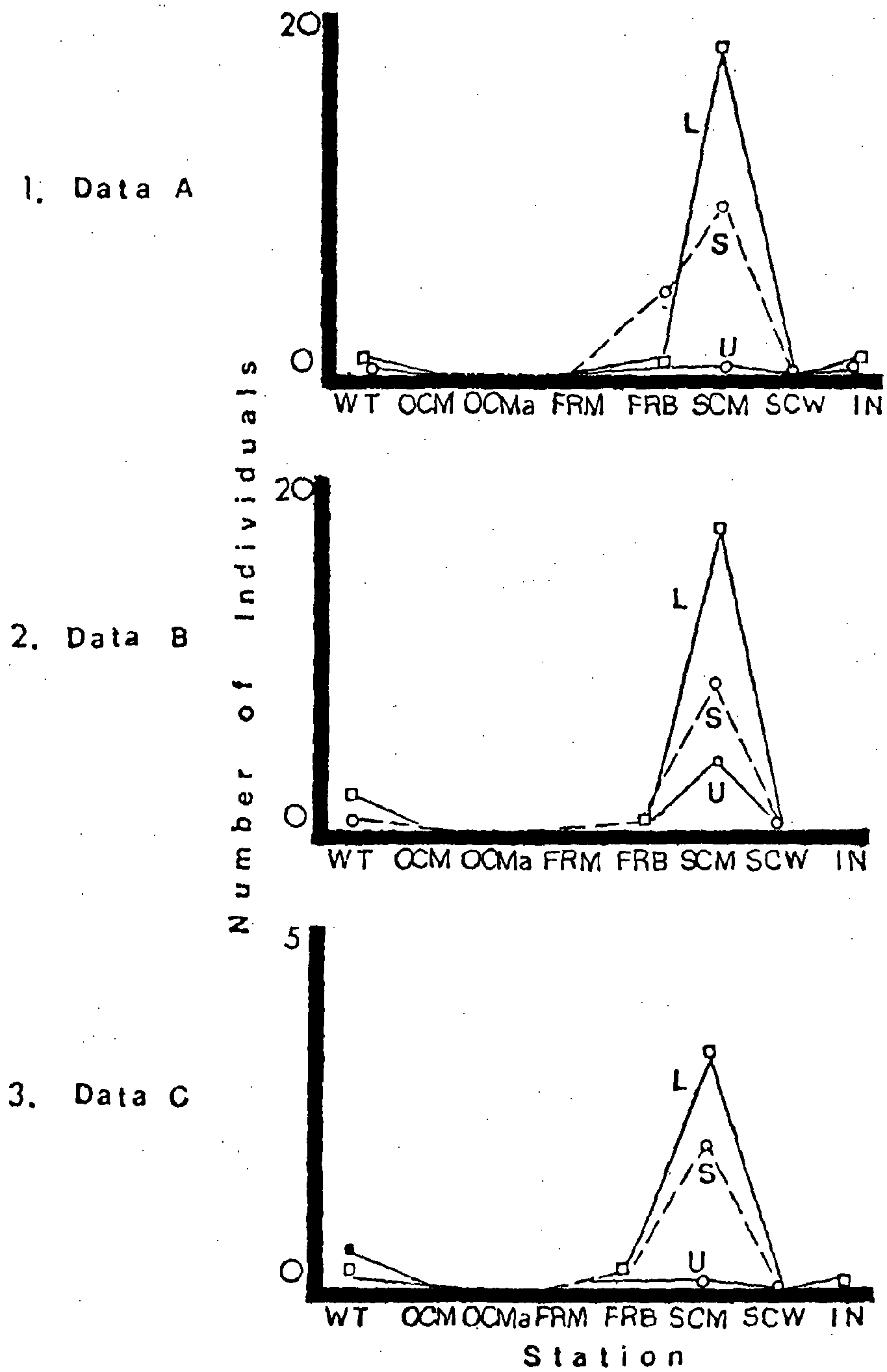


Figure II-3-C

Figure II-4: Mean Number of Individuals of Bowerbankia gracilis Which Settled for Each Surface Orientation (Upper, Side, or Lower) at Each Depth (Top or Bottom). Least significant intervals for Surface Orientation are given (if $p < 0.05$) from analysis of variance results for (1) Data Set A, (2) Data Set B, (3) Data Set C.

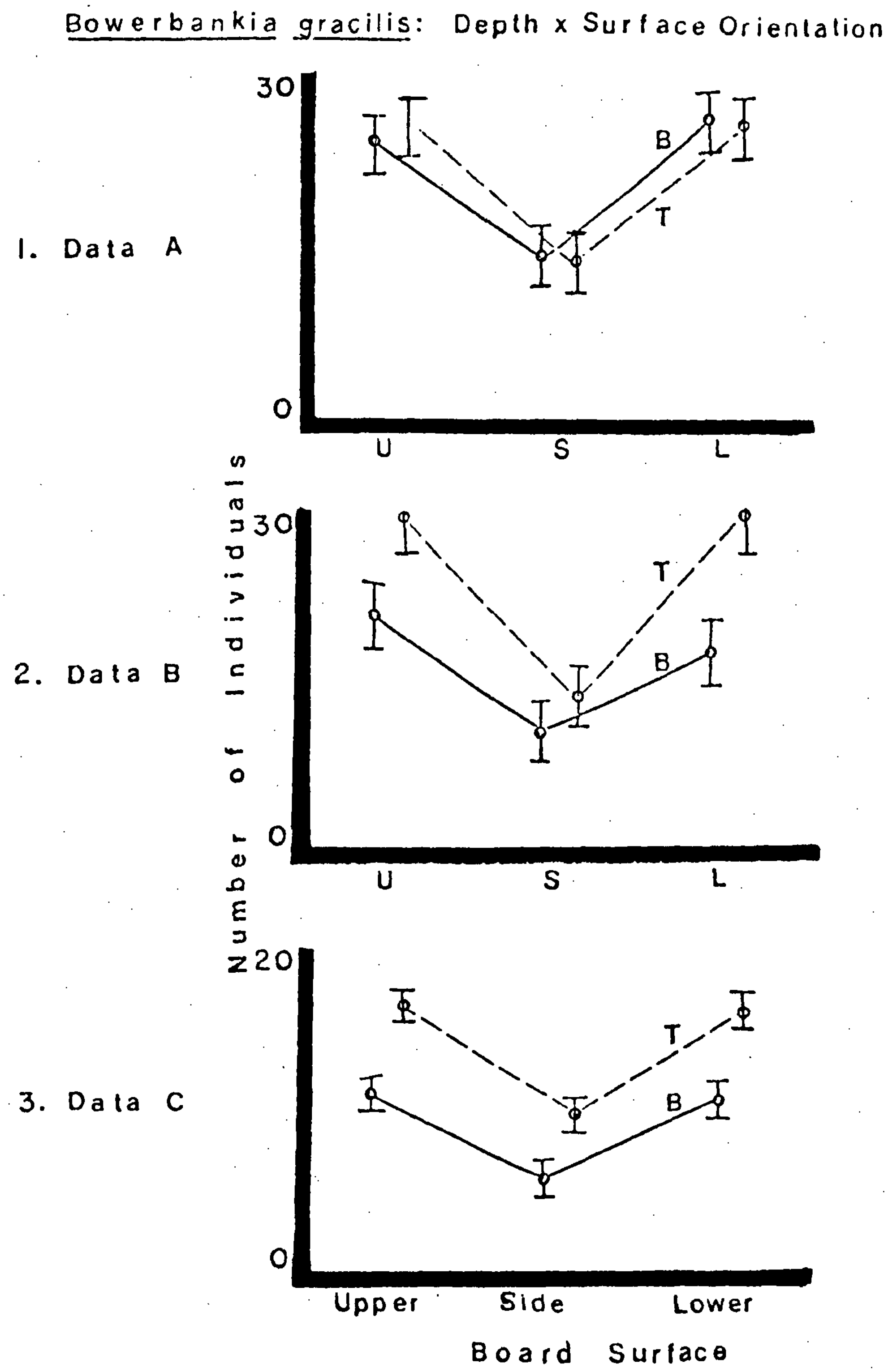

Bowerbankia gracilis: Depth x Surface Orientation
1. Data A
2. Data B
3. Data C
Number of Individuals
30
0
U
S
L
B
T
20
Upper
Side
Lower
Board Surface

Figure II-4

Figure II-5: Mean Number of Individuals of *Hydroides dianthus* Which Settled for Each Surface Orientation (Upper, Side, or Lower) at Each Depth (Top or Bottom). Least significant intervals for Surface Orientation are given (if $p < 0.05$) from analysis of variance results for (1) Data Set A, (2) Data Set B, (3) Data Set C.

Hydroides dianthus: Depth x Surface Orientation

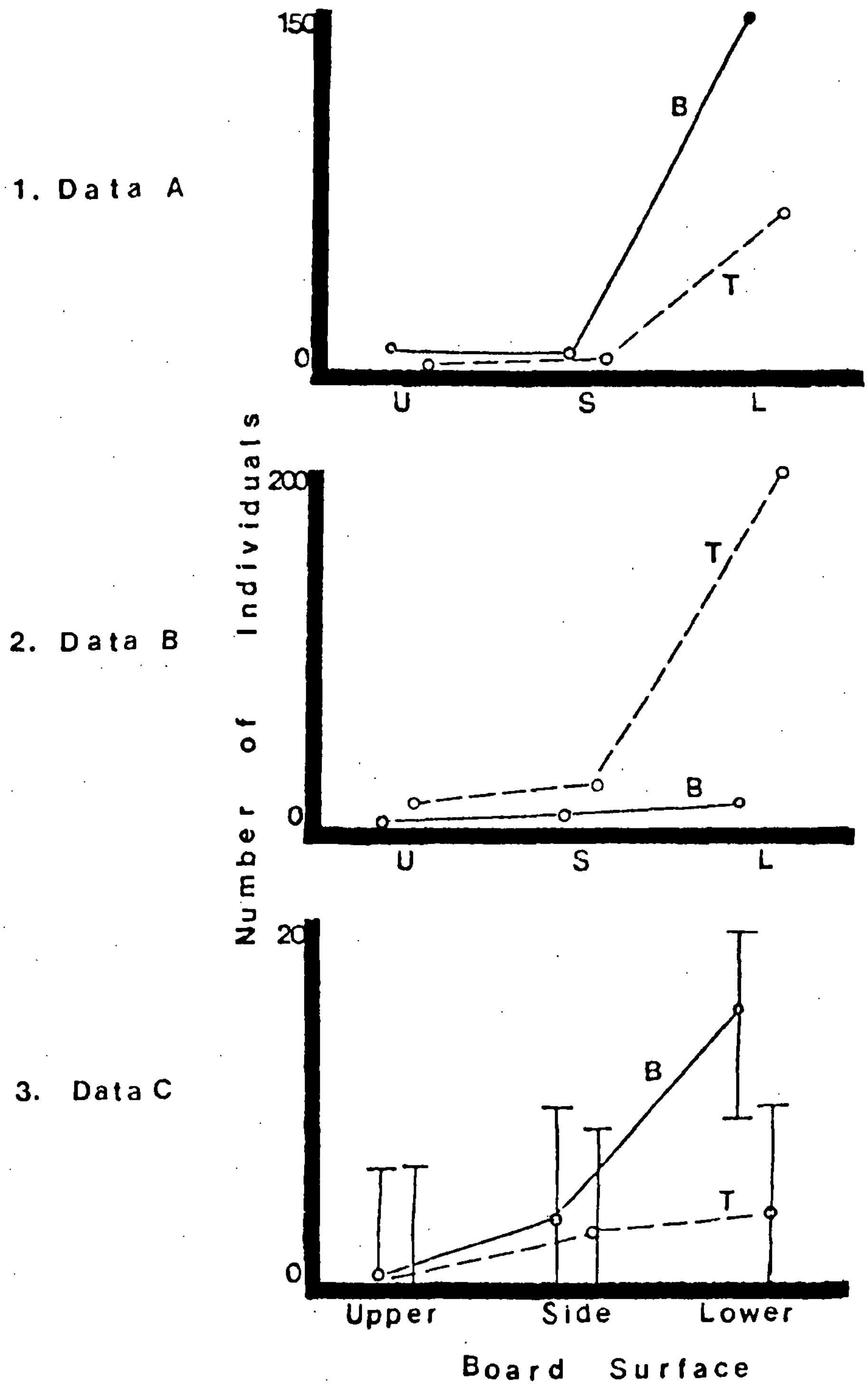


Figure II-5

Hydroides dianthus settled most heavily on the bottom board and on the lower surface. Table II-1 shows that 61% of the total number were on the bottom board, and 76% of the total settled on the lower surface. The four most heavily settled positions were ranked as follows: lower surface, bottom board; lower surface, top board; side surface, bottom board; side surface, top board. Analysis of variance results are summarized in Table II-2 and Figure II-5. Depth effect was not significant in any of the three data sets, and surface orientation effect was significant only in Data Set C, where the lower surface was what appeared to be strong depth and surface orientation effects to be statistically significant probably relates to the extremely high sample variance which occurred in the *Hydroides dianthus* data. The data used in these anlyses included values for numbers which settled ranging from 0 to 6000. Thus, the data was certainly not normally distributed and sample variance was extremely high.

Membranipora sp. settled mostly heavily on the top board and on the lower surface. Table II-1 shows that 55% of the total number on the top board, and 45% of the total were on the lower surface. The two most heavily settled positions were ranked as follows: lower surface, top board; lower surface, bottom board. Analysis of variance results are summarized in Table II-2 and Figure II-6 (A and B). There was no significant depth effect in any of the data sets. The lower surface was significantly higher than the upper or side surfaces. There was a significant interaction effect of time with surface orientation in board; lower surface, bottom board. Analysis of variance results are summarized in Table II-2 and Figure II-6 (A and B). There was no significant depth effect in any of the data sets. There was a significant surface orientation effect in all three data sets. The lower surface was significantly higher than the upper or side surfaces. There was a significant interaction effect of time with surface orientation in Data Sets A and C. This was probably due to greatly reduced settling during September.

Melita nitida settled most heavily on the bottom board and the upper surface. Table II-1 shows that 56% of the total number were on the bottom board, and 55% of the total were on the upper surface. The four most heavily settled positions were ranked as follows: upper surface, bottom board; upper surface, top board; lower surface, top board; upper surface, top board. Analysis of variance results are summarized in Table II-2 and Figure 7. Although the mean number which settled on the bottom board was consistently higher than for the top board, none of the data sets indicated a significant depth effect. Data Set A did show a significant interaction of surface orientation with depth, though, indicating that depth was important. Only Data Set B showed a significant surface orientation effect the side surface was significantly lower than the upper and lower surfaces. There was also a significant interaction effect of time with surface orientation in Data Set B; this was probably bbcause the data used included month-data for July/August and August/September. These particular sampling times had very low numbers of *Melita nitida*; thus significant effects were determined

Figure II-6-A: Mean Number of Individuals of _Membranipore sp._ Which Settled for Each Surface Orientation (Upper, Side, or Lower) at Each Depth (Top or Bottom). Least significant intervals for Surface Orientation are given (if $p < 0.05$) from analysis of variance results for (1) Data Set A, (2) Data Set B, (3) Data Set C.

A. *Membranipora sp.*: Depth x Surface Orientation

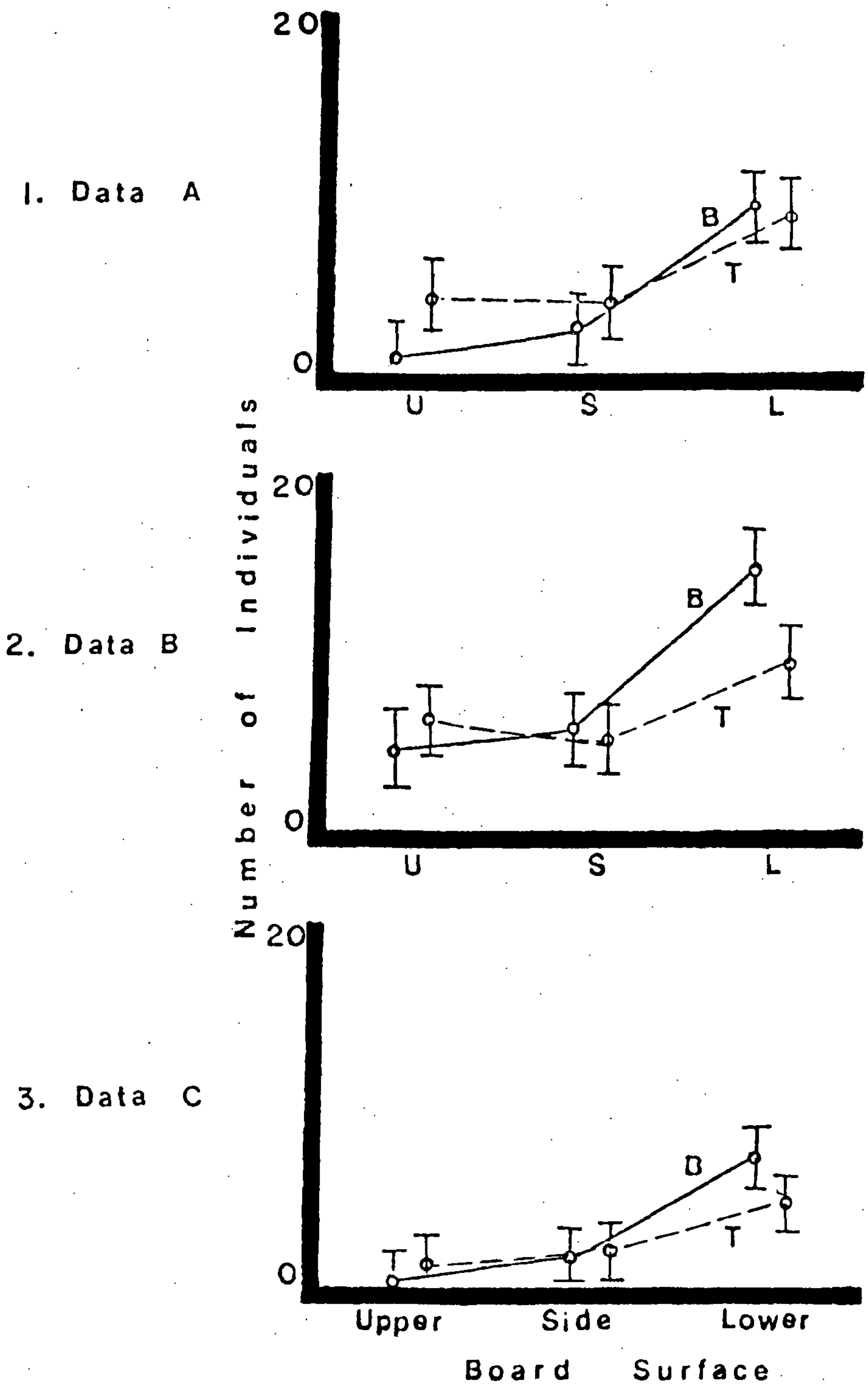


Figure II-6-A

Figure II-6-B: Mean (as generated from analysis of variance) Number of Individuals of Membranipora sp. Which Settled for Each Surface Orientation (Upper, Side or Lower) during Each Month (July, August, or September) for (1) Data Set A, (2) Data Set B, (3) Data Set C.

B. *Membranipora sp.*: Month x Surface Orientation

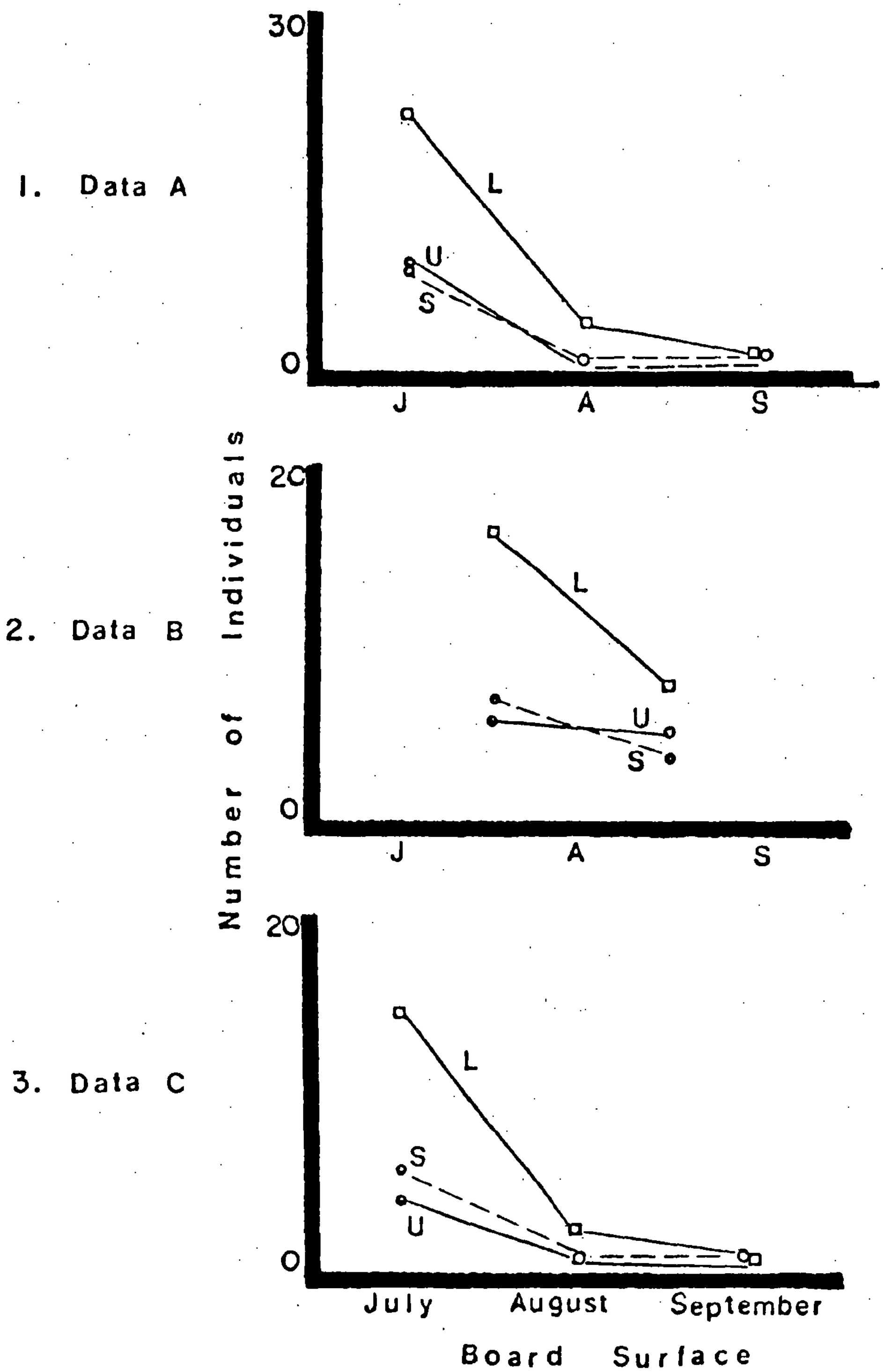


Figure II-6-B

Figure II-7-A: Mean Number of Individuals of _Melita nitida_ Which Settled for Each Surface Orientation (Upper, Side, or Lower) at Each Depth (Top or Bottom). Least significant intervals for Surface Orientation are given (if $p < 0.05$) from analysis of variance results for (1) Data Set A, (2) Data Set B, (3) Data Set C.

Melita nitida: Depth x Surface Orientation

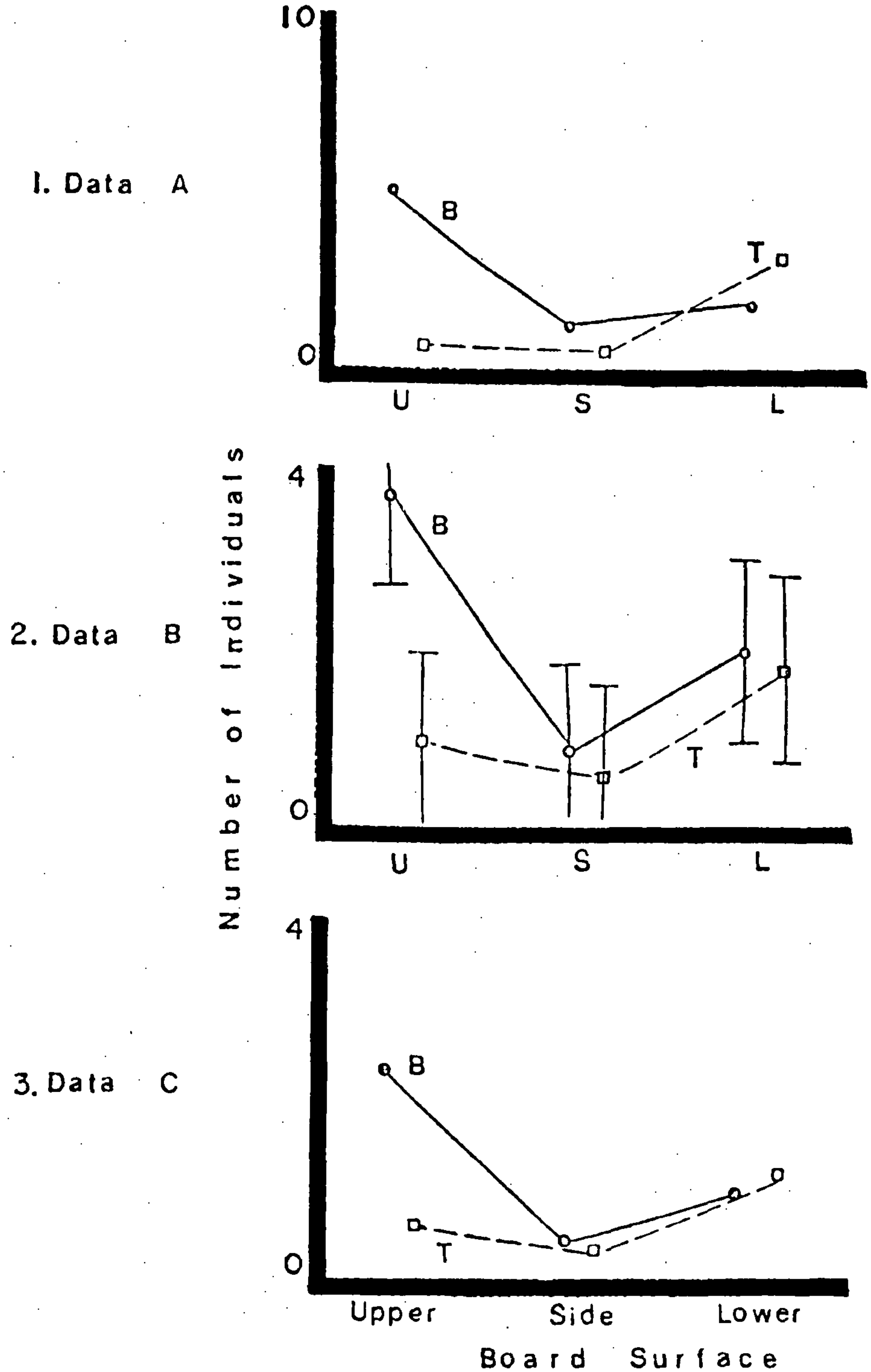


Figure II-7-A

upper and lower surfaces. There was also a significant interaction effect of time with surface orientation in Data Set B; this was probably because the data used included month-data for July/August and August/September. These particular sampling times had very low numbers of Melita nitida; thus significant effects were determined by the settling positions of one or two individuals.

Molgula manhattensis settled most heavily on the bottom board and on the lower surface. Table II-1 shows that 63% of the total number settled on the bottom board, and 53% of the total settled on the lower surface. However, the specific position with the heaviest settling was the side surface of the bottom board, followed by the lower surfaces of the two boards (which were fairly similar). Analysis of variance results are summarized in Table II-2 and Figure II-8. The three data sets showed that although means are consistently higher for bottom boards, there was no significant depth effect. The only significant surface orientation effect was in Data Set C where the lower surface was more heavily settled than the upper or side surfaces. It appears that one sample in particular, July at Waretown, had a high number which settled on the side surface of the bottom board. In fact, this one sample accounts for 680 of the 802 total individual Molgula manhattensis which settled in that position. The July data was only used in Data Set A. Thus, except for that sample, settling appears to be heaviest on lower surfaces; this effect may have been more consistently significant if more Molgula manhattensis had settled per sample, thus reducing sample variance.

Polydora ligni settled most heavily on the bottom board and on the upper surface. Table II-1 shows that 66% of the total number on the bottom board, and 66% of the total settled on the upper surface. The two most heavily settled positions were upper surface, bottom board; and upper surface, top board. Analysis of variance results are summarized in Table II-2 and Figure II-9 (A-C). There was a significant depth effect only in Data Set A. In this case the bottom board had significantly heavier settling of Polydora ligni than the top board; the other data sets show this same trend. The surface orientation effect was significant for each of the three data sets the upper surface was consistently higher than the side or lower surfaces. There was a significant interaction effect of time with surface orientation. In Data Set A which was probably due to very low numbers found in September (although that implies that the same interaction should be significant using Data Set C). In all three data sets, there was a significant interaction effect of station with surface orientation. This interaction appears to have been due to a change in the settling pattern over surfaces at the Stouts Creek Winthrop St. Station. There was relatively heavier settling on the side surface and lighter settling on the upper surfaces at this station. For Data Set A, there was also relatively heavier settling on the side surface at Forked River Intake.

Figure II-8: Mean Number of Individuals of *Molgula manhattensis* Which Settled for Each Surface Orientation (Upper, Side, or Lower) at Each Depth (Top or Bottom). Least significant intervals for Surface Orientation are given (if $p < 0.05$) from analysis of variance results for (1) Data Set A, (2) Data Set B, (3) Data Set C.

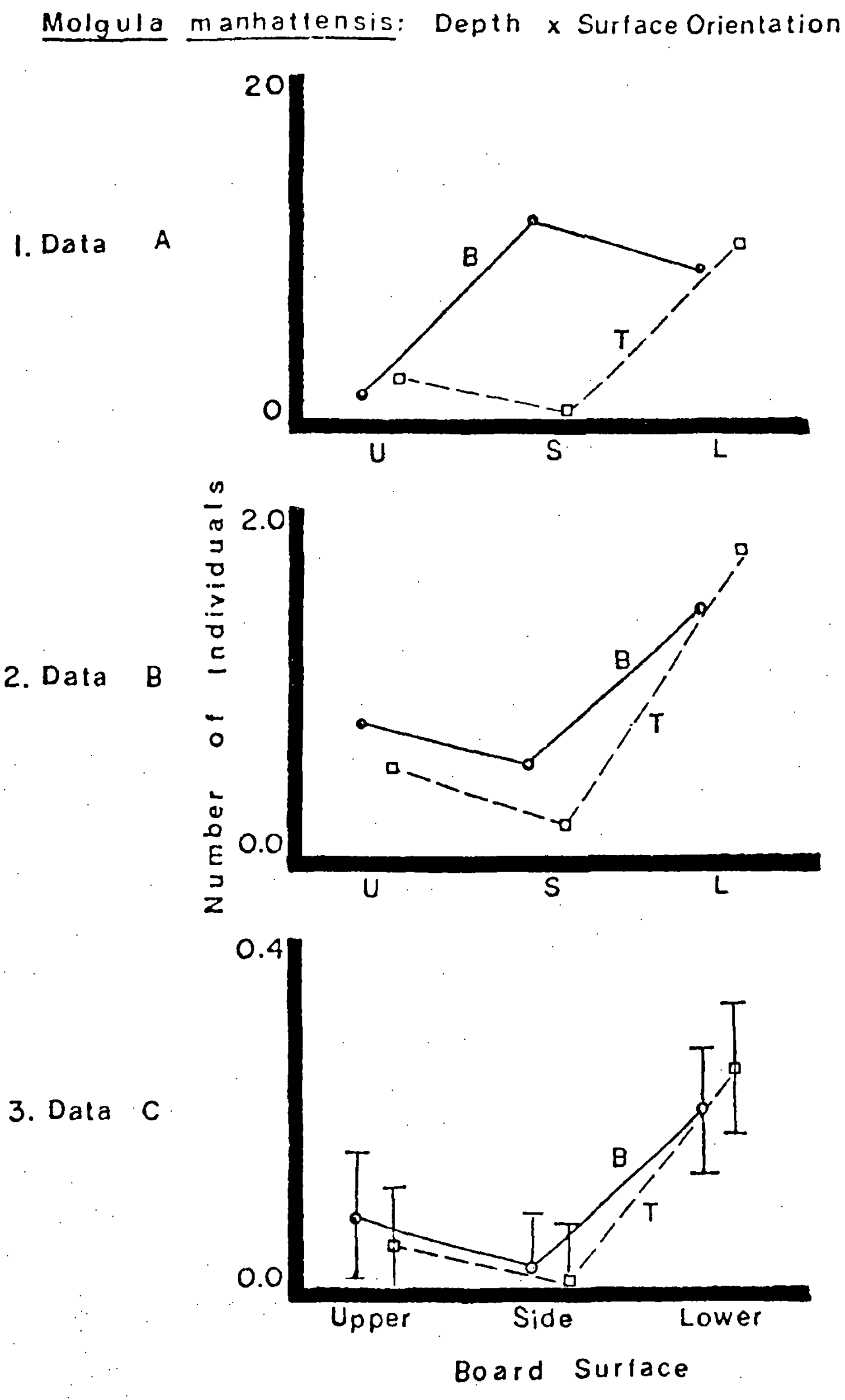

Molgula manhattensis: Depth x Surface Orientation
1. Data A
2. Data B
3. Data C
Number of Individuals
20
0
2.0
0.0
0.4
0.0
B
T
U
S
L
Upper
Side
Lower
Board Surface

Figure II-8

Figure II-9-A: Mean Number of Individuals of Polydora ligni Which Settled for Each Surface Orientation (Upper, Side, or Lower) at Each Depth (Top or Bottom). Least significant intervals for Surface Orientation are given (if $p < 0.05$) from analysis of variance results for (1) Data Set A, (2) Data Set B, (3) Data Set C.

A. Polydora ligni: Depth x Surface Orientation

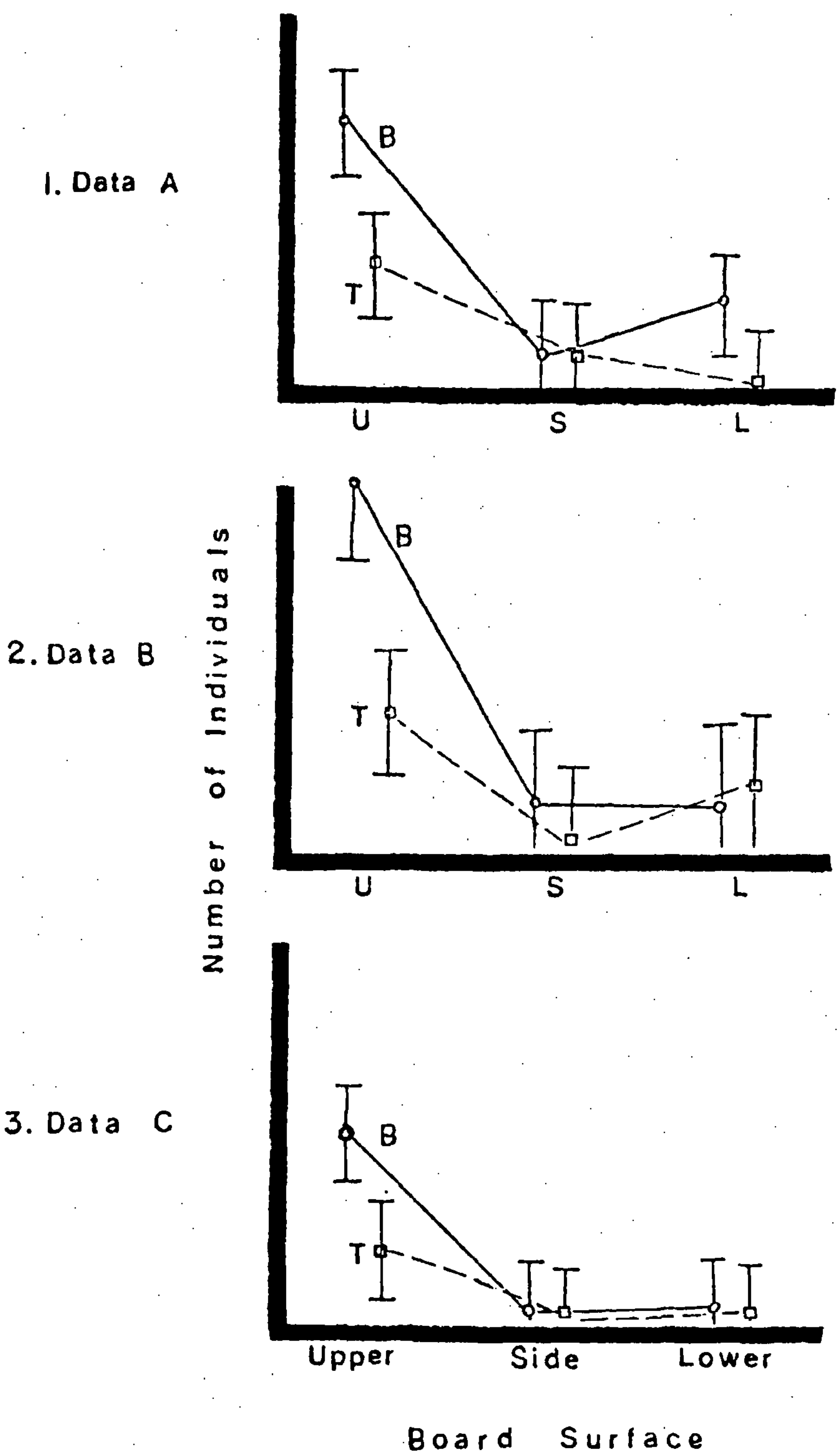


Figure II-9-A

Figure II-9-B: Mean (as generated from analysis of variance) Number of Individuals of *Polydora ligni* Which Settled for each Surface Orientation (Upper, Side or Lower) during each Month (July, August, or September) for (1) Data Set A, (2) Data Set B, (3) Data Set C.

B. *Polydora ligni*: Month x Surface Orientation

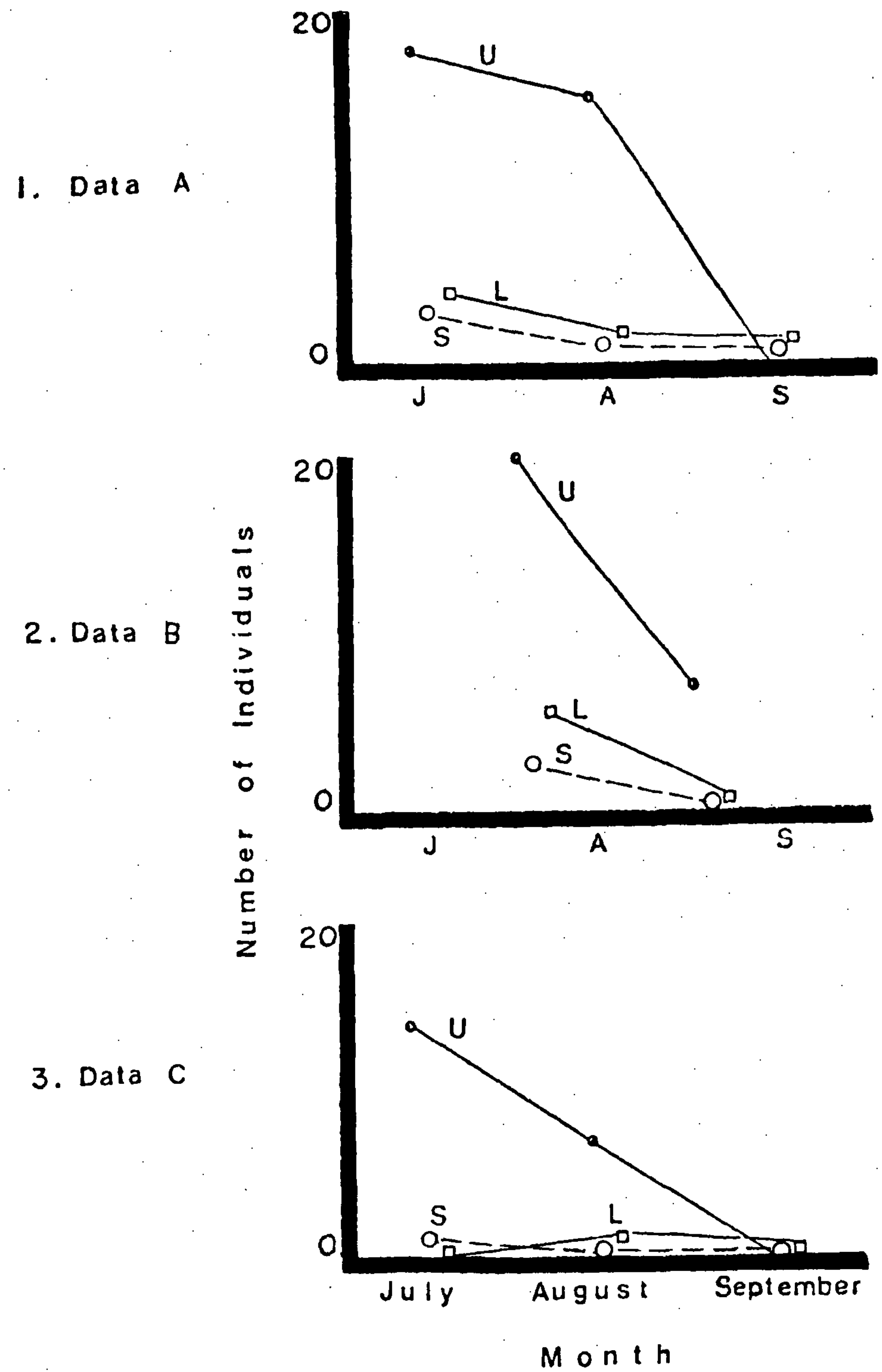


Figure II-9-B

Figure II-9-C: Mean (as generated from Analysis of Variance) Number of Individuals of *Polydora ligni* which Settled for Each Surface Orientation (Upper, Side, or Lower) at each Station for (1) Data Set A, (2) Data Set B, (3) Data Set C. The stations are: WT=Waretown; OCM=Oyster Creek Mouth; OCMa=Oyster Creek Marina; FRM=Forked River Mouth; FRB=Forked River Bridge; SCM=Stouts Creek Mouth; SCW=Stouts Creek, Winthrop St.; IN=Forked River Intake.

C. Polydora ligni: Station x Surface Orientation

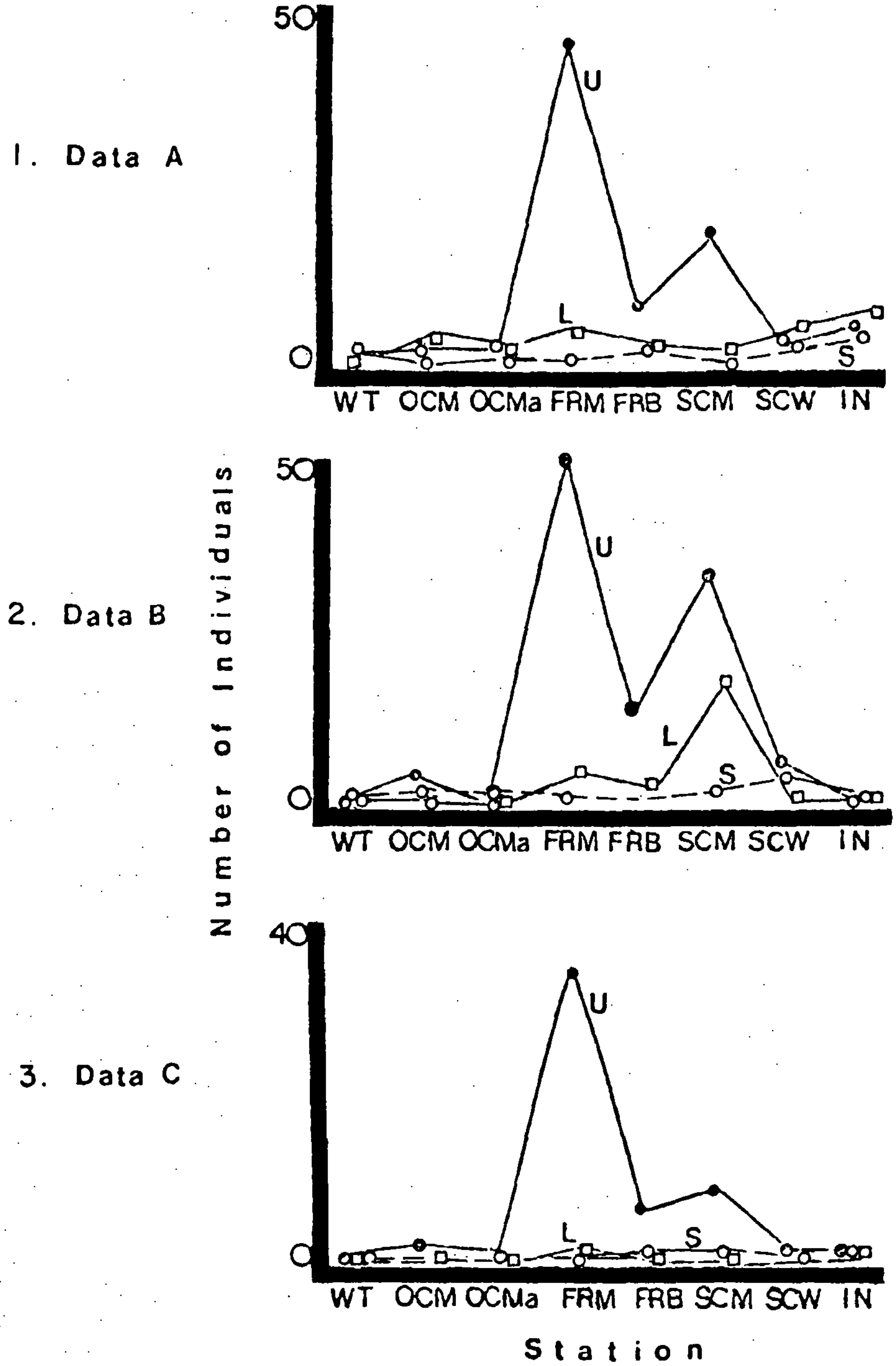


Figure II-9-C

IV. Discussion

Many general studies of estuarine settling organisms (particularly intertidal species) have described differential settling of species on surfaces such as the under sides of rocks (e.g., Allee, 1923). Little has been done in the way of quantifying settling, though, perhaps because settling rate cannot be clearly separated from survival rate.

The assumption of the present study is that during the two-week and one-month sampling periods adult and settling larval survival rates did not vary over the different settling surfaces. This assumption is only supported to the extent that all ten of the species to be discussed were found on all six settling positions.

Apparent settling patterns can be discussed in terms of behaviors of the larvae that may account for their settling predominantly in certain positions. For instance, if each species has a unique set of larval responses to light and/or gravity, it could have a unique set of settling preferences. Thorson (1964) suggested that most estuarine species have planktonic larvae which are photopositive at first and then photonegative as they start to settle. He also pointed out that whatever photic response may be involved, it is not absolute, but statistical for the whole population. Furthermore, it probably involves simple genetics. For example, 60% of the larvae of the ascidian *Perophera viridis* were photopositive while 31% became photonegative (Grave and McCash, 1923).

On the basis of raw data (number of individuals of each species which settled on each of the six positions) two major "settling types" were found: A. Upper Surface Settler, and B. Lower Surface Settlers. The latter could be further divided into three sub-types: 1. Lower Surface Top Board Settlers, 2. Lower Surface Bottom Board Settlers, and 3. Bottom Board Lower Surface Settlers. These types express the order of preference in settling. In the following discussion, evidence for the validity of these settling types and sub-types is provided from the analysis of variance for each species. The settling types are interpreted in terms of known relevant behaviors of the species during their planktonic and settling stages.

A. Upper Surface Settlers

Corophium volutator, *Melita nitida*, and *Polydora ligni* settled most heavily on lower surfaces of first bottom and then top boards. Analysis of variance indicated that the tendency to settle more heavily on upper surfaces was significant for all three species. Thus if these species represent a settling type, it is one where settling is primarily on horizontal surfaces (especially upper) and secondarily at lower depths (i.e., not immediately near the water surface).

The members of this group are similar in other ways. Corophium volutator and Melita nitida are the only amphipods among the dominant species, and Corophium volutator, Melita nitida and Polydora ligni are all detritus feeders and are the only species living in soft, detrital-mud tubes or burrows.

If more suspended detritus and mud settles out of the water onto upper surfaces than onto lower or side surfaces, then upper surfaces would be the most ideal settling choices for these species. The more detritus and mud, then the more material available for food and protection. If the availability of mud and detritus is important in explaining the settling pattern of these species, it is still not clear what the settling mechanism might be. The mechanism could be one where the individual selects upper surfaces (which are the surfaces most likely to have heavy detritus and mud layers), or the mechanism could be one where the individual selects surfaces with the heaviest detritus and mud layer (most likely to be the upper surfaces).

Polydora ligni showed a significant change in settling pattern at the Stouts Creek at Winthrop St. station where settling of that species increased on the sides and decreased on the upper surfaces. That station had the lowest mean salinity of all stations. Thorson (1964) suggested that, in general, photopositive behavior is reduced or reversed for estuarine animals under conditions of low salinity. This suggests that the mechanism whereby Polydora ligni selected upper settling surfaces involved a response to light rather than to substrate.

Previous studies on settling behavior of these and related species have indicated that responses to light and substrate may have been involved in surface selection. Corophium volutator is photopositive while it is swimming or crawling; it is also positively attracted to "organic material" in the substrata (Meadows and Reid, 1966). The four species of the genus Polydora which were discussed by Thorson (1964) were all initially photopositive during the planktonic larval stage. Only one species, however, remained phtopositive until it settled. As suggested above, Polydora ligni may also remain photopositive.

These studies suggest that planktonic forms of Corophium volutator and Polydora ligni choose upper surfaces because those surfaces are the most exposed to light and collect the thickest detrital layer.

Following the above general explanation for settling behavior, the reason that Molita nitida settled almost as heavily on the lower as on the upper surfaces may be that Melita nitida does not respond to light in the same way that Corophium volutator and Polydora ligni respond. The bottom surfaces may collect almost as much mud and detritus as the upper surfaces, particularly since the water was shallow and the distance to the mud layer was not very far. Mud could billow up from the bottom, heavily coating lower surfaces. This would also explain why all three species settled more heavily on the bottom board as compared to the top board. Clearly the hypothesis that these species settle most heavily where the heaviest mud and detritus layers form can be easily tested in the field. All that is necessary is to measure the amount of material collecting on the different surfaces.

B. Lower Surface Settlers

1. Lower Surface, Top Board Settlers

Balanus eburneus, Bowerbankia gracilis, and Membranipora sp. were the only ones among the dominant species that showed any tendency to settle more heavily on top boards. Balanus eburneus and Membranipora sp. showed a significant tendency to settle most heavily on the lower surfaces, then the side surfaces, and then the upper surfaces. Bowerbankia gracilis, on the other hand, showed a tendency to settle most heavily on the lower surfaces, and then the side surfaces, with little difference between the upper and lower surfaces. These three species represent a settling type for which settling of the total number is fairly evenly distributed over the two depths and tends to be heaviest on the lower surfaces.

These species are similar in other ways. Membranipora sp. and Bowerbankia gracilis are the only ectoprocts among the dominant species, and Membranipora sp.,Bowerbankia gracilis and Balanus eburneus are all attached,filter feeders.

Unlike the previously discussed detritus feeders, settling position as it relates to food availability may not be too important to these species, because they are all filter feeders. The concentration of plankton and suspended detritus probably does not vary much within the three to four foot water column.

Previous studies on these or related species indicate that settling patterns relate to larval behaviors which are species specific. Balanus species have been shown to be gregarious settlers (Crisp and Meadows, 1963). Larvae are attracted to settle on or near adult barnacle shells. The attraction is strongest for members of the same species although larvae are attracted to shells of other species. This is an important settling behavior to Balanus because an attached individual must settle near individuals of the same species if successful reproduction is to take place.

Balanus eburneus larvae are photopositive during planktonic lite (Fales, 1928). When they settle onto a surface, they begin to crawl and apparently become photonegative (McDougall, 1943). McDougall also found that Balanus eburneus settled at a fairly shallow depth with maximum numbers at only five to six feet below the water surface. Daniel (1957) found that Balanus eburneus settled most heavily on dark-colored and shaded surfaces. These observations on larval photic responses and preferred settling depths help to account for the heavy settling of Balanus eburneus on first the lower, then the side, and then the upper surfaces, with somewhat heavier settling on the top board. The settling preferences demonstrated by Balanus eburneus in the present study can thus be explained by know larval behaviors.

Balanus eburneus showed a significant change in settling pattern at the Stouts Creek at Winthrop St. station where settling of the total number increased on side surfaces. As previously discussed, this particular interaction of station with surface was also found for Polydora ligni. However, the general principle that low salinity reduces a photopositive response (Thorston, 1964) does not apply to Balanus eburneus since there was, instead, a reduction in its photonegative response under low salinity conditions. Perhaps marginal (stressful) environmental conditions generally reduce the strength of any photic response.

Membranipora sp. and Bowerbankia gracilis asexually form colonies of individuals. When these species reproduce sexually, fertilization is external. Therefore individuals do not need to settle near members of the same species to insure successful sexual reproduction. It is probable that larvae of these species of ectoprocts have very short planktonic lives (less than one-half of a day) (Meglitch, 1967). Thus, larvae tend to settle near their parents. Planktonic larvae of a different species of the genus Bowerbankia are photopositive at first, but become photonegative before they settle (Thorson, 1964). If this is true for Bowerbankia gracilis larvae, however, it is not clear why settling was almost as heavy on the upper as on the lower surfaces. If Membranipora sp. larvae show the same photic responses, then that would explain the low numbers of Membranipora sp. found on side and upper surfaces.

As discussed previously, the number of larvae which settled could not be directly determined for these two ectoprocts. It is assumed that the amount of area on a board covered by a colony was a direct reflection of the number of larvae which settled. However, if there is any differential growth of colonies on different surfaces which would appear during the two-week or one-month samplings,observations made in this discussion about settling patterns would be completely misleading.

2. Lower Surface, Bottom Board Settlers

Botryllus schlosseri, Hydroides dianthus, and Molqula manhatteniss settled most heavily on lower surfaces and on the bottom board. As was previously discussed for Membranipora sp. and Bowerbankia gracilis, the problems of relating colony size to numbers of individuals which settled also applies to Botryllus schlosseri.

Molqula manhattensis and Botryllus schlosseri settled most heavily on the side surfaces of the bottom board, and on the lower surfaces of both boards. The results of analysis of variance show that the heavy settling of these species on the side surface was not a significant effect. Instead, these two species settled significantly more on the lower surfaces. Apparently, then, these two species have settling patterns which are the same as that of Hydroides dianthus. For Hydroides dianthus settling of the total number was very low on the side surface of the board and on the upper surfaces of both boards. For reasons given in the Results section, this discussion will assume that the summarized raw data adequately describes differential settling of Hydroides dianthus over the six positions.

A study by Zelenky (1905) indicated that Hydroides dianthus larvae are photopositive at first, but become photonegative before they settle. If the two lower surfaces are the two darkest positions among the six tested, then the settling pattern of Hydroides dianthus could be explained by its larval photic responses. If the two lower surfaces are not the two darkest positions, however, then the settling behavior of Hydroides dianthus may be similar to that of Balanus eburneus. In that case, a larva initially settles on a preferred board and secondarily selects the darkest surfaces. With either explanation, a single physical gradient, light, would be responsible for determining the proportionate amount which settle on different positions. Zonation as determined by light need not be along a single gradient that corresponds to depth since different spatial orientations of settling surfaces may produce differentially illuminated surfaces.

Botryllus schlosseri planktonic larvae are photopositive at first but become photonegative (Grave and Woodbridge, 1924). Molgula manhattensis may behave similarly since another related tunicate, Ascidia nigra, shows the same pattern of responses as Botryllus schlosseri (Grave and Nicholl, 1940). Thus, known larval behavior might explain the apparent settling preferences if, as discussed for Hydroides dianthus, the lower surfaces of the two boards are the two darkest positions. To test this hypothesis, all that is necessary is to measure, in the field, the relative light intensity on all of the settling positions.

Botryllus schlosseri larvae and probably Molgula manhattensis larvae have an extremely short planktonic life and tend to settle next to their parents (Barrington, 1965). Botryllus schlosseri larvae are, in fact, attracted to colonies of the same species (Grave and Nicholl, 1940). For Botryllus schlosseri and Molgula manhattensis, a second generation could have been produced and could have settled during a one-month sampling period. Thus the settling pattern of the first generation would be magnified by gregarious settling of the second generation larvae.

3. Bottom Board, Lower Surface
   Settler

Bankia gouldi settled most heavily on the three surfaces of the bottom board. Settling of the total number was heaviest on the lower surface of the bottom board, and lightest on the upper surface of the top board. Analysis of variance showed that these various settling trends were significant.

The most obvious physical gradient which relates to this settling pattern is depth. The greater number of adults which were found on the bottom board could be due to a geopositive response of the larvae prior to settling on the boards. Mawatari (1950) and Imai, Hatanka, and Sato (1950), however, concluded that the larvae of another shipworm, *Teredo navalis*, is geonegative at first. Others have found that the general shipworm community settled most heavily under a low light regime of 166 foot candles (Isham, Smith and Springer, 1951). There are several observations of other species of the genus *Teredo* settling most heavily near the mudline, and on the under surfaces of boards (Dons, 1944; Owen, 1953).

In addition, substrate may be important to settling patterns of *Bankia gouldi*. Nelson (1923) suggested that *Bankia gouldi* are attracted to chemicals in wood; Lane (1961), however, argued that larvae of a related species, *Bankia setacea*, are attracted to microflora on settling surfaces. Lane also found that *Bankia setacea* larvae would not settle on sterile surfaces; thus the formation of the bacterial layer on the settling surfaces may influence settling pattern.

It seems likely that most *Bankia gouldi* larvae stay in the darkest water, hence settle on the deepest objects (the bottom boards), and then search for the darkest surface (lower). *Bankia gouldi* larvae do crawl around for a while after they settle (Clench and Turner, 1946) so that they, like *Balanus eburneus* larvae, may be photonegative during that searching stage.

Bankia gouldi is the only one of the species considered in this study that lives on wood exclusively. Wood debris in the water is probably found either floating on the water surface, or lying on the bottom. Thus it would be most adaptive for larvae of a wood-boring organism to either swim to the surface or else to swim to the bottom before searching for a settling surface. The tendency for *Bankia gouldi* to settle most heavily at lower depths may have been due to a behavioral adaptation for locating a suitable habitat.

It is apparent that at least some of the species discussed have distinct settling patterns that probably relate to larval settling behaviors. To confirm any of the above proposed mechanisms, at least two environmental factors need to be considered, illumination at each settling and specific attractants such as microflora, bacteria, and substrate chemicals must also be considered.

It is interesting that for all species, there is relatively little settling of the total number on vertical surfaces. This may be important for future study of this community because often the fouling community is sampled using pieces of plywood placed vertically in the water (Turner, 1959). It is apparent that if this were the only sampling of the community that was done, one could get a distorted view of the make-up of the community, especially in a few species preferentially settled on vertical surfaces.

Literature Cited

1. Allee, W. C. 1923. Studies in marine ecology. III. Some physical factors related to the distribution of littoral invertebrates. Biological Bulletin 44(5): 205-253.

2. Barrington, E.J.W. 1965. Biology of Hemichordata and Protochordata. University Reviews in Biology, W.H. Freeman & Co. San Francisco. 176 Pages.

3. Broekhuysen, G.J. 1940. A preliminary investigation of desiccation, temperature, and salinity as factors controlling the vertical distribution of certain intertidal marine gastropods in False Bay, S. Africa. Trans. Roy. Soc. S. Africa 28(3): 255-292. (Cited in Moore, 1964. Pages 369-371.)

4. Butler, D.H., A. S. Kamlet, R. A. Monty 1969. A multi-purpose analysis of variance Fortran IV computer program. Technical Memorandum 4-69. U.S. Army Human Engineering Laboratories. Aberdeen Proving Ground, Maryland. 319 Pages.

5. Carriker, M. R. 1967. Ecology of estuarine benthic invertebrates: a perspective. In: Estuaries. C. H. Lauff, ed. Publication No. 83. American Assoc. for The Advancement of Science, Washington, D.C. Pages: 442-487.

6. Clapp, W. F., and R. Kenk, 1963. Marine Borers: An Annotated Bibliography, ACP-74, Office of Naval Research, Department of the Navy. Washington, D.C.

7. Clench, W.J. And B. D. Turner, 1946. The genus Bankia in the western Atlantic. Johnsonia i(19): 1-28.

8. Connell, J. H. 1961. The influence of interspecific competition and other factors on the distribution of the barnacle Chthamalus stellatus. Ecology 42: 710-723.

9. Coutant, C. C. 1968. Thermal pollution - biological effects. Journal of the Water Pollution Control Federation 46: 1947-1952.

10. Crisp, D. J. a1964. Racial differences between North America and European forms of Balanus balanoides. Journal of Marine Biological Association, United Kingdom 44: 33-45.

11. Crisp, D. J. b1964. Surface chemistry, a factor in the settlement of marine invertebrate larvae. In: Proceedings of the Fifth Marine Biological Symposium, Marine Botanical Institute, Goteborg. T. Levring, editor. ACTA Universitatis Gothoburgensis. Pages 51-65.

12. Crisp, D. J., and P. S. Meadows. 1963. Adsorbed layers: the stimulus to settlement in barnacles. Proceedings Royal Society of Britain 158: 364-387.

13. Culliney, J. L. 1970. Larval biology and recruitment of the shipworms Teredo navalis and Bankia gouldi in the New Port Estuary, North Carolina. Duke University, Ph.D., Zoology.

14. Daniel, A. 1957. Illumination and its effect on the settlement of barnacle cyprids. Proceedings of the Zoological Society, london 129: 305-313.

15. DePalma, J. R. 1968. An annotated bibliography of marine fouling for marine scientists and engineers. Journal of Ocean Technology 2(4): 33-44.

16. Dons, C. 1944. (Marine boring organisms. VII dependence of Teredo attack on structure and position of wood.) Norske, Vidensk, Selsk. Forh. 17(10): 40-42. (Cited in Clapp and Kenk, 1963.)

17. Fales, D. E. 1928. The light receptive organs of certain barnacles. Biological Bulletin, Woods Hole, 54: 534-547. (Cited in Clapp and Kenk, 1963.)

18. Friedrich, H. 1961. Physiological significance of light in marine ecosystems. In: Oceanography. American Association for the Advancement of Science. Publication 67. Pages 257-270.

19. Gosner, K. L. 1971. Guide to identification of marine and estuarine invertebrates. Wiley-Interscience. New York, New York. 693 Pages.

20. Grave C. and G. K. McCash. 1923. Perophora viridis. The activities and structure of the free-swimming larvae. Wash. Univ. Stud. sci. Ser. 11: 89-116.

21. Grave, C., and P. A. Nicholl. 1940. Studies of larval life and metamorphoses in Ascidia nigra and species of Polyandrocarpa. Papers, Tortugas Lab., Washington, 32: 1-46.

22. Grave, C., and Woodbridge, H. 1924. Botryllus schlosseri (Pallas): the behavior and morphology of the free-swimming larva. Journal of Morphology 39: 207-247.

23. Harger, J. R. E. 1972. Competitive coexistence among intertidal invertebrates. American Scientist 60(5): 600-607.

24. Haskin, H. H. 1964. The distribution of oyster larvae. In: Symposium on Experimental Marine Ecology; Occ. Publ. No. 2. Narranganset Marine Laboratory, University Rhode Island. Kingston, Rhode Island. Pages 76-80.

25. Hedgepeth, J. W. 1962. Intertidal zonation and related matters. In: Between Pacific Tides, Third Edition. E. F. Ricketts and J. Calvin. 1962. Revised by J. W. Hedgepeth. Stanford University Press. Stanford, California. Pages 345-372.

26. Imai, T., M. Hatanka, and R. Sato. 1950. Breeding of marine timber-borer, Teredo navalis L., in tanks and its use for anti-boring test. Tohoku Journal Agricultural 1(2): 199-208. (Cited in Clapp and Kenk, 1963.)

27. Isham, L. B., F. G. Walton Smith, and V. Springer. 1951. Marine borer attack in relation to conditions of illumination. Bulletin Marine Science, Gulf and Caribbean 1(1): 46-63.

28. Jardine, N., and R. Sibson. 1971. Mathematical Taxonomy. John Wiley and Sons, Ltd. New York. 286 Pages.

29. Johnson, S. C. 1967. Hierarchical clustering schemes. Psychometrika 32: 241-254.

30. Jones, G. F. 1969. The Benthic Macrofauna of the Mainland Shelf of Southern California. Allan Hancock Foundation, University of Southern California. Los Angeles, California. 219 Pages.

31. Kennedy, V. S., and J. A. Mihursky. 1967. Bibliography. University of Maryland Natural Resources Institute. Contribution 326.

32. Kinne, O. 1963. The effects of temperature and salinity on marine and brackish animals. I. Temperature. Oceanography and Marine Biology Annual Review 1: 301-340.

33. Kinne, O. 1967. Physiology of estuarine organisms with special reference to salinity and temperature: general aspects. In: Estuaries (Conference, Jekyll Island, 1964). G. H. Lauff, editor. American Association for the Advancement of Science, Washington, D. C. Publication No. 83. Pages 525-540.

34. Knudsen, M. 1962. Hydrographical tables. In: The Determination of Chlorinity by the Knudsen Method. G. M. Manufacturing Co. New York, New York. 63 Pages.

35. Lane, C. E. 1961. The Teredo. Scientitic American 204(2): 132-142.

36. Lewis, J. R. 1964. The Ecology of Rocky Shores. English Universities Press, Ltd. London. 323 Pages.

37. Loveland, R. E., G. Hendler, G. Newkirk. 1969. New records of nudibranchs from New Jersey. The Veliger 11: 418-420.

38. Margalet, D. 1958. Information theory in ecology. General Systems 3: 36-71.

39. Mawatari, S. 1950. (Biological and industrial study of marine borer problem in Japan). Suisan Dobutsu Nokenkyo 1(1): 45-124. (Cited in Clapp and Kenk, 1963.)

40. McDougall, K. D. 1943. Sessile marine invertebrates at Beaufort, North Carolina. Ecological Monographs 13: 321-374.

41. Meadows, P. S., and A. Reid. 1966. The behavior of Corophium volutator (Crustacea: Amphipoda). Journal of Zoology 150: 387-399.

42. Meglitsch, P. A. 1967. Invertebrate Zoology. Oxford University Press. New York. 834 Pages.

43. Miner, R. W. 1950. Field Book of Seashore Life. G. P. Putnam's Sons. New York, New York. 888 Pages.

44. Moore H. B. 1964. Marine Ecology. John Wiley & sons, Inc. New York. 493 Pages.

45. Moskovitz, M. R. 1971. Thermal addition and the diversity of the benthic macroinvertebrate community in Barnegat Bay. Thesis submitted to Rutgers University in partial requirement for Master of Science degree. 117 Page.

46. Naylor, E. 1965. Effects of heated effluents upon marine and estuarine organisms. Advances in Marine Biology 3: 63-103.

47. Nelson, T. C. 1923. Report of the Department of Biology, Marine Borers. New Jersey Agricultural College Experiment Station, New Bruswick, New Jersey. Pages 204-208.

48. Odum, B. P. 1971. Fundamentals of Ecology. Third Edition. W. B. Saunders Company. Philadelphia. 574 Pages.

49. Owen, G. 1953. Vertical distribution of Teredo norvegica. Nature (London) 171(4350): 484-485.

50. Oxner, M. 1962. Chloruration par la Methode de Knudsen. In: the Determination of Chlorinity by the Knudsen Method. G. M. Manufacturing Co. New York, New York. 63 Pages.

51. Pannell, J. P. M., A. E. Johnson, and J. E. G. Raymont. 1962. An investigation into the effects of warmed water from Marchwood Power Station into Southampton Water. Proceedings Inst. Civil Engineering 23: 35-62. (Cited in: Naylor, 1965).

52. Pielou, E. C. 1966. Species diversity and pattern diversity in the study of ecological succession. Journal of Theoretical Biology 10: 370-383.

53. Pielou, E. C. 1969. An Introduction to Mathematical Ecology. Wiley-Interscience. New York, New York. 285 Pages.

54. Ray, D. L. 1959. Marine Boring and Fouling Organisms. University of Washington Press. Seattle, Washington. 536 Pages.

55. Ricketts, E. F., and J. Calvin. 1962. Between Pacific Tides, Third Edition. Revised by J. W. Hedgepath. Stanford University Press. Stanford, California. 516 Pages.

56. Ryland, J. S. 1962. The effect of temperature on the photic responses of polyzoan larvae. Sarsia 6: 41-48.

57. Scheltema, R. S. and R. V. Truitt. 1954. Ecological factors related to the distribution of Bankia gouldi Bartsch. Chesapeake Bay Publication 100. Chesapeake Biological Laboratory. Solomon Islands, Maryland.

58. Smith, R. I., editor. 1964. Keys to Marine Invertebrates of the Woods Hole Region. Spaulding Co., Inc. Randolph, Massachusetts. 208 Pages.

59. Stephenson, T. A., and A. Stephenson. 1933. The universal features of zonation between tide marks on rocky coast. Journal of Ecology 37(2): 289-305.

60. Tabata, S., and R. J. LeBrasseur. 1958. Sea water instrusion into the Fraser River and its relation to the incidence of shipworms in Stevenson Cannery Basin. Journal of Fisheries Research Board of Canada 15(1): 91-113.

61. Thorson, G. 1950. Reproductive and larval ecology of marine bottom invertebrates. Biological Reviews 25: 1-45.

62. Thorson, G. 1964. Light as an ecological factor in the dispersal and settlement of larvae of marine bottom invertebrates. Ophelia 1: 167-208.

63. Turner, R. D. 1959. The status of systematic work in the Teredinidae. In: Marine Boring and Fouling Organisms; Friday Harbor Symposium. D. L. Ray, editor. University of Washington Press. Seattle, Washington. Pages 124-136.

64. Virgina Institute of Marine Sciences and University of Delaware Marine Laboratories. Taxonomic Keys and Checklists of Local Flora and Fauna. Not in publication.

65. Zelenky, C. H. 1905. The rearing of serpulid larvae with notes on the behavior of the young animals. Biological Bulletin, Woods Hole 8: 308-312.

APPENDIX

Sampling Scheme

The following table gives the time periods when each of the nine stations was sampled for the settling community.

Stations

Dates of Time Periods	Waretown	Oyster Creek Mouth	Oyster Creek Marina	Forked River Mouth	Forked River Bridge	Stouts Creek Mouth	Stouts Creek Winthrop St.	Forked River Intake	Oyster Creek Outfall
10/1971	x	x	x						
11/1971	x	x	x	x	x				
1/1972	x	x	x	x	x				
2/1972	x	x	x	x	x				
3/1972	x	x	x	x	x				
4/1972	x		x	x	x	x	x		
5/5-6/1/72	x	x	x	x	x	x	x	x	x
5/22-6/1/72	x	x	x	x	x	x	x	x	x
5/22-6/20/72	x	x	x	x	x	x	x	x	x
6/1-6/20/72	x	x	x	x	x	x	x	x	x
6/1-7/5/72	x	x	x	x	x	x	x	x	x
6/20-7/5/72	x	x	x	x	x	x	x	x	x
6/20-7/5/72*	x	x	x	x	x	x	x	x	x
7/5-7/19/72	x	x	x	x	x	x	x	x	x
7/5-8/6/72	x	x	x	x	x	x	x	x	x
7/19-8/6/72	x	x	x	x	x	x	x	x	x
7/19-8/18/72	x	x	x	x	x	x	x	x	x
8/6-8/18/72	x	x	x	x	x	x	x	x	x
8/6-8/31/72	x	x	x	x	x	x	x	x	x
8/18-8/31/72	x	x	x	x	x	x	x	x	x
8/18-9/15/72	x	x	x	x	x	x	x	x	x
8/31-9/15/72	x	x	x	x	x	x	x	x	x
8/31-9/29/72	x	x	x	x	x	x	x	x	x
9/15-9/29/72	x	x	x	x	x	x	x	x	x
9/15-10/13/72	x	x	x	x	x	x	x	x	x

*All samples taken after and including this time period were analyzed for each board surface (surface orientation) as well as for depth, station and time.

Salinity Data

The following table gives the salinity data collected for every sampling data and station. (Salinity in o/oo.)

Dates of Time Periods	Waretown	Oyster Creek Mouth	Oyster Creek Marina	Forked River Mouth	Forked River Bridge	Stouts Creek Mouth	Stouts Creek Winthrop St.	Forked River Intake	Oyster Creek Outfall
1972									
1/27	29.99	20.70	20.15	22.37	20.28	22.25			
2/5	23.33	20.31	21.52	26.11	23.39				
2/15	28.33	22.64	23.76	25.25	24.77	22.15	13.39		
3/7		19.79	20.32	20.85	20.53	20.10	11.68		
3/21	22.87	19.17	18.45	20.09	19.65	20.01	5.77	19.60	20.23
3/31	21.02	20.01	20.04	20.82	20.01	21.00	12.88	20.64	20.80
4/18	22.81	20.21	20.00	22.69	22.36	20.31	11.21	22.54	22.64
5/5	23.51	18.01	18.21	21.37	10.07	16.09	11.09	20.50	20.34
5/22	16.55	15.50	15.52	17.51	15.90	15.15	11.61	17.00	17.01
6/1	22.22	17.10	17.15	20.25	16.54	19.32	13.15	18.30	18.34
6/20	18.89	17.55	17.59	19.45	19.20	18.76	6.01	18.50	18.53
7/5	20.76	18.78	18.79	18.09	17.70	18.77	11.25	18.10	19.12
7/19	21.80	19.00	19.30	20.38	19.77	18.00	9.90	19.05	20.05
8/6	22.31	19.80	19.91	19.30	19.87	19.77	14.22	18.93	19.98
8/18	24.05	22.45	22.65	23.80	22.76	22.62	19.32	22.61	23.20
8/31	21.89	21.05	21.30	21.66	21.39	21.70	15.94	21.38	22.18
9/29	23.63	22.36	22.13	22.52	22.31	22.62	8.71	22.13	22.13
10/13	21.91	20.30	20.04	21.26	20.75	19.52	15.92	20.80	20.65

Temperatuire Data

The following table gives the temperature data (°C) collected for every sampling date and station.

Station

Dates of Time Periods	Waretown	Oyster Creek Mouth	Oyster Creek Marina	Forked River Mouth	Forked River Bridge	Stouts Creek Mouth	Stouts Creek Winthrop St.	Forked River Intake	Oyster Creek Outfall
1971									
10/5	14.70	14.10	14.10	13.30	13.80	15.00			
1972									
1/27	3.00	12.50	14.40	2.09	2.81	4.50	5.00		
2/5	-3.00	5.04	6.48	0.80	1.61				
2/15	4.61	10.99	10.09	4.49	4.33	6.08	7.09		
3/7		9.67	10.53	8.15	9.04	6.00	6.70		
3/21	7.52	12.52	13.52	7.10	6.98	6.89	10.75	7.45	20.23
3/31	9.50	12.04	17.50	6.38	6.79	6.40	7.02	6.45	18.74
4/18	12.98	17.67	18.68	13.61	13.51	13.69	16.35	12.35	22.65
5/5	16.38	16.09	16.00	16.15	16.31	16.00	16.98	16.00	16.00
5/22	16.90	13.30	16.71	17.05	17.85	17.75	18.61	17.00	17.00
6/1	19.52	19.00	19.48	19.50	19.83	19.98	19.87	19.45	19.50
6/20	22.33	28.25	22.21	22.28	22.86	23.48	24.23	22.30	22.25
7/5	22.95	29.25	28.21	22.67	22.95	22.98	22.25	23.85	33.72
7/19	29.50	34.50	35.88	30.95	30.75	32.38	32.75	30.95	39.38
8/6	22.35	28.55	27.85	22.98	23.75	24.45	25.55	22.98	31.45
8/18	22.11	26.95	26.61	22.20	22.40	22.52	24.78	22.25	29.00
8/31	23.00	30.65	30.80	25.65	25.86	25.20	27.28	24.92	35.36
9/15	22.30	28.89	29.10	23.30	22.30	21.9	23.5	23.5	33.5
9/29	21.8	25.2	25.9	19.6	19.1	19.2	18.3	19.2	30.5
10/13	15.5	20.5	21.0	15.8	15.8	15.9	14.5	15.9	26.1

Number of Individuals of Each Species

Number of individuals which settled are given for each species. Sampling date, Station (1 = Waretown, 2 = Oyster Creek Mouth, 3 = Oyster Creek Marina, 4 = Forked River Mouth, 5 = Forked River Bridge, 6 = Stouts Creek Mouth, 7 = Stouts Creek Winthrop St., 8 = Forked River Intake, 9 = Oyster Creek Outfall), Board (T = Top, B = Bottom) and Surface Orientation (U = Upper, S = Side, L = Lower) are designated for each datum. Values given are raw data; thus Side-Surface Orientation values must be multiplied by 0.75 to obtain values for number-of-individuals-per-surface-area that are proportional to values for the Upper and Side Surfaces.

Date		Station 1	2	3	4	5	6	7	8	9
<u>Ampalisca macrocephala</u>										
1972:										
5/22-6/20	T								2	
	B								2	
6/1-6/20	T	1								
	B									1
6/1-7/5	B								1	
<u>Balanus eburneus</u>										
10/1971	T	39		4						
	B	7	5	18						
1972:										
1/2-2/5	T			19						
	B	31	24	589	6	796				
2/5-3/7	B		6	2						
3/7-3/31	B		10	2	1	1	6			
3/31-5/5	T								22	
	B								47	
5/5-6/1	T	14	4	53		10	3		27	30
	B	3	10			11	108	1		20
5/22-6/1	T	3							5	
	B						3	8	5	
5/22-6/20	T		43	250	2		553	20	1180	251
	B		46	210			400	5	3000	
6/20-7/5	T	3		50	30		183		340	88
	B	18		190	30	5	10	7	315	
6/1-7/5	T	500		422	50	255	431	42	439	196
	B	508		237	20	280	554	15	649	303
6/20-7/5	T	700		24	2	5	67	20	52	52
	B	52		29	2	1	10		86	39
7/5-7/19	T-U	19				6		23		
	T-L	94		16	4	75		22	112	
	T-S	2		6		13	1	4	22	
	B-U					1			2	
	B-L	2	2		3	29		2	76	
	B-S							1	27	
6/20-7/19	T-U		1	15			33	6	27	
	T-L		12			6	5	6	110	
	T-S	119	4	8			19	10	83	
	B-U		4	6		1	10	10	30	
	B-L	1		45		1	50	63	78	
	B-S		2	19		1	8	65	118	

Date		Station 1	2	3	4	5	6	7	8	9
Balanus eburneus										
7/5-8/6	T-U	30	1					110	1	
	T-L	98	5	18		14		119	9	82
	T-S	5		5		2	1	356	9	
	B-U	1				14		20		4
	B-L	5	6	18	1			48	88	19
	B-S	1	4	6		2		79	46	45
7/19-8/6	T-U			3				26		
	T-L	1	12	31				180		
	T-S		1	11				331	3	
	B-U		2	3	1			5	1	
	B-L		10	23				30		
	B-S			13				138	2	
7/19-8/18	T-U			21				24		
	T-L					1		97	1	1
	T-S	1		6				150	3	
	B-U			11						
	B-L							61	13	
	B-S			12			5	93	2	
8/6-8/18	T-U			1					2	1
	T-L	2					5	6	3	
	T-S	1						1	2	
	B-U					2	2			
	B-L							5		
	B-S			2		2		1		
8/6-8/31	T-U		4		67	55	4	1	8	4
	T-L		12	39	104	1	18	2	21	20
	T-S		1	9	38	27	10		11	13
	B-U		4	1	5		2	1	31	5
	B-L		17	20	25	18	2	13	46	25
	B-S		10	15	18	18	1	5	48	17
8/18-8/31	T-U				14	2			2	
	T-L			31	109	12	4	2	22	
	T-S			7	3	13	9	1	14	
	B-U			2	2				31	
	B-L			18	7				12	
	B-S				11			3	16	
8/31-9/15	T-U			5	8		216		35	8
	T-L	9		12	9	102	310	1	321	58
	T-S	7		12	38	134	200		103	31
	B-U			8	33	5	57		75	10
	B-L	1		24	113	124	332		236	52
	B-S			8	121	151	239		259	27
8/18-9/15	T-U	17		1	8		12		53	4
	T-L	97		60	31		166	2	38	26
	T-S	59		18	2	7	101	6	29	
	B-U			1	2		47		70	7
	B-L	2		39	13		88	5	134	108
	B-S	3		13	5		55		115	37

Date		Station 1	2	3	4	5	6	7	8	9
Balanus eburneus										
9/15-9/29	T-U		3	2	5	8	1		36	
	T-L		10	19	80	74	13	4	251	3
	T-S		4	2	6	81	34	6	224	19
	B-U		6	3	4	61	21		254	20
	B-L		15	39	27	5	12		27	22
	B-S		5	20	7	38	5		127	25
8/31-9/29	T-U		2	35		5	40		239	166
	T-L		13	33		104	67		329	45
	T-S			47		84	88		9	25
	B-U		7	8		3	40	1	133	44
	B-L		5	36		85	90	16	373	150
	B-S		4	22		94	55	16	202	76
9/15-10/13	T-U	5	11	2		1			1	10
	T-L	6	44	7	37	50	33	15	15	96
	T-S	3	10		2	44	24	3	7	54
	B-U		5	1	23		3		54	4
	B-L	3	16	26	20	27	30	14	197	17
	B-S		10	4		22	10	6	90	27
6/1-7/5	T	2			3					
	B				10					
7/5-7/19	T-L				32	3			1	
	T-S				2	3				
	B-U				1	1				
	B-L	2			17	3	3			
	B-S	1	1		21	1	7			
6/20-7/19	T-U			1		2	1			
	T-L	4			8	7	10			
	T-S			1	2	2	1			
	B-U	1		1	4	4				
	B-L				49	9	13			
	B-S	4	2	1	14	11	2			
7/5-8/6	T-U	33	1	3	18	1			4	
	T-L	259		1	76	87				
	T-S	113			32	16	1			
	B-U	233		1	101	105	3		11	
	B-L	372			202	8	48		1	
	B-S	256		1		7	8		2	
7/19-8/16	T-U	30		1		2				
	T-L	78			3	1				
	T-S	13		2	9	1				
	B-U	29	1		41	68			1	
	B-L	148			79	72	22			
	B-S	25		1	71	59	17			
8/6-8/18	T-U	1			1					
	B-U	1			1	1				
	B-L	5			2					
	B-S	2			1					
7/19-8/18	T-U	30			11	2				
	T-L	80		3	45	2	2			
	T-S	20		2	12	22	1			

Date		Station 1	2	3	4	5	6	7	8	9
7/19-8/18	B-U	41			18	124	33		1	
	B-L	160			53	16	44			
	B-S	31		1	45	37	21			
8/18-9/15	T-L	1								
	B-L				2					
8/6-8/31	T-U				2					
	T-L				2					
	T-S				1					
	B-L				11					
	B-S		1		15					
8/18-8/31	T-L				1					
	B-S				1					
<u>Bittium alternatum</u>										
7/5-7/19	T-U	1								
6/20-7/19	T-U					1				
7/19-8/6	T-U					1				
7/5-8/6	T-L					1				
7/19-8/18	B-U					1				
	B-L					1				
8/6-8/18	B-S				1					
8/6-8/31	T-U					1				
	T-L		1							
	B-L						1			
8/18-8/31	B-U	1	1							
9/15-9/29	B-S						1			
8/18-9/15	B-L	1								
	B-S	1								
8/31-9/15	T-L	1								
<u>Botrvllus schlosseri</u> (in % surface covered)										
10/1971	T	5								
1972										
5/22-6/20	T						0.5		0.1	
8/18-8/31	B-L	1								
8/6-8/31	B-L						30			
	B-S						20			
8/31-9/5	T-U						0.01			
	T-L	2				1	5			
	T-S					0.01	1			
	B-L	1				1	5			
	B-S					0.1	5			
8/18-9/15	T-L	1					50			
	T-S	0.1								
	B-U						30			
	B-L	10					75			
	B-S	5					80			
9/15-9/29	T-L					0.5	10			
	T-S						10			
	B-U	5				1	1			
	B-L						20		1	
	B-S					1	15			

Date		Station 1	2	3	4	5	6	7	8	9
Botryllus schlosseri										
8/31-9/29	T-L	2				1	50		5	
	T-S					5	50			
	B-L					5	95		5	
	B-S				0.1	70	50	5		
9/15-10/13	T-U						1			
	T-L					80	50			
	T-S	1				10	50			
	B-U						1			
	B-L	10				1				
	S-S					1	75			
Bowerbankia cracilis (in % surface covered)										
10/1971	T			20						
	B			30						
1972										
6/20-7/5	T							70	70	90
	B									80
7/15-7/19	T-U		70							
	T-L		30						10	
	T-S		50							
	B-L							10		
6/20-7/19	T-U							20		
	T-L		50	50				20		
	T-S		10					20		
	B-U							50		
	B-L			70				70		
7/5-8/6	T-U	1	80	85	20	5			20	
	T-L		90	85		10				
	T-S		70	80						
	B-U		5	80			20	5	30	
	B-L		70	90		15	20	80	45	
	B-S		80	70				70		
7/19-8/6	T-U	30	20	30			20	95	15	
	T-L	20	30					100		
	T-S	20						85		
	B-U	5	20	20			30		50	
	B-L	5	30	30				40		
	B-S		1				5	80		
7/19-8/18	T-U			40	1			25	60	10
	T-L			95			1	45	70	5
	T-S			40				30		
	B-U				2			70		
	B-S							15		
8/6-8/18	T-U	20		40			15		5	10
	T-L			50			20			
	T-S	10		50			15			
	B-U	2		15	1	1	5	60	5	5
	B-L	5		5				80	20	
	BOS			50	5			85	15	
8/6-8/31	T-U			20				30		
	T-L			50						

Date		Station 1	2	3	4	5	6	7	8	9
<u>Bowerbankia gracilis</u>										
8/6-8/31	T-S			40				70		
	B-U		70	60	80			40	70	
	B-L		80	80		40		80	80	
	B-S			80				60	90	
8/18-8/31	T-U							80	70	
	T-L			80					60	
	T-S								50	
	B-U	70		40				30	70	
	B-L							50	80	
	B-S	10							60	
8/18-9/15	T-U	80			50			20	50	40
	T-L	70			70			20	40	70
	T-S	75						20	30	40
	B-U	40							70	40
	B-L								50	80
	B-S								60	80
8/31-9/15	T-U	30		80				40	75	
	T-L	50		80		10				
	T-S	30		80						60
	B-U	0.1		20				40	15	50
	B-L			40				40		70
	B-S	1						40		
8/31-9/29	T-U		5	70		20	50		80	80
	T-L		60	80		30		50	70	80
	T-S		20	70		60	20		25	
	B-U		10	70		30	5	50	90	90
	B-L		70	70		10			40	95
	B-S			70		60		30		80
8/31-9/15	T-U	80		30				20		10
	T-L	90		30			15	10		60
	T-S	90		40			1	5		30
	B-U	10		50						
	B-L	10		40						20
	B-S	45		40				10		10
9/15-10/13	T-U			80		5	50	70	10	10
	T-L	90	80	80			33		95	45
	T-S	95	70						80	40
	B-U	80	5	40			60		80	50
	B-L	80	15	30					70	90
	B-S	75	5	20		15			95	70
<u>Callipallene brevirostris</u>										
8/6-8/31	B-U				6					
	B-L				8					
	B-S				6					
8/31-9/15	T-U								3	
	T-L								21	
	T-S								4	
	B-U								11	
	B-L								6	
	B-S								15	

Date		Station 1	2	3	4	5	6	7	8	9
<u>Calligallene brevirostris</u>										
8/18-9/15	B-U							2		
	B-L				1					
	B-S							1	2	
8/31-9/29	T-U								2	
	T-L								2	
	B-U								5	
	B-L								9	
	B-S								12	
9/15-10/13	T-L									1
	T-S	1								
	B-S	1								
	B-L	1								
	B-S									1
<u>Capitella capitata</u>										
6/1-7/5	B							1		
6/20-7/5	T		1							
8/6-8/18	B-U						1			
7/19-8/18	B-S							5		
	T-U							10		
	T-L							5		
8/6-8/31	T-S					1		3		
	T-L							2		
8/31-9/15	T-L							1		
	T-S							7		
8/18-9/15	T-U							23		
	T-L							18		
	T-S							68		
<u>Caprella geometrica</u>										
8/6-8/31	T-L								2	
	B-U								2	
	B-L				4				3	
	B-S				2					
6/1-7/5	B				1					
7/19-8/18	B-L				1					
	B-S				1					
8/18-9/15	T-U								5	
	T-L								89	
	T-S								30	
	B-U							1	13	
	B-L								13	
	B-S								4	
8/31-9/15	T-U								11	
	T-L								4	
	T-S			1					9	
	B-U								30	
	B-L								20	
	B-S								30	
9/15-9/29	B-L								1	
8/31-9/29	T-U								5	
	T-S								1	
	B-U								2	

Date		Station 1	2	3	4	5	6	7	8	9
<u>Caprella geometrica</u>										
8/31-9/29	B-L								2	
	B-S								2	
9/15-10/13	T-L								7	1
	T-S								2	
	B-U									1
	B-L								32	8
	B-S									3
<u>Cirolana concharum</u>										
6/20-7/19	T-1	1								
<u>Corophium cylindricum</u>										
3/31-5/5	T	3		3	2	3				350
	B	5								400
5/5-6/1	T	25					20		2	
	B	25								
5/22-6/20	T		3			3	55		2	80
	B	2	2		5		30		50	
6/1-7/5	T			2	1		6			
	B			2			16			
6/20-7/5	T	1							1	
	B						4			
7/5-7/19	T-L	2								
	B-U	1								
	B-S								2	
6/20-7/19	T-U	1				2	3		2	
	T-S	1								
	B-U					3	1			
	B-S						1			
7/5-8/6	T-U					1				
	T-L					1				
	B-U						2			
	B-L				1	1	1			
7/19-8/6	T-U						1	1		
	B-U							2		
	B-L							1		
7/19-8/18	T-S								1	
	B-U				2	2	1		5	1
	B-S				2					
8/6-8/18	B-U					1				
	B-L				1				1	
	B-S	1				1			2	
	T-U	1				2				
8/6-8/31	B-U		1		3					
	B-L		1			1				
8/18-9/15	B-U								1	
8/31-9/15	B-L	1								
8/31-9/29	T-U								2	
9/15-9/29	B-L					1				
<u>Cyathura polita</u>										
6/20-7/19	T-S								1	
	B-U								1	

Date		Station 1	2	3	4	5	6	7	8	9
Cyathura polita										
8/18-8/31	B-U								1	
8/6-8/31	B-U				17					
	B-L				18					
	B-S				42					
	T-L				13					
Crepidula fornicata										
11/1971	B	1								
1972										
6/20-7/5	B	1				1				
7/19-8/6	T-U					1				
	T-L	1								
6/20-7/19	T-L	1								
	B-L		2							
7/5-8/6	B-L	1								
7/19-8/18	B-S					1				
8/6-8/18	B-S	1								
8/18-8/31	B-U	3					1			
	B-S	1				1	1			
	T-U			16						
	T-S					1				
8/31-9/15	T-U	2								
	T-L	7								
	T-S	3								
	B-U	4			1					
	B-L	1				1				
	B-S	5								
8/18-9/15	T-U	15								
	T-L	2								
	T-S					1				
	B-U	4								
	B-S	4								
9/15-9/29	T-U	1								
	B-U	6								
	B-L	27								
	B-S	5								
9/15-10/13	T-U	6								
	T-S	6								
	B-U	35								
	B-L	34								
	B-S	14								
Diadumene leucolena										
7/19-8/6	B-U				4				1	
7/19-8/18	B-U								4	
8/31-9/15									1	
Diopatra cuorea										
6/20-7/19	B-L								1	
Doridella obacura										
11/1971	B		1							
7/5-7/19	T-U									
	B-U						2			
	B-L				11	2				

Date		Station 1	2	3	4	5	6	7	8	9
7/5-7/19	B-S				9			5		
6/20-7/19	T-L					1	3			
	B-U					1				
	B-S					3				
7/19-8/6	T-L				2					
7/5-8/6	B-L						2			
7/19-8/18	T-U				2				1	
	T-L				1	13	1			
	T-S								1	
	B-U								3	
	B-L					3			4	
	B-S					1				
8/6-8/18	B-L					1				
8/6-8/31	T-L						2			
	B-U				3					
8/18-9/15	T-1						1			
8/18-8/31	B-S				4					
9/15-10/13	T-U	2								
	T-S	1								
<u>Erichsonella sp.</u>										
6/20-7/5	T	1								
<u>Eteone trilineata</u>										
6/1-7/5	T	1								
<u>Electra hastingsae</u>(in % surface covered)										
7/19-8/6	B-U	0.5								
	B-L	1								
6/20-7/19	T-U	10	50							
	T-L	40	60				1			
	T-S	15	22							
	B-U	1	80							
	B-L	50	25				8			5
	B-S	2	40			5	0.5			
7/5-8/6	T-U	50					5		10	
	T-L	5				5			75	
	T-S	60				25				
	B-U	10								
	B-L	60	5		10	10	0.5			
	B-S	50					0.2		20	
7/19-8/6	T-U	80							50	
	T-L	70							60	
	T-S	70								
	B-U	15							80	
	B-L	25							85	
	B-S	20							80	
7/19-8/18	T-U	30				80	40		75	
	T-L	1				80	30		65	
	T-S	15			30	70	60			
	B-U				20		30		90	
	B-L				60	60	30			
	B-S				5	40	40			
8/6-8/18	B-U					0.1				
	B-L							0.1		

Date		Station 1	2	3	4	5	6	7	8	9
<u>Electra hastingsae</u>										
8/6-8/31	B-L				5		5			
8/18-9/15	T-L						25			
8/31-9/29	T-L					0.5				
	T-S					0.1				
	B-L					0.5				
9/15-9/29	T-L						15			
9/15-10/13	T-L	25				1				
	T-S						0.1			
	B-L				0.5	12				
<u>Euplana gracilis</u>										
6/20-7/19	T-U					1	1			
7/5-7/19	T-U						1			
7/19-8/6	B-U		1							
	B-L		1							
8/6-8/19	B-L				1					
9/15-9/29	T-U						1			
9/5-10/13	B-L						1			
<u>Goniada maculata</u>										
7/19-8/6	T-U					3				
7/19-8/18	B-U				1					
<u>Haliclona canaliculata</u> (in % surface covered)										
7/18-8/18	T-L					1				
8/6-8/31	T-U					10				
8/18-9/15	T-L						4			
8/31-9/29	B-S						0.1			
	B-L				0.01					
9/15-9/29	B-U						0.01			
<u>Haliplanella luciae</u>										
7/5-8/6	T-U				5					
	T-L				3					
	B-L				3	2				
7/19-8/6	T-U								1	
8/6-8/18	B-L				1					
7/19-8/18	B-S								1	
8/6-8/31	T-S				1					
8/18-8/31	T-S					1				
	B-S					1				
8/31-9/15	B-L								1	
	T-L				1					
	T-U				1					
8/18-9/15	B-L				3					
8/31-9/29	T-U						1			
	B-U								1	
8/31-9/15	T-U									1
9/15-10/13							1			
<u>Hydroidus dianthus</u>										
6/1-7/5	T	19					14			
6/20-7/5	B	32				8				
	T						1			
7/5-7/19	T-U	6					1			

Date		Station								
		1	2	3	4	5	6	7	8	9
<u>Hydroides dianthus</u>										
7/5-7/19	T-L	131			1	5	14		2	
	T-S	129					14		1	
	B-U	12			1					
	B-L	220			6	30	28		6	
	B-S	51			2	4	28			
6/20-7/19	T-U	3								
	T-L	1332				12	25			
	T-S	260				6	4			
	B-U	180			4				2	
	B-L	1060			2	15	1		5	
	B-S	540			2	20	5		3	
7/5-8/6	T-U	54					1		4	
	T-L	3000			112				3	
	T-S	400								
	B-U	380			1					
	B-L	402			5976	17	101			
	B-S	150				14	93			
7/19-8/6	T-U	1							8	
	T-L					4			12	
	T-S					5			7	
	B-U								12	
	B-L	86			1				5	
	B-S	9				11			6	
7/19-8/18	T-U	450								
	T-L	6300				9				
	T-S	1020								
	B-U				1				17	
	B-L					2	1			
	B-S				1	8	13		6	
8/6-8/31	B-U				1		1			
	B-L				5	1	10			
	B-S				2		23			
	T-U						1			
	T-L				1		2			
8/18-8/31	B-L						1			
	B-S				31					
8/31-9/15	T-L					1			1	
	T-S								1	
	B-U	1								
	B-L	20			1		280		3	
	B-S	16					58			
8/18-9/15	T-U						5			
	T-L						33			
	T-S	1								
	B-L	27					11			
	B-S	3					4			
9/15-9/29	T-L						6	1		
	T-S					1	15			
	B-U					9	33			
	B-L						8			
	B-S				1		12			

Date		Station 1	2	3	4	5	6	7	8	9
Hydroides dianthus										
8/31-9/29	T-L			1		18	7	1	1	
	T-S					2				
	B-U						72			
	B-L			2		25	75		3	
	B-S			1		8	72			
9/15-10/13	T-L		1		1	3				1
	T-S	3								
	B-L	17				9	60			
	B-S	50					39			
Leptochelia savignyi										
6/1-7/5	T								1	
6/20-7/19	B-U					1			1	
7/19-8/6	B-U		1							
7/5-8/6	T-L					1				
8/6-8/18	B-U				1					
7/19-8/18	B-L					1				
8/6-8/31	T-U		2			2				
	T-L					1				
9/15-10/13	T-L		1							
Membranipora sp. (in % surface covered)										
11/1971	T	50		10						
	B	10	50	20						
1/1972	B	0.1		5						
5/7-5/31	T		50	10			0.5	5	40	1
	B		50					1		
5/22-6/20	T	5		1	0.1	0.1	0.1	95	0.1	
	B	10	80	5	30	0.1		5		
6/1-6/20	T	0.1					5	40		
	B	0.5					0.1	70		0.1
6/1-7/5	T	5			10	45				
	B	20		5	50	35			1	
6/20-7/5	T	2			1	7	10	10		
	B	0.5		5	1	5	5	0.5	1	
7/5-7/19	T-U							0.1	0.1	
	T-L		0.1		0.05	0.1	0.5	1		
	T-S	0.5			0.03	0.05	0.5			
	B-U	0.1				0.1	1			
	B-L				1	0.1	1	1	0.1	
	B-S	2				0.05				
6/20-7/19	T-U	5			10	5	1	95		
	T-L	20	5	1		50	2	95	15	
	T-S	10	1	1		12	0.5	95	10	
	B-U		1	1	10		0.5	60	30	
	B-L		0.5	5	5	30	1	65	40	
	B-S			1		12	4		20	
7/5-8/6	T-U		20			6	80			
	T-L		80		70		5			
	T-S				10	3	80			
	B-U		5			25	5		25	
	B-L		70			15			10	
	B-S		10			35				

Date		Station 1	2	3	4	5	6	7	8	9
7/19-8/6	T-U				50	5	40			
	T-L				90	75	40			
	T-S				60	70				
	B-U				10	15	5			
	B-L				60	95	30	1		
7/19-8/18	T-U				20					
	B-U						10			
	B-L						40			
	B-S						40			
8/6-8/18	T-U					0.05	0.05			
	T-L						0.05	0.05		
8/6-8/31	T-U				5					
	T-L				30		35	2	6	
	T-S			0.5	4	0.5	20			
	B-U						0.05			
	B-L					5		2	1.5	
	B-S				4		1	1	4	
8/18-8/31	T-L				1					
	B-L				1					
8/18-9/15	T-U		80		1					
	T-L		80				5			
	T-S		80						0.5	
	B-U	0.01	70						1	
	B-L		70		3				1	
	B-S		70						5	
8/31-9/15	T-L					0.01				
	T-S						0.01		0.1	
	B-U								0.5	
	B-L			0.01		0.5			0.5	
8/31-9/29	T-U		5	15					0.1	
	T-L		0.5			1	0.01			
	T-S		20			0.01				
	B-U						1			
	B-L		7			1			2	
	B-S		10			0.1				
9/15-9/29	T-U					0.01		1		
	T-S					0.1		0.5		
	B-U					0.5	0.01			
	B-L						0.01			
	B-S								0.1	
9/15-10/13	T-U		0.01					0.05		
	T-L							50		
	T-S							5		
	B-U	0.1			0.01		0.1	5		
	B-L	1	0.01						40	
	B-S		0.01						5	
Melita nitida										
10/1971	T	1								
	B		1							
1972										
3/31-5/5	T					1				
	B			1						

Date		Station 1	2	3	4	5	6	7	8	9
Melita nitica										
4/18-5/22	B								2	
6/1-7/5	T					1				
	B				2		1			
6/20-7/5	T				1					
	B				2					
6/20-7/19	T-U	4				59	10			
	T-L						1			
	T-S					1				
	B-U	1				31				
	B-L					2				
7/5-7/19	T-U					2	1			
	T-L					1				
	B-U					5	10			
	B-S						1			
7/5-8/6	T-U				1					
	B-L				1					
7/19-8/6	T-U	3			1	1				
	B-U				1		2			
	B-S				1					
7/19-8/18	T-S								3	
	T-L			1						
	B-U				2				8	
	B-L				4	2			3	
	B-S				1	3				
8/6-8/18	B-U								1	
	B-L								1	
	B-S					1			1	
	T-U				1					
	T-L								2	
	T-S	1								
8/6-8/31	T-U		7		24	6	14			
	T-L		2		69	4	3		3	
	T-S		3		8	4	1		3	
	B-U		3		99	8	3		5	
	B-L		5		16	1		1	2	
	B-S		1		40	11	2		2	
8/18-8/31	T-U			1	2	6	2		2	
	T-L				1	3	1			
	T-S				1		1			
	B-U	3	43		2	9	9	1	5	
	B-L		2		4	8	3			
	B-S		4		2				1	
8/31-9/15	T-U				4		1		3	
	T-L	1		1	12	1			30	
	T-S				7	6			1	
	B-U	1			1				14	
	B-L				2		2		18	
	B-S				3					
8/18-9/15	T-U	2			1				1	
	T-L	1			1		1		1	
	T-S				1		1			

Date		Station 1	2	3	4	5	6	7	8	9
Melita nitica										
8/18-9/15	B-U	6			1				5	
	B-L	3			7				2	
	B-S	3			1				2	
8/31-9/29	T-U		1			2			14	
	T-L		1	1			1		4	
	T-S			1					2	
	B-U		2				4		10	
	B-L		2				1		8	
	B-S					2			4	
9/15-9/29	T-U				1	1				
	T-L				1					
	T-S		1			1			2	
	B-U					2			2	
	B-L	3		1		2				
	B-S	1				1	1			
9/15-10/13	T-U	4	2		2	2			1	
	T-L				2					
	T-S				1				2	
	B-U	1	1		2		1			
	B-L	1	2				1			1
	B-5	2	1				2			1
3/31-5/5	B					1				
7/5-7/19	B-U				2					
7/19-8/6	B-U					1	1			
7/19-8/18	B-U				1					
	B-L								1	
8/6-8/31	B-U						1			
	T-L		1			1				
9/15-10/13	B-U	1								
	B-L	1								
	B-S	8								
8/18-8/31	T-U	1								
	B-U		1							
Molgula manhattensis										
10/1971	T	51								
	B	1								
6/1-7/5/72	T						2			
	B						25		1	
6/20-7/19	T-U					3	2			
	T-L					1	6			
	B-L						4			
7/5-8/6	T-U					21			2	
	T-L					39				
	T-S								1	
	B-U	1				37				
	B-L	4			1	8				
	B-S	680				4				
7/19-8/6	B-S					1				
7/18-8/18	T-L					38			1	
	B-L					7				
	B-S								2	

Date		Station 1	2	3	4	5	6	7	8	9
Molgula manhattensis										
8/6-8/18	T-L			1						
	B-L					3				
8/6-8/31	T-U					90	4			
	T-L						48			
	T-S					4	2			
	B-U	7				1	4			
	B-L					57	3			
	B-S					6	1			
8/18-8/31	T-U			2						
	T-L	2								
	B-L					2	1			
8/31-9/15	T-L	1				3				
	B-L						4			
8/18-9/15	T-U	1					10			
	T-L	2					9			
	T-S	4					4			
	B-U	2					19			
	B-L	20		1	5				2	
	B-S	3			1		2		8	
9/15-9/29	T-L					1	4			
	B-U					1	3			
8/31-9/29	T-U		1							
	T-L		3			308	75			
	T-S					25				
	B-U						19		3	
	B-L		16	1		232	30		3	
	B-S		1			25	4		8	
9/15-10/13	T-U		1					1		
	T-L	12				29	53			
	T-S	1				10	20			
	B-U	7					3			
	B-L	64				73	25			
	B-S	24				16	16			
Mytilus edulis										
1/1972	B		1							
3/31-5/5	T				1					
	B									1
8/6-8/31	B-L		1							
Nereis succinea										
10/1971	T	5		1						
	B		2	1						
5/5-6/1	T									1
	B									1
6/1-7/5	T							1		
	B					1	9			
6/20-7/5	T							1	3	
	B					1		1	9	
6/20-7/19	T-U	8				5	3			
	T-L		1				2			
	B-U	6			11	18			1	
	B-L	1		4		2	1	2	5	

Date		1	2	3	4	5	6	7	8	9
					Station					
Nereis succinea										
6/20-7/19	B-S				3			1	4	
7/5-7/19	T-U					7			2	
	T-L			1					6	
	T-S								1	
	B-U					1	1		1	
	B-L								3	
	B-S						1		2	
7/5-8/6	T-U					9	2			
	T-L		1	1	1	1		1		
	T-S							1		
	B-U					2	1			
	B-L		1		2	1	1			
	B-S					1				
7/19-8/6	T-U	1			4					
	T-L		1		1					
	T-S		1				1			
	B-U	1			1	1	4			
	B-L		2							
	B-S		3				1			
7/19-8/18	T-U							1	1	
	T-L			2		3	2			
	T-S			2					3	
	B-U			5	1	2			4	
	B-L			1	2					
	B-S			2	1				1	
8/6-8/18	T-U			1						
	T-S				1					
	B-U			1					2	
	B-L				2				1	
	B-S								1	
8/6-8/31	T-U		3	1	2		4			
	T-L		1	2	1		1		1	
	T-S			1						
	B-U		1	3	5		2			
	B-S					1				
8/18-8/31	T-U						1			
	T-L			1						
	B-U				1					
	B-L						1			
	B-S					2				
8/18-9/15	T-U	2					10	1	1	
	T-L	1			4		5		1	
	T-S			1			1			
	B-U				3		6			
	B-L	1			10				1	
8/31-9/15	T-U			1						
	T-S	1								
	B-U								2	
	B-L								1	
	B-S			1						1

Date		Station 1	2	3	4	5	6	7	8	9
Nereis succinea										
8/31-9/29	T-U			2						
	T-L			1					1	
	T-S							1		
	B-U						1	1	1	
	B-L			2						
	B-S								1	
9/15-9/29	T-U			1			1			
	B-U	1								
9/15-10/13	T-L								1	
	T-S								1	
	B-U	2			2					
	B-S	1								
Nassarius obsoletus										
6/20-7-5	T				1					
8/18-9/15	B						1			
8/31-9/29	T-U					1				
9/15-9/29	B-L						1			
Phyllodocid sp.										
6/20-7/19	B-S					11				
7/5-8/6	T-L				1					
Polydora ligni										
5/5-6/1	T						350			1
	B									20
5/22-620	T	1						52		145
	B	4						20		150
6/1-6/20	T				30		30			36
	B				30		2			17
6/1-7/5	T		1	1	10			17		
	B	1		1	20	1		6		3
6/20-7/5	B						12			
7/5-7/19	T-U	1			4		6	10		
	T-L	2		1					10	
	B-U	1					15		3	
	B-L							9	1	
6/20-7/19	T-U	1		2						
	T-L	1			36					
	T-S		1		4					
	B-U	2							42	
	B-L	1							1	
	B-S							1	17	
7/5-8/6	T-U			1	24	3			48	
	T-L				1	2				
	T-S					1			74	
	B-U			21	1	2	18	4	3	
	B-L		6	10	15		10	10	75	
	B-S			20		3			5	
7/19-8/6	T-U		5		28	81				
	T-L		7	2						
	T-S		10			1				
	B-U	1	20		200		38	8	5	

Date		Station 1	2	3	4	5	6	7	8	9
Polydora ligni										
7/19-8/6	B-L			2						
	B-S		14			2		5		
7/19-8/18	T-U				1		2	35	1	
	T-L			5		3	80	10		
	T-S			6						
	B-U			4	14	20	115	7		
	B-L				20	2	40	2		
	B-S						30	51		
8/6-8/18	T-U				22		7			
	B-U			7			27			
	B-L			1						
	B-S			6		1				
8/6-8/31	T-U				69	1	2			
	T-S				12					
	B-U				61	2	63	19		
	B-L		4		33			1		
	B-S							11		
8/6-8/18	T-U				2	2	7			
	B-U				154	3	5	1		
	B-L	1			19				1	
8/31-9/15	T-L				1					
	B-U						1		3	
	B-L						4			
8/18-9/15	T-U						44			
	T-S							1		
	B-U	2					13			
	B-S		1							
8/31-9/15	B-U						1			
	B-L					1				
8/31-9/29	B-U							1		
	B-L			1				26		
	B-S							12		
	T-U							1		
	T-L							5		
	T-S							16		
Sabellaria vulgaris										
10/1971	T	1								
6/20-7/19/72	B-U	2							15	
	B-S								2	
7/5-8/6	T-U				1				3	
7/19-8/6	B-L				1					
7/5-8/6	B-U								1	
	T-S								1	
7/19-8/18	B-U								1	
Solemya velum										
7/5-7/18	B-L				1					
7/19-8/18	B-5				1					
Stylochus ellipticus										
10/1971	T	1								
	B		2							
5/22-6/20	T		1	1				1	2	
	B							3		

Date		Station 1	2	3	4	5	6	7	8	9
Stylochus elipticus										
6/1-6/20	T						3	1		
	B							3		
6/1-7/5	T	7			1		2			
	B				1		3			
6/20-7/5	T	5								
6/20-7/19	T-U	3			1					
	T-L						1		4	
	T-S	6							1	
	B-U				1	1				
	B-L	2			2		10			
	B-S				1		3		1	
7/5-7/19	T-U				1	1	1			
	T-L	1							5	
	T-S	5								
	B-U				2					
	B-L				2	1			1	
	B-S								5	
7/5-8/6	T-U	1			2		5			
	T-L					3				
	B-U					2				
	B-L				1				1	
	B-S					3				
7/19-8/6	T-U					1				
	T-L							1		
	T-S					2				
	B-U						1			
	B-L	3								
	B-S	1								
7/19-8/18	B-L							2		
	B-S							3		
8/6-8/31	T-L						1			
8/6-8/19	B-S						1			
8/6-9/15	B-U								2	
	B-L					1				
	B-S								1	
8/18-9/15	T-L						1		1	
Tellina sp.										
7/5-8/6	B-U						1			
Tendinedida sp.										
7/19-8/18	T-U							20		
	T-L							45		
	T-S							30		
	B-L							1		
	B-U							1		
	B-S							15		
8/6-8/31	B-L							6		
	B-S							8		
8/18-8/31	B-U							1		
	T-U							2		
	T-L							1		
8/19-9/15	B-S							4		

Date		Station 1	2	3	4	5	6	7	8	9
Tendinedida sp.										
8/18-9/15	T-U							11		
	T-L							1		
	T-S							4		
8/31-9/29	T-U							2		
	T-L							4		
	T-S							10		
	B-U							3		
	B-L							20		
	B-S							1		
9/15-9/29	T-L				1					
	B-L							3		
	B-S							1		
9/15-10/13	B-U							1		

Hierarchical Cluster Analysis

Hierarchical cluster analysis is a technique for recognizing patterns of association of taxonomic units (points) based on a set of association values of those taxonomic units. An association value can be chosen to represent either the similarity of units or to represent the dissimilarity of units.

The following example illustrates the procedure of cluster analysis used in this study (Johnson, 1967). A set of five species are the taxonomic units which will be examined for patterns of association. A matrix of dissimilarity values based on some measured property of the five species is generated:

	Species I	Species II	Species III	Species IV	Species V
Species: I	0.0	0.73	0.74	0.66	0.50
II		0.0	0.20	0.70	0.31
III			0.0	0.72	0.46
IV				0.0	0.51
V					0.0

The two species which are the least dissimilar (hence the most similar) are species II and III (dissimilarity value = 0.20). These two species constitute the first cluster at the first hierarchical level. To determine the clusters occurring at the second hierarchical level, the matrix is rewritten with species II and III as one unit. The dissimilarity between every other species and this new species-unit is determined by using the highest value of dissimilarity of a species with either of the two members of the unit. Thus, the dissimilarity of species II and IV = 0.70, and of III and IV = 0.72. The new dissimilarity of species IV and the species-unit II-III = 0.72. The new matrix thus appears:

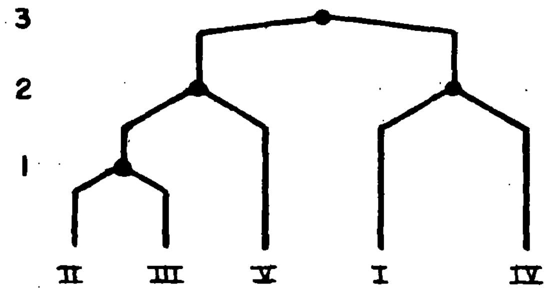
	Species I	Species II-III	Species IV	Species V
Species: I	0.0	0.74	0.46	0.50
II-III		0.0	0.72	0.46
IV			0.0	0.51
V				0.0

The lowest dissimilarity value in the matrix is now 0.46 which is the dissimilarity between II-III and V <u>and</u> between I and IV. Thus two clusters are formed at the second hierarchical level including species-unit I-IV and species-unit II-III-V. The matrix is again rewritten:

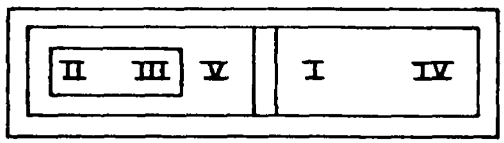
	Species I-IV	Species II-III-V
I-IV	0.0	0.74
II-III-V		0.0

There is only one final cluster remaining which is formed at the third hierarchical level.

The pattern of clustering can be illustrated as follows:



or by designating the hierarchical level of clusterings by using nested figures:



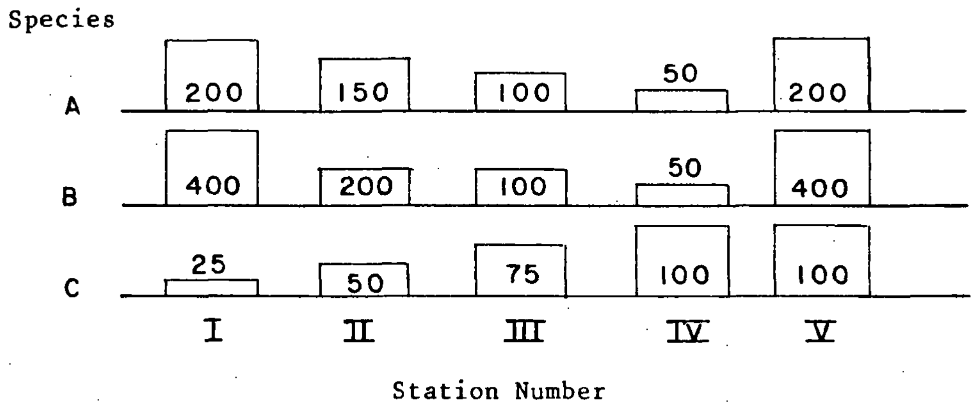
Information Radius

A measure of dissimilarity of taxonomic units that was used in the present study to compare species and to compare stations was the information radius (Jardine and Sibson, 1971, pp. 12-13). This value can be calculated to compare simultaneously any number of units using probability measures of those units on some characteristic. For instance, information radius values for species dissimilarity were calculated to compare two species at one time, based on the total numbers that settled of each species over the nine stations (using a relative frequency histogram as an estimate of the probability distribution of each species over the stations).

Specifically, Information Radius -

$$\sum_{x} \sum_{i} \frac{\omega_i P_i(x)}{\sum_j \omega_j} \log_2 \frac{P_i(x) \sum_j \omega_j}{\omega_j P_j(x)}$$

In this case, $p_i(x)$ - the probability that a randomly selected individual of the i^{th} species was found at the x^{th} station; w_i = the weighting of the i^{th} species, or the probability of a randomly selected individual organism being of the i^{th} species.
Consider the following numbers of each of three species for five stations:



To compare the settling patterns over stations, the numbers of individuals of each species which settled at each station are converted to proportions of the total number of individuals of that species which settled at all stations. Thus 700 total individuals of Species A settled; the relative frequency (p) of species A (i = species A) at station I (x = station I) equals 200/700 = 0.285. The following table gives the same data as above but expressed as relative frequencies for each species over all the stations.

	Station I	Station II	Station III	Station IV	Station V
Species A	0.285	0.214	0.143	0.071	0.285
B	0.308	0.154	0.154	0.073	0.308
C	0.071	0.143	0.214	0.286	0.286

The question asked is how dissimilar are two species based on the relative effect of each station on the settling intensity of the species. As can be seen from the histograms, Species A and B have similar settling profiles over stations. However, a total of 1300 individuals of species B settled, compared with 700 of species A. If, in determining the dissimilarity of two species, it is necessary to include the factor of absolute numbers which settled, then the weighting factor, w_i, could reflect that; for instance, $w_A = 7$, and $w_B = 13$. In the present study, however, the total number of individuals was ignored and only relative settling intensities were considered: $w_A = w_B$, and (arbitrarily) all $w_i = 0.5$. The information radius values can now be calculated for all pairs of species using the values described above.

Species Dissimilarity Using Information Radius

The matrix below contains the actual information radius values used in this study. The information radius is a measure of the dissimilarity between a pair of species, based on the relative distribution of numbers of each species over the nine stations.

	Species									
	Bow.	Ban.	Bal.	Hyd.	Gam.	Mol.	Cor.	Pol.	Mem.	Bot.
Bowerbankia		.591	.193	.677	.460	.600	.414	.229	.221	.704
Bankia			.442	.075	.293	.202	.687	.573	.559	.568
Balanus				.591	.432	.366	.352	.203	.227	.352
Hydroides					.485	.416	.752	.668	.703	.791
Gammarus						.388	.658	.337	.280	.516
Molgula							.655	.652	.555	.298
Corophium								.331	.669	.606
Polydora									261	.478
Membranipora										568
Botryllus										

Information Radius Values for Station Dissimilarity

The following is a matrix of actual information radius values for this study, showing dissimilarity of stations based on the relative numbers of individuals of ten dominant species which settled at those stations.

	Stations							
	O.C. Mouth	O.C. Mar	F.R. Mouth	F.R. Br.	S.C. Mou.	S.C. Win.	In-take	Out-fall
Waretown	0.734	0.739	0.062	0.496	0.470	0.754	0.722	0.755
Oyster Cr. Mouth		0.196	0.694	0.307	0.268	0.045	0.243	0.248
Oyster Cr. Marina			0.719	0.455	0.432	0.142	0.155	0.208
Forked R. Mouth				0.513	0.461	0.679	0.617	0.744
Forked R. Bridge					0.143	0.352	0.436	0.444
Stouts Cr. Mouth						0.255	0.462	0.291
Stouts Cr. Winthrop							0.206	0.182
Forked R. Intake								0.355
Oyster Cr. Outfall								

Station Similarity from Species in Common

The following is a matrix of similarity values of stations based on the species that were present or absent at any pair of stations. The value is the sum of the number of species that were present in common at both stations plus the number of species that were absent in common from both stations out of the total 39 species.

	Stations								
	WT	OC Mou.	OC Mar.	FR Mou.	FR Br.	SC Mou.	SC Win.	Int	Out
Waretown		10	13	16	12	11	16	14	16
Oyster Cr. Mouth			9	12	4	7	12	16	16
Oyster Cr. Marina				17	13	12	7	13	9
Forked R. Mouth					10	13	18	12	18
Forked R. Bridge						5	16	16	16
Stouts Cr. Mouth							15	15	17
Stouts Cr. Winthrop								14	10
Intake									12
Outfall									

Salinity and Temperature Analysis of Variance

Analysis of variance for hydrographic data over time and station used an (8 months) x (9 stations) factorial design for temperature, and a (7 months) x (9 stations) factorial design for salinity. For both analyses, within-cell variance was estimated using two samples that were taken two weeks apart during one month of the above design.

Temperature data included all measurements taken from March 7 through October 13, 1972. Mean temperature and within-month variance for March were estimated by using March 7 and March 21 data. The remaining seven months were obtained in like manner. Data was missing for Waretown, Forked River Intake, and Oyster Creek Outfall stations for March 7, 1973.

Salinity data included all samples taken from March 21 through October 13, 1972. Mean salinity and within-month variance for March were estimated by using March 21 and March 31 data, with subsequent months' data obtained similarly. Because all salinity data for the middle of August is missing, the last month's data is based on measurements taken on September 29 and October 13.

A summary of the results of analysis of variance for salinity and temperature follows.

Temperature Analysis

Effect	d.f.	Mean Square Estimate	F-ratio	p≤
Time	7	782.541	84.253	0.001
Station	8	110.441	11.891	0.001
Station X Time	56	8.182	0.881	n.s.
Within + Residual	69	9.288		

Salinity Analysis

Effect	d.f.	Mean Square Estimate	F-ratio	p≤
Time	6	49.7702	18.222	0.001
Station	8	112.162	41.065	0.001
Station X Time	48	2.0487	0.750	n.s.
Within + Residual	63	2.7313		

Number of Species, Diversity Index, and Evenness

Analysis of Variance

Analysis of variance for the numbers of species Diversity Index, and Evenness Index over time and station used a (4 month) x (9 station) factorial design with two data replicates.

Because of the sampling technique used, the data obtained from May 22, 1972, through September 29, 1972, could be arranged in three separate sets. Each of the above community indices were analyzed using all three data sets.

Data Set A consisted of data obtained from June 1 through September 29, 1972. Mean values and within-month variance at each station for June were estimated by using the one-month samples taken for June 1 - July 5, and try summing the raw data obtained from the two-week samples for June 1 - June 20 and for June 20 - July 5. The following three months' data were arranged similarly, using one-month and summed two-week data.

Data Set B consisted of data obtained from May 22 through September 15, 1972. Mean values and within-month variance at each station for the month of May 22 - June 20 were estimated by using the one-month samples taken for May 22 - June 20, and by summing the raw data obtained from the two-week samples for May 22 - June 1 and for June 1 - June 20. The following three months' data were arranged similarly, using one-month and two-week data.

Data Set C consisted of data obtained from May 22 through September 15, 1972. Mean values and within-month variance at each station for the month of May 22 - June 20 were estimated by using the two-week samples for May 22 - June 1, and for June 1 - June 20. The following three months' data were arranged similarly, using only two-week sample data.

A summary of the results of analysis of variance for number of species, Diversity Index, and Evenness using three different data sets follows.

VALUE	EFFECT	DATA SET A				DATA SET B				DATA SET C			
		d.f.	M.D.	F	p≤	d.f.	M.S.	F	p	d.f.	M.S.	F	p≤
Number of Species	Month	3	57.68	9.818	.001	3	118.977	19.513	.001	3	87.222	19.03	.001
	Station	8	72.375	12.319	.001	8	63.031	10.338	.001	8	36.1806	7.894	.001
	Month X Station	24	14.8056	2.520	.005	24	2.717	2.086	.02	24	5.6806	1.239	n.s.
	Error MonthXStat.	36	211.5000			36	6.097			36	4.5833		
	Total	71				71				71			
Diversity Index (H')	Month	3	2.1237	6.524	.001	3	1.889	6.711	.001	3	3.1846	9.046	.001
	Station	8	1.7974	5.522	.001	8	1.247	4.427	.001	8	1.4022	3.983	.002
	Month X Station	24	0.7102	2.182	.01	24	0.498	1.769	n.s.	24	0.3878	1.102	n.s.
	Error MonthXStat.	36	0.3255			36	0.282			36	0.3520		
	Total	71				71				71			
Evenness	Month	3	0.921	2.512	n.s.	3	0.129	0.255	n.s.	3	0.2554	2.737	n.s.
	Station	8	0.0879	2.397	.035	8	0.1657	3.271	.006	8	0.1461	1.566	n.s.
	Month X Station	24	0.0790	2.155	.02	24	0.0736	1.453	n.s.	24	0.0472	0.506	n.s.
	Error MonthXStat.	36	0.0367			36	0.0507			36	0.0933		
	Total	71				71				71			

Dominant Species Analysis of Variance

Analysis of variance for the numbers of individuals which settled over time, station, depth and surface orientation was done for each of the nine dominant species. The design used was a (3 month) x (8 station) x (2 depth) (3 surfaces within depths) factorial-within design, with two replicates. Oyster Creek Outfall data was not used in most of these analyses because the number of individuals which settled was always low or zero. This data would consistently introduce a great deal of station variance. The analyses for *Bowerbankia gracilis* did include the Oyster Creek Outfall station since that species settled heavily at that station.

Because of the sampling technique used, the data obtained from July 5, 1972, through September 29, 1972, could be arranged into three separate data sets. Numbers of individuals which settled for each of the nine species were analyzed using all three data sets.

Data Set A consisted of data obtained from July 5, 1972, through September 29, f972. Mean values and within-month variance for July were estimated by using the one-month samples taken for July 5 - August 6, and by summing the raw data obtained from the two-week samples for July 5 - July 19 and for July 19 - August 6, yielding two replicates of one month's sampling period. The following two months' data were arranged similarly.

Data Set B consisted of data obtained from July 19 through September 15, 1972. Mean values and within-month variance for the period July 19 through August 18, 1972, were estimated by using the one-month samples taken for July 19 - August 18 and by summing the raw data obtained from the two-week samples for July 19 - August 6 and for August 6 - August 18. The following month's data, for August 18 through September 15, was obtained in a similar manner. Because only two months' data was used in Data Set C, the design described above was modified by using (2 month) rather than (3 month).

Data Set C consisted of data obtained from July 5 through September 29, 1972. Mean values and within-month variance for the month of July were estimated by using the two-week samples for July 5 - July 19 and for July 19 - August 6 as two samples of the one-month period. The following two months' data were arranged similarly, using only two-week sample data.

A summary of the results of analysis of variance for numbers of individuals settling over time, station, depth, and surface are given for each species, using all three data sets.

SPECIES	EFFECT	DATA SET A				DATA SET B				DATA SET C			
		d.f	M.S.	F	p<	d.f.	M.S.	F	p<	d.f	M.S.	F	p<
Balanus aburneus	Time	2	88581.6	20.418	.001	1	57469.3	13.953	.001	2	46699.8	13.085	.001
	Station	7	35021.6	12.026	.001	7	15377.3	3.734	.005	7	12914.2	3.618	.005
	T x St.	14	36818.3	12.643	.001	7	28515.4	6.924	.001	14	14090.8	3.948	.001
	Depth	1	3806.2	1.307	n.s.	1	1217.6	0.296	n.s.	1	1657.9	0.465	n.s.
	T x D	2	2456.4	0.843	n.s.	1	782.1	0.190	n.s.	2	1112.5	0.312	n.s.
	St. x D	7	1901.4	0.653	n.s.	7	1822.3	0.443	n.s.	7	474.1	0.133	n.s.
	T x St. x D	14	2447.5	0.840	n.s.	7	1796.4	0.436	n.s.	14	643.6	0.180	n.s.
	Error TxSt.xD	48	2912.1			32	4118.0			48	3569.0		
	Surface	2	25993.6	20.306	.001	2	18126.1	17.449	.001	2	11998.9	9.718	.001
	Sur.xT	4	6658.9	5.202	.005	2	9421.2	9.069	.001	4	2676.3	2.168	n.s.
	Sur.xSt.	14	3848.6	3.007	.005	14	2142.6	2.063	.05	14	1080.1	0.875	n.s.
	Sur.xTxSt.	28	3112.9	2.432	.005	14	3094.0	2.978	.005	28	1086.2	0.880	n.s.
	Sur.xD	2	1589.5	1.282	n.s.	2	605.2	0.583	n.s.	2	2533.9	2.052	n.s.
	Sur.xTxD	4	367.7	0.287	n.s.	2	665.7	0.641	n.s.	4	184.6	0.149	n.s.
	Sur.xSt.xD	14	986.5	0.771	n.s.	14	301.6	0.290	n.s.	14	1199.1	0.971	n.s.
	Sur.xTxSt.xD	28	1174.8	0.918	n.s.	14	323.6	0.311	n.s.	28	1066.2	0.872	n.s.
	Error TxSt.xDxSur	96	1280.1			64	1038.8			96	1234.7		
Bankia gouldi	Time	2	25092.8	15.914	.001	1	7440.7	21.248	.001	2	2261.2	6.254	.005
	Station	7	7847.7	4.977	.001	7	1261.8	3.603	.01	7	501.2	1.386	n s.
	T x St.	14	7610.9	4.827	.001	7	1253.2	3.578	.01	14	468.8	1.297	n.s.
	Depth	1	4842.9	3.071	n.s.	1	2850.2	8.139	.01	1	789.2	2.183	n.s.
	T x D	2	4512.5	2.862	n.s.	1	2854.0	8.150	.01	2	744.2	2.058	n.s.
	St. x D	7	1063.8	0.675	n.s.	7	622.8	1.778	n.s.	7	164.0	0.454	n.s.
	T x St. x D	14	991.3	0.629	n.s.	7	623.5	1.780	n.s.	14	157.9	0.454	n.s.
	Error TxSt.xD	48	1576.8			32	350.2			48	361.6		
	Surface	2	3100.6	13.298	.001	2	413.1	2.478	n.s.	2	298.4	4.039	.025
	Sur.xT	4	3016.2	12.935	.001	2	410.9	2.465	n.s.	4	285.2	3.861	.01
	Sur.xSt.	14	1141.1	4.894	.001	14	285.6	1.713	n.s.	14	129.4	1.752	n.s.
	Sur.xTxSt.	28	1109.9	4.760	.001	14	284.1	1.704	n.s.	28	122.0	1.652	n.s.
	Sur.xD	2	221.2	0.949	n.s.	2	87.1	0.523	n.s.	2	45.4	0.615	n.s.
	Sur.xTxD	4	246.8	1.059	n.s.	2	91.0	0.546	n.s.	4	40.2	0.545	n.s.
	Sur.xSt.xD	14	178.3	0.764	n.s.	14	119.6	0.717	n.s.	14	21.3	0.288	n.s.
	Sur.xTxSt.xD	28	176.5	0.757	n.s.	14	119.5	0.717	n.s.	28	17.8	0.241	n.s.
	Error TxSt.xDxSur	96	233.2			64	166.7			96	73.9		

SPECIES	EFFECT	DATA SET A				DATA SET B				DATA SET C			
		d.f	M.S.	F	p<	d.f.	M.S.	F	p<	d.f	M.S.	F	p<
<u>Botryllus</u>	Time	2	443.3	7.319	.005	1	332.9	2.419	n.s.	2	21.9	9.143	.001
<u>schlosseri</u>	Station	7	363.3	5.998	.001	7	270.9	1.968	n.s.	7	14.1	5.872	.001
	T x St.	14	236.2	3.901	.001	7	270.9	1.968	n.s.	14	14.1	5.882	.001
	Depth	1	98.7	1.629	n.s.	1	86.6	0.636	n.s.	1	2.0	0.833	n.s.
	T x D	2	39.9	0.659	n.s.	1	86.9	0.636	n.s.	2	1.8	0.733	n.s.
	St. x D	7	42.8	0.707	n.s.	7	69.9	0.508	n.s.	7	0.9	0.390	n.s.
	T x St. x D	14	18.1	0.299	n.s.	7	69.9	0.508	n.s.	14	0.9	0.385	n.s.
	Error TxSt.xD	48	60.6			32	137.7			48	2.4		
	Surface	2	149.9	5.225	.01	2	59.6	3.373	.05	2	4.1	4.954	.01
	Sur.xT	4	101.4	3.534	0.25	2	59.6	3.373	.05	4	3.8	4.577	.005
	Sur.xSt.	14	42.9	2.427	.01	14	42.9	2.427	.01	14	3.8	4.659	.001
	Sur.xTxSt.	28	83.7	2.917	.001	14	42.9	2.427	.01	28	3.9	4.695	.001
	Sur.xD	2	20.1	0.700	n.s.	2	6.5	0.370	n.s.	2	0.1	0.066	n.s.
	Sur.xTxD	4	8.0	0.279	n.s.	2	6.5	0.370	n.s.	4	0.0	0.032	n.s.
	Sur.xSt.xD	14	29.4	1.025	n.s.	14	7.2	0.408	n.s.	14	0.4	0.501	n.s.
	Sur.xTxSt.xD	28	16.5	0.574	n.s.	14	7.2	0.408	n.s.	28	0.5	0.557	n.s.
	Error TxSt.xDxSur	96	28.7			64	17.7			96	0.8		
<u>Bankia</u>	Time	2	2704.5	1.916	n.s.	1	2233.8	1.332	n.s.	2	822.9	1.102	n.s.
<u>gouldi</u>	Station	8	11522.7	8.163	.001	8	7757.9	4.627	.001	8	3718.2	4.982	.001
	T x St.	16	3608.0	2.556	.005	8	3860.4	2.303	.05	16	1619.4	2.170	.025
	Depth	1	3812.3	0.025	n.s.	1	3089.6	1.843	n.s.	1	1375.8	1.843	n.s.
	T x D	2	3812.3	2.701	n.s.	1	36.6	0.016	n.s.	2	734.5	0.984	n.s.
	St. x D	8	923.7	0.654	n.s.	8	1015.5	0.606	n.s.	8	395.5	0.530	n.s.
	T x St. x D	16	936.3	0.663	n.s.	8	308.2	0.184	n.s.	16	652.5	0.874	n.s.
	Error TxSt.xD	54	1411.6			36	1676.5			54	746.4		
	Surface	2	5094.6	15.345	.001	2	3851.9	9.588	.001	2	1405.2	6.958	.001
	Sur.xT	4	115.8	0.349	n.s.	2	264.3	0.658	n.s.	4	50.1	0.248	n.s.
	Sur.xSt.	16	641.8	1.933	.05	16	506.8	1.262	n.s.	16	192.6	0.954	n.s.
	Sur.xTxSt.	32	385.7	1.172	n.s.	16	319.2	0.795	n.s.	32	178.8	0.886	n.s.
	Sur.xD	2	43.4	0.131	n.s.	2	425.3	1.059	n.s.	2	45.9	0.227	n.s.
	Sur.xTxD	4	420.0	1.265	n.s.	2	256.2	0.638	n.s.	4	101.2	0.501	n.s.
	Sur.xSt.xD	16	224.5	0.676	n.s.	16	245.2	0.610	n.s.	16	182.5	0.904	n.s.
	Sur.xTxSt.xD	32	312.0	0.940	n.s.	16	492.7	1.226	n.s.	32	169.2	0.838	n.s.
	Error TxSt.xDxSur	108	332.0			72	401.7			108	201.9		

SPECIES	EFFECT	DATA SET A				DATA SET B				DATA SET C			
		d.f	M.S.	F	p<	d.f.	M.S.	F	p<	d.f	M.S.	F	p<
Membranipora sp.	Time	2	4959.9	18.316	.001	1	930.7	1.217	n.s.	2	1991.9	5.283	.01
	Station	7	815.1	3.010	.025	7	1365.3	1.785	n.s.	7	366.0	1.016	n.s.
	T x St.	14	631.0	2.330	.025	7	2665.1	3.471	.01	14	444.6	1.234	n.s.
	Depth	1	108.1	0.399	n.s.	1	97.6	0.128	n.s.	1	13.9	0.039	n.s.
	T x D	2	63.9	0.236	n.s.	1	9.3	0.012	n.s.	2	19.4	0.054	n.s.
	St. x D	7	434.7	1.605	n.s.	7	129.3	0.169	n.s.	7	101.3	0.281	n.s.
	T x St. x D	14	290.4	1.073	n.s.	7	140.0	0.183	n.s.	14	98.6	0.274	n.s.
	Error TxSt.xD	48	270.8			32	765.0			48	360.4		
	Surface	2	1132.1	6.811	.005	2	877.0	5.351	.01	2	561.8	5.744	.001
	Sur.xT	4	546.2	3.286	.025	2	248.5	1.516	n.s.	4	309.9	3.168	.025
	Sur.xSt.	14	237.0	1.426	n.s.	14	146.3	0.893	n.s.	14	80.4	0.822	n.s.
	Sur.xTxSt.	28	172.9	1.040	n.s.	14	221.1	1.349	n.s.	28	112.8	1.153	n.s.
	Sur.xD	2	65.0	0.391	n.s.	2	186.0	1.135	n.s.	2	114.8	1.173	n.s.
	Sur.xTxD	4	25.9	0.156	n.s.	2	20.3	0.124	n.s.	4	37.1	0.379	n.s.
	Sur.xSt.xD	14	86.8	0.522	n.s.	14	89.5	0.546	n.s.	14	51.5	0.526	n.s.
	Sur.xTxSt.xD	28	103.8	0.625	n.s.	14	114.0	0.696	n.s.	28	61.2	0.626	n.s.
	Error TxSt.xDxSur	96	166.2			64	163.9			96	97.8		
Molgula manhattends	Time	2	788.8	0.494	n.s.	1	13.2	0.872	n.s.	2	0.7	6.628	.005
	Station	7	2818.9	1.765	n.s.	7	20.3	1.349	n.s.	7	0.7	6.516	.001
	T x St.	14	1796.7	1.125	n.s.	7	29.9	1.985	n.s.	14	0.5	4.328	.001
	Depth	1	431.4	0.270	n.s.	1	0.0	0.003	n.s.	1	0.0	0.018	n.s.
	T x D	2	1155.0	0.723	n.s.	1	17.7	1.173	n.s.	2	0.0	0.117	n.s.
	St. x D	7	1049.4	0.657	n.s.	7	6.9	0.454	n.s.	7	0.2	1.552	n.s.
	T x St. x D	14	916.2	0.574	n.s.	7	3.6	0.236	n.s.	14	0.3	2.491	.025
	Error TxSt.xD	48	1597.2			32	15.1			48	0.1		
	Surface	2	1147.2	0.796	n.s.	2	30.7	2.484	n.s.	2	1.3	5.065	.01
	Sur.xT	4	2732.4	1.896	n.s.	2	4.1	0.333	n.s.	4	0.4	1.613	n.s.
	Sur.xSt.	14	2188.4	1.519	n.s.	14	17.9	1.445	n.s.	14	0.4	1.498	n.s.
	Sur.xTxSt.	28	1735.4	1.205	n.s.	14	15.8	1.281	n.s.	28	0.2	0.940	n.s.
	Sur.xD	2	1300.2	0.902	n.s.	2	2.0	0.159	n.s.	2	0.0	0.173	n.s.
	Sur.xTxD	4	892.5	0.619	n.s.	2	9.7	0.785	n.s.	4	0.4	1.579	n.s.
	Sur.xSt.xD	14	903.6	0.627	n.s.	14	7.5	0.606	n.s.	14	0.1	0.275	n.s.
	Sur.xTxSt.xD	28	1047.1	0.727	n.s.	14	5.6	0.449	n.s.	28	0.3	1.150	n.s.
	Error TxSt.xDxSur	96	1440.8			64	12.4			96	0.3		

SPECIES	EFFECT	DATA SET A				DATA SET B				DATA SET C			
		d.f	M.S.	F	p<	d.f.	M.S.	F	p<	d.f	M.S.	F	p<
Polydora ligni	Time	2	1493.8	6.119	.005	1	2219.2	4.684	.05	2	583.6	2.091	n.s.
	Station	7	119.4	4.585	.001	7	1372.2	2.896	.025	7	546.2	1.957	n.s.
	T x St.	14	472.0	1.933	n.s.	7	295.3	0.623	n.s.	14	150.9	0.541	n.s.
	Depth	1	1000.3	4.097	.05	1	1117.7	2.359	n.s.	1	417.5	1.496	n.s.
	T x D	2	194.7	0.798	n.s.	1	138.0	0.291	n.s.	2	91.2	0.327	n.s.
	St. x D	7	433.7	1.776	n.s.	7	699.6	1.477	n.s.	7	382.0	1.369	n.s.
	T x St. x D	14	135.2	0.544	n.s.	7	202.1	0.426	n.s.	14	122.4	0.438	n.s.
	Error TxSt.xD	48	244.1			32	473.8			48	279.1		
	Surface	2	2308.4	8.871	.001	2	2874.7	6.829	.005	2	1347.8	5.505	.01
	Sur.xT	4	671.1	2.579	.05	2	449.9	1.069	n.s.	4	408.5	1.669	n.s.
	Sur.xSt.	14	948.7	3.646	.001	14	876.4	2.082	.05	14	517.7	2.114	.05
	Sur.xTxSt.	28	260.1	0.999	n.s.	14	119.0	0.283	n.s.	28	152.5	0.623	n.s.
	Sur.xD	2	399.8	1.536	n.s.	2	799.2	1.888	n.s.	2	320.1	1.308	n.s.
	Sur.xTxD	4	135.6	0.521	n.s.	2	193.6	0.460	n.s.	4	78.2	0.319	n.s.
	Sur.xSt.xD	14	342.5	1.316	n.s.	14	599.1	1.423	n.s.	14	332.7	1.359	n.s.
	Sur.xTxSt.xD	28	153.1	0.588	n.s.	14	311.3	0.739	n.s.	28	114.5	0.468	n.s.
	Error TxSt.xDxSur	96	260.2			64	421.0			96	244.8		

APPENDIX C4

APPENDIX C4

ANNUAL REPORT

For the Period June 1, 1975 to May 31, 1976

on

WOODBORER STUDY ASSOCIATED WITH THE OYSTER CREEK GENERATING STATION

to

JERSEY CENTRAL POWER & LIGHT COMPANY

November 30, 1976

by

B. R. Richards, A. E. Rehm, C. I. Belmore and R. E. Hillman

TABLE OF CONTENTS

LIST OF FIGURES

MANAGEMENT SUMMARY

This report, which addresses the effects of the Oyster Creek nuclear generating station on the shipworms in Barnegat Bay, New Jersey, covers a 12-month period from June, 1975, through May, 1976. Four species of shipworms were identified: *Teredo navalis*, *Bankia gouldi*, *Teredo furcifera*, and *Teredo bartschi*. Of the four species, *Bankia gouldi* was the most abundant and had the greatest distribution; it was found throughout the bay. *T. furcifera* and *T. bartschi* are considered subtropical species. The former species was not found in Oyster Creek, whereas the latter species was found only there.

The distribution of shipworms in Barnegat Bay was not limited by salinity, oxygen, and pH. *T. bartschi* appeared to be the only species of shipworm influenced by temperature. However, additional research will be required to show if this is true.

Based on the available thermal plume and water current data, the following nine areas are not being impacted by the heated discharge: Coast Guard Station; Ashton's Marina, Manahawkin; Iggies Marina, Conklin Island; Stouts Creek; Roknak's Yacht Basin, Cedar Creek; Dick's Landing, Holly Park; Winter Yacht Basin, Mantoloking; Berkley Yacht Basin, Seaside; and Island Beach State Park.

Forked River can be exposed to the thermal plume when recirculation occurs. It has been estimated that recirculation can occur for approximately four percent of the year (14.6 days). It is doubtful that such a brief thermal impact period could have an influence on the shipworm population in Forked River.

Liberty Harbor Marina, Waretown is approximately 1.5 miles south of Oyster Creek and is in the area that can be occupied by the thermal plume throughout the year. The available data suggest that shipworm attack at this location is independent of power plant operations.

It was not possible to determine if shipworms in the area of the thermal plume were able to extend their breeding season due to elevated temperatures. When the exposure panels were initially installed (June 3-6, 1975), water temperatures throughout Barnegat Bay were already high enough

for *T. navalis* to release larvae and for *B. gouldi* to spawn. The power plant was not operating from December 26, 1975, to March 11, 1976; therefore, it was not possible to determine if shipworms could extend their breeding season into the winter and spring.

The extent to which the long-term exposure panels were destroyed at the 17 exposure panel stations was variable and appeared to be independent of the effects of the thermal plume, salinity, oxygen, and pH.

The only pattern of long-term panel destruction observed occurred north of Oyster Creek. Along the west side of the bay, north of Forked River, there was a progressive increase in the mean percent destruction of the long-term panels as the distance from the power plant increased. The areas involved were south branch of Forked River, Stouts Creek, Cedar Creek, and Holly Park, and they are beyond the influence of the thermal plume.

It was not possible to determine from the monthly teredinid larvae plankton sampling program if the Oyster Creek shipworm population was contributing significantly to the Barnegat Bay teredinid population.

The removal of the trash wood and the marinas from Oyster Creek substantially reduced the teredinid population in this body of water, and the number of shipworm larvae that could have originated from this source.

However, the amount of untreated wood remaining in Oyster Creek is probably no greater than what can be found in other areas of the bay, e.g., Cedar Creek. The removal of this wood and the teredinids it contains would probably not result in a reduction in the intensity of shipworm attacks in other parts of Barnegat Bay.

WOODBORER STUDY ASSOCIATED WITH THE OYSTER CREEK GENERATING STATION

by
B.R. Richards, A.E. Rehm, C.I. Belmore, and R.E. Hillman

INTRODUCTION

Temperature is a major factor influencing the activities and reproductive behavior of marine invertebrates. Loosanoff (1942), for example, showed how breeding seasons of oysters were keyed to temperature, with spawning occurring when, as the water warmed in the spring, a certain critical water temperature was reached, depending on the location of the population.

Considering the effect that temperature has on breeding cycles, it has been suggested that the heated discharge from the Oyster Creek nuclear generating station is extending the breeding season of the wood-boring mollusks of the Family Teredinidae, commonly called shipworms, in those areas that are impacted upon by the thermal plume.

Turner (1966) pointed out that shipworm larvae can settle, grow, and reach sexual maturity in as little as six weeks. If the affect of the thermal discharge was to subject the Oyster Creek shipworm populations to an earlier-than-normal critical water temperature, thereby inducing an early spawning, the usual time for settlement of the larvae would be increased, since a larvae could be spawned, settle, grow to maturity and spawn, itself, within a single season. Indeed, the warmed water could allow for several generations to be spawned and settle before it cooled sufficiently in the fall or winter to terminate the breeding season.

Battelle was contracted by Jersey Central Power & Light Company in June, 1975, to determine (1) whether the thermal discharge from the Oyster Creek generating station was causing an extension of the breeding season in the Oyster Creek teredinid populations, and (2) to determine whether larvae spawned by the Oyster Creek population were being broadcast throughout Barnegat Bay, particularly during any extension of the breeding season, and were significantly influencing borer-caused damage in other areas of the Bay.

To accomplish this goal four integrated research approaches were used: (1) wooden exposure panels were installed at 17 locations (stations) in Barnegat Bay and adjacent areas to obtain information on woodborer distribution and activity, (2) plankton samples were obtained monthly from six stations in Barnegat Bay and adjacent waters to determine if Oyster Creek was serving as the primary source of teredinid larvae in Barnegat Bay, (3) the gonads of teredinids collected throughout Barnegat Bay and adjacent areas were studied to determine if the shipworms in the area of the thermal plume were experiencing an extended breeding season, and (4) water temperature, salinity, oxygen, and pH were recorded at all stations monthly to determine if these parameters influenced the distribution, reproduction, and abundance of the ship worms (Figure 1).

The information reported on here covers the period from June, 1975, to May, 1976.

The Materials and Methods and detailed Results for the four portions of this study: woodborers, plankton, gonad analysis, and water quality are presented in Appendices A, B, C, and D, respectively.

DISCUSSION AND CONCLUSIONS

The results of this study have shown that during the first year of the program at least four species of teredine borers were present in Barnegat Bay: *Bankia gouldi*, *Teredo navalis*, *Teredo bartschi*, and *Teredo furcifera*. The first two species have been present throughout Barnegat Bay for many years (Richards and Belmore, 1975). *Teredo bartschi* and *Teredo furcifera*, which are considered subtropical species, were first reported in Barnegat Bay in 1974 (Firth, et al., 1976). The presence of subtropical species in the exposure panels indicated that

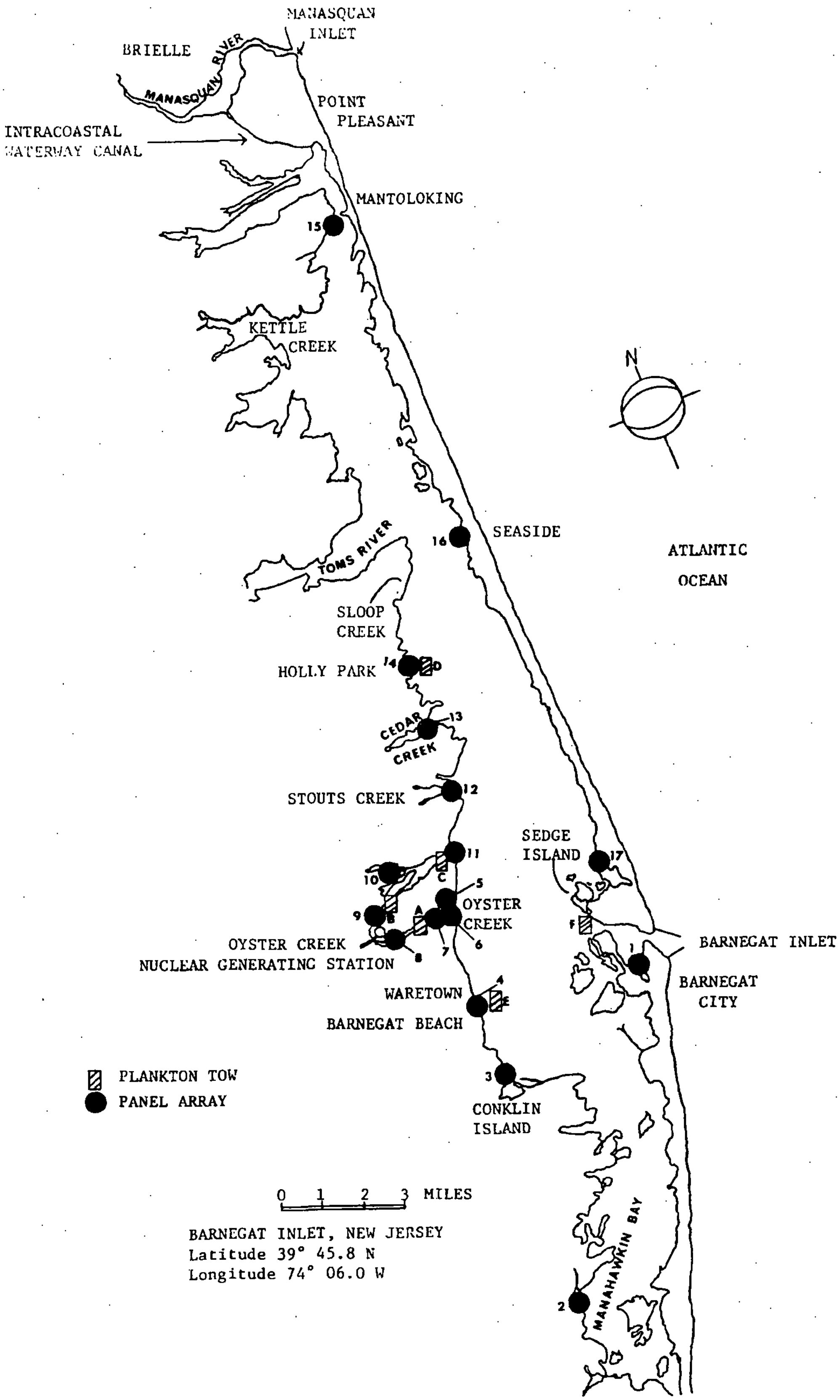


FIGURE 1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHICAL LOCATIONS OF EXPOSURE PANELS AND PLANKTON TOWS

environmental conditions, especially salinity and temperature, have remained favorable since 1974 for them to survive, reproduce, and successfully settle.

Teredo bartschi was found only in the exposure panels at Stations 5 and 6, which are located in lagoons that open into Oyster Creek (Figure 2). It was the dominant teredinid at both stations.

Teredo furcifera was present at seven stations--1, 2, 4, 10, 11, 15, and 17 (Figure 2). It was never dominant at any of these stations. Of these stations, only 4, 10, and 11 may be influenced by the thermal plume. The presence of *T. furcifera* at stations beyond the area of the thermal plume suggest that: (1) *T. furcifera* may have always been present in Barnegat Bay, but has only recently been found because of the increased research interest in teredinids in the bay, or (2) the larvae were released by adults that were in the hulls of wooden boats that previously had been in subtropical areas where *T. furcifera* was present.

The distribution of *Bankia gouldi* and *Teredo navalis*, which are commonly found in Barnegat Bay, was similar to previous years (Richards and Belmore, 1975). *B. gouldi* was the most widely distributed species, and was dominant at more stations than any of the other teredinids found. It was present at all 17 exposure panel stations. It was the dominant teredinid at all stations except 1, 5, 6, 7, and 17, and was co-dominant with *Teredo navalis* at Station 15.

Teredo navalis was the dominant species at Stations 1 and 17, and was present at all stations except 5, 6, 7, 14, and 16.

Based upon Table A-13, *Teredo* spp. was dominant at Station 7.

The distribution of teredinids in Barnegat Bay was not limited by salinity. The salinities recorded at each of the exposure panel and plankton stations were in the range to support breeding populations of *Bankia gouldi, Teredo navalis, Teredo bartschi, Teredo furcifera, Teredo* spp., and their offspring when they entered the plankton.

Most species of teredinids require normal marine conditions for spawning; however, adults may withstand long periods under a variety

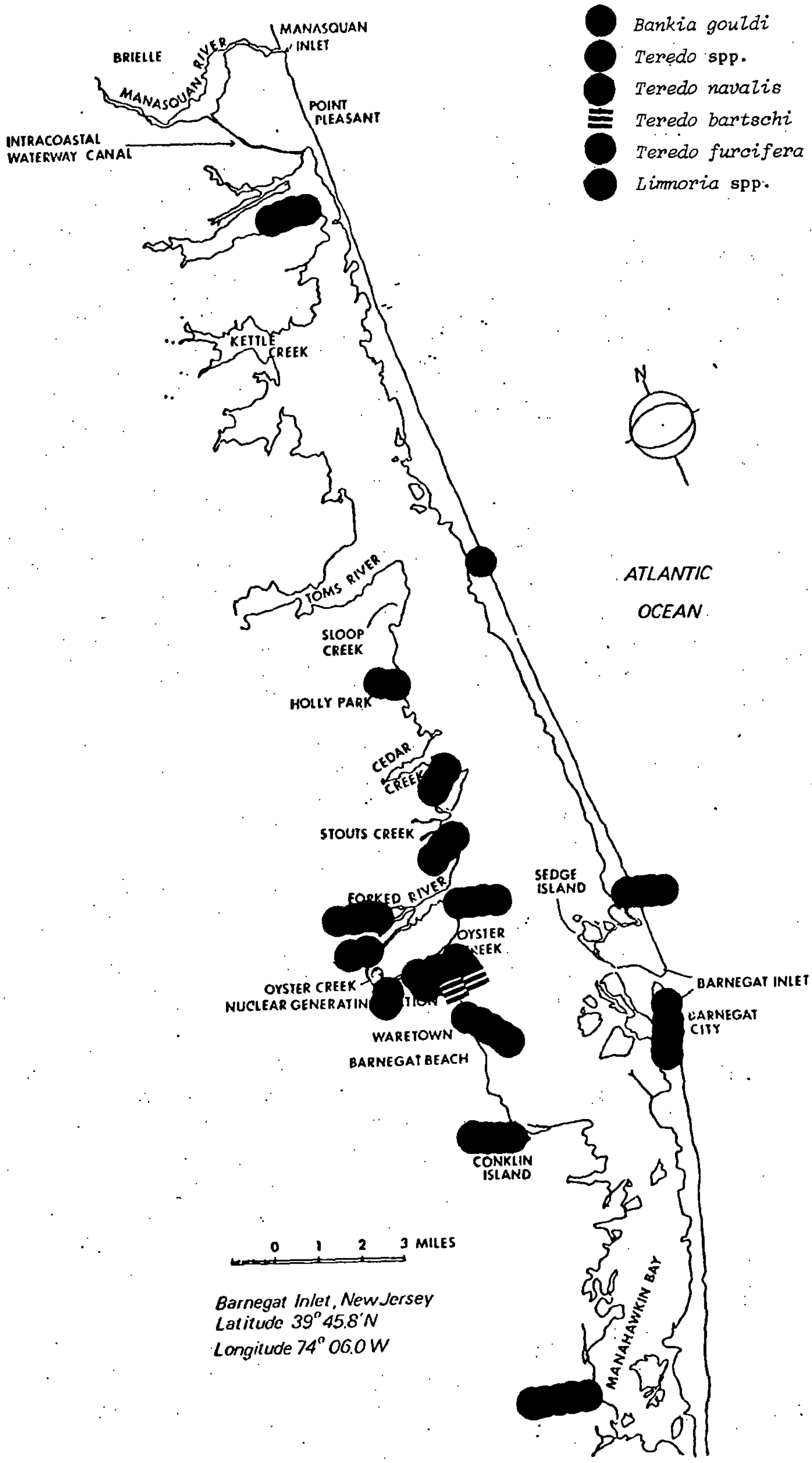


FIGURE 2. GEOGRAPHIC DISTRIBUTION OF MARINE BORERS IN BARNEGAT BAY, NEW JERSEY JUNE, 1975, TO JUNE, 1976.

of extreme conditions by closing the burrow and becoming relatively inactive (Turner, 1966). Available salinity ranges for adult survival and reproduction of *T. navalis* and *B. gouldi* are presented in Table D-47. The salinity range in which *T. furcifera* and *T. bartschi* survives and reproduces is presently unknown.

According to available data, temperature may influence the distribution of *T. bartschi*. However, before that can be determined, additional research will be required. Temperature did not appear to limit the distribution of the other teredinids.

The oxygen and pH values recorded monthly were high enough for teredinid survival and would not have limited their distribution or activities.

The extent to which the thermal effluent released by the Oyster Creek nuclear power generating station can extend the breeding season of teredinids is dependent on the dimensions of the thermal plume, its ΔT, and its direction of flow. The area covered by the thermal plume as calculated by Woodward-Envicon (1974) was from a line not more than 1.5 miles to the north of the mouth of Oyster Creek south for a distance not exceeding 3.0 miles and to the east for about 1.0 to 1.5 miles, depending on wind conditions. Recirculation of the thermal plume into Forked River has been estimated to occur for approximately four percent of the year (14.6 days). However, before recirculation can occur the wind must be from the south or southeast, blowing at 12 knots or greater, and the tide must be in the flood stage. The thermal plume flows essentially to the south. This can be attributed to the predominantly southward flow of the water currents in Barnegat Bay (Carpenter, 1967).

Based on the above information, the following nine stations were beyond the influence of the thermal plume: Station 1, Coast Guard Station; Station 2, Ashton's Marina, Manahawkin; Station 3, Iggies Marina, Conklin Island; Station 12, Stouts Creek; Station 13, Rocknak's Yacht Basin, Cedar Creek; Station 14, Dick's Landing, Holly Park; Station 15, Winter Yacht Basin, Mantoloking; Station 16, Berkely Yacht Basin, Seaside; and Station 17, Island Beach State Park, near Sedge Island (Figure A-1).

Station 4 was the only station outside of Oyster Creek that was located in an area that could be continually occupied by the thermal plume. It is located approximately 1.5 miles south of Oyster Creek at Liberty Harbor Marina, Waretown. Stations 9 and 11 were located in Forked River (Figure A-1) and may be exposed to the thermal plume when recirculation occurs. Stations 5, 6, 7, and 8 were located in Oyster Creek (Figure A-1).

Since the exposure panels were initially installed from June 3-6, 1975, and the power plant was shut down from December 26, 1975, to March 11, 1976, it was not possible to determine from the teredinid gonad studies if the shipworms in the area of the thermal plume were experiencing an extended breeding season.

Optimum water temperatures for molluscan borer breeding range from 13 to 30 C. When the exposure panel arrays were initially installed in June, the seawater temperature at the 17 stations was already high enough for *Teredo navalis* to release larvae and for *Bankia gouldi* to spawn. The seawater temperatures recorded in June at all stations except Station 1 ranged from 21 to 25 C. At Station 1, the seawater temperature was 17.0 C.

Seawater temperatures recorded monthly up through November 4-6, 1975, remained high enough for *Teredo navalis* to release larvae. Temperatures high enough for *B. gouldi* to spawn occurred through October at all stations. By November, only Oyster Creek had seawater temperatures high enough for *B. gouldi* to spawn. The seawater temperatures recorded from December, 1975, through March 9-11, 1976, were too low for any of the teredinid species occupying Barnegat Bay and adjacent areas to remain or become sexually active. By April 6-7, 1976, seawater temperatures were above the known minimum for *Teredo navalis* to release larvae only in Oyster Creek. By May 5-6, 1976, water temperatures were high enough at all stations except 1 and 17 for *T. navalis* to release larvae.

At the time of the May, 1976 sampling, temperatures high enough for *B. gouldi* to be sexually active were recorded at 10 stations which included the four Oyster Creek stations (Table D-12).

However, specimens of *Bankia gouldi* and *Teredo navalis* with gonads in various stages of development were found through February, 1976, for the former species and through March 11, 1976, for the latter species. In January and February, some of the alveoli in the *B. gouldi* specimens appeared to be undergoing cytolysis and resorption. Apparently as the water temperature cooled, gonad development was arrested, and the gonads rarely proceeded past the early active stage. However, specimens of *T. navalis* with ripe gonads were found at Stations 2, 9, and 15 as late as February, 1976.

The minimum seawater temperature required for *Teredo furcifera* and *Teredo bartschi* to become sexually active in Barnegat Bay is presently unknown. However, Nelson (1923) described Barnegat Bay as having sub-tropical temperatures during the summer. His findings were supported by our temperature data.

Specimens of *Teredo furcifera* with gonads in the late active through spent stage were present in September and October at Stations 2, 10, 11, and 17; and in the late active stage at Stations 2 and 11 in November. In January, 1976, specimens in the late active through partially spent stage were found at Stations 2 and 11, respectively.

Adult *Teredo bartschi* containing embryos at the umbonate stage were found each month in the long-term panels removed from the lagoons in Oyster Creek (Stations 5 and 6) from August, 1975, through February, 1976. Both the embryos and the adult specimens that were removed from Stations 5 and 6 in February were dead. It is probable that warm water conditions were favorable for maturation and breeding, but the drop in water temperature as a result of the plant shut-down prevented any release of viable embryos. *Teredo bartschi* were only found in Oyster Creek, and the severe low water temperatures that resulted after the plant shut-down on December 26, 1975, apparently killed them.

The direction of water flow determines the horizontal path that planktonic organisms will travel; therefore, it would be expected that the shipworm larvae produced by the adult population in Oyster Creek would exhibit a net transport south and would probably show up first in the exposure panels located at Station 4.

However, based on the available teredinid larval settlement data obtained from the short-term panels at Station 4, it does not appear that the larvae leaving Oyster Creek were settling at this station. For example, in September, there were no shipworms found in the short-term panel removed from Station 4. Yet, during this same period, teredinid settlement had reached its yearly peak in the Oyster Creek lagoons, Stations 5 and 6. The short-term panel at Station 5 contained 1,310 shipworms, and the panel from Station 6 contained 2,125 shipworms (Table A-14). If the shipworm larvae released by the Oyster Creek populations were responsible for the teredinid attacks at Station 4, this should have resulted in the presence of shipworms in the short-term panel removed in September. The seawater temperatures recorded in August and September were high enough to prevent shipworm larval mortality from cold water thermal shock.

The fact that *T. bartschi* was able to become established on the exposure panels at Stations 5 and 6 suggests that the larvae of this species would also be carried out into Barnegat Bay. The absence of this shipworm at exposure panels stations near Oyster Creek (Stations 4, 10, and 11) may be attributed to its behavior. Lane, et al. (1954) reported that *T. bartschi* near Miami, Florida were free swimming for not more than 72 hours. If the larvae of *T. bartschi* that enter Barnegat Bay also behave in this manner, it would explain their absence on the exposure panels located at stations in the vicinity of Oyster Creek. If *Teredo bartschi* remains confined to Oyster Creek during the 1976 season, it may be assumed that there is no successful settlement of this species into other parts of Barnegat Bay.

Shipworms continued to settle on the short-term panels in Oyster Creek, Stations 5 and 6, through December. However, there was no shipworm settlement on the short-term panels at Station 4 from September through December. The short-term panels at these three stations were free of shipworms through May, 1976.

The shipworms that were settling on the short-term panels at Station 4 more than likely originated in the area of the Station, since there is untreated wood present that probably housed teredinids.

The seawater that enters the Forked River system is drawn in from Barnegat Bay. The shipworm larvae that enter the mouth of Forked River may originate in Oyster Creek or they could come from other areas of Barnegat Bay, which seems more plausible given the conditions necessary for recirculation to occur.

Of the three exposure panel stations established in the Forked River system, complete data were available only for Stations 10 and 11. The exposure panel arrays at Station 9, Forked River Railroad Bridge, were lost due to vandalism and new arrays had to be intalled in July and August.

At Station 10, Ted's Marina, north branch of Forked River, only the short-term panels removed in August and September contained shipworms. Each panel contained only one shipworm.

Shipworm larval settlement on the short-term panels at Station 11, mouth of Forked River, only occurred in July, August, and September. The number of larvae that settled on each short-term panel was variable. The largest number was recorded in August (320), the smallest in September (9).

It is not known if the *B. gouldi* larvae from Oyster Creek were becoming established on the short-term panels at Stations 10 and 11. As mentioned earlier, the conditions required for recirculation would suggest that the larvae that settled on the short-term panels at these stations were either being transported in from other areas in Barnegat Bay or they were originating from adult shipworms that more than likely occupy the untreated wood in the vicinity of the exposure panel stations in Forked River.

However, if larvae from Oyster Creek were settling on the short-term panels at Stations 10 and 11, a larger number should have been recorded in September if recirculation was occurring at the time, since it was the peak month for larval settlement on the short-term panels at Stations 5 and 6, Oyster Creek.

The remaining nine exposure panel stations (1, 2, 3, 12, 13, 14, 15, 16, and 17) were beyond the influence of the thermal plume. The shipworms that settled on the short-term panels at these stations probably originated from adult shipworm populations in the vicinity of the exposure panel arrays (Table A-14). The settlement of shipworm larvae on the short-term panels at Station 1, Coast Guard Station, Barnegat Inlet will serve as an example.

More shipworm larvae settled on the short-term panels at Station 1 from August through November than at any of the other 16 exposure panel stations. During this period, a total of 15,407 teredinids were present in all the short-term exposure panels. The short-term panels at Station 1 accounted for 53 percent, or 8,182 teredinids. Station 1 is probably influenced more by the Atlantic Ocean than the physical conditions of Barnegat Bay. The presence of such large numbers of teredinids at this station can probably be attributed to a well-established adult teredinid population in the area. Station 6 was the only other station that had shipworm larvae settlement in November; there were nine entrances (Table A-14).

The percent to which the long-term panels were destroyed at each exposure panel station was variable and appeared to be independent of the effects of the temperature, salinity, oxygen, and pH (Table A-16 and Figure A-5).

Of the 17 exposure panel stations, the most severe attack occurred on the east side of the bay at Station 1 (Coast Guard Station). The mean percent destruction of the long-term panels was 74.4 percent. This station was beyond the influence of the thermal plume and was dominated by *Teredo navalis*. This shipworm was not found in Oyster Creek (Station 8) until December. This suggests that the *T. navalis* larvae that settled on the long-term panels at Station 1 and other stations where it was found (Table A-13) had to originate locally or from some other areas.

The only pattern of long-term panel destruction observed ocurred north of Oyster Creek. Along the west side of the bay, north of Station 11 (Forked River), there was a progressive increase in the mean percent destruction of the long-term panels as the distance from the power plant increased (Table A-16). The stations involved were 12, 13, and 14 (Figure A-1). *Bankia gouldi* was the dominant teredinid at these stations.

Because of the location of Station 10 (Figure A-1), it was considered to be unaffected by the thermal plume in view of the number of conditions required for recirculation to occur and the brief amount of time that it could take place.

Stations 12, 13, 14, 15, 1, 2, and 3 are beyond the influence of the thermal plume. Stations 2 and 3 are located south of it; the remaining stations are to the north and northeast of it (Figure A-1). The intensity of the teredinid attack at these stations probably reflects the size of the local populations and the amount of untreated wood in each area that can house teredinids.

It was not possible to determine from the monthly teredinid larvae plankton sampling program if the Oyster Creek population was contributing significantly to the Barnegat Bay teredinid population, since there was no correlation between larvae distribution, temperature, and salinity (Figures D-6, D-7, and D-8).

The largest numbers of larvae were captured in July and August, which generally corresponded with the time when the greatest amount of larval settlement occurred on the short-term exposure panels. This agrees with the 1972-73 short-term exposure panel studies conducted in Barnegat Bay by Turner (1973) and Shafto (1972).

Teredinid larvae were captured at the mouth of Oyster Creek in June, July, and August, 1975, indicating that some larvae were being dispersed into Barnegat Bay.

No comparison with extended settlement time and warm water effluent can be made, since the water temperature throughout Barnegat Bay during the winter was below the minimum for teredinid spawning.

Quayle (1959) pointed out the desirability of studying the occurrence of shipworm larvae in the plankton as a measure of the breeding intensity relating to settlement on exposure panels. It is expected that the increase in the 1976 sampling frequency from monthly to bimonthly may provide data which show the relationship between breeding and the distance from the power plant.

Limnoria were present at four locations: Station 1 (Coast Guard Station, Barnegat Inlet), Station 2 (Ashton's Marina, Manahawkin), Station 3 (Iggies Marina, Conklin Island), and Station 4 (Liberty Harbor Marina, Waretown). *Limnoria tripunctata* was the only species identified. The attack rate at each station was minimal. *Limnoria* was not found in any of the creosoted panels installed at the 17 exposure panel stations.

The winter of 1975-76 was very severe, and ice up to four inches thick was present in January and part of February, 1976. During this same period, the nuclear generating plant was not operating (down from December 26, 1975, to March 11, 1976). As a result of these two factors, water temperature conditions in the bay and estuaries could be considered similar to natural conditions before plant operations. A natural "winter kill" of many borers was a real possibility.

The removal of the trash wood and the marinas from Oyster Creek substantially reduced the teredinid population in this body of water and the number of shipworm larvae that could have originated from this source.

However, the amount of untreated wood remaining in Oyster Creek is probably no greater than what can be found in other areas of the bay, e.g., Cedar Creek. Subsequent removal of the remaining wood with teredinids probably would not result in a reduction in the intensity of shipworm attacks in other parts of Barnegat Bay.

LITERATURE CITED

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

Firth, R.W. Jr., et al. 1976. Woodward-Clyde Consultants, Final Report of 1974-1975 Field and Laboratory Studies for Jersey Central Power and Light Company.

Lane, C.E., Tierney, J.Q., and R.E. Hennacy. 1954. The respiration of normal larvae of Teredo bartschi Clapp. Biol. Bull. Mar. Biol. Lab. Woods Hole, 106: 323-327.

Loosanoff, V.L. 1942. Seasonal gonadal changes in adult oysters, Ostrea virginica, of Long Island Sound. Biol. Bull. 82: 195-206.

Nelson, T.C. 1923. Annual Report New Jersey State Agricult. Exper. Station, 43 (for 1922): 321-343.

Quayle, D.B. 1959. Early development of Bankia setacea. Marine Biology and Fouling Organisms. Ed. Dixie Lee Ray. Univ. Wash. Press, Seattle, Washington. 157-172 pp.

Richards, B.R. and C.I. Belmore. 1975. Evaluation of the Extent and Effect of the Marine Woodborer Population in Oyster Creek Upon the Overall Barnegat Bay Marine Woodborer Population. Report No. 14609 to Jersey Central Power & Light Company, 39 pp.

Shafto, S.S. 1972. The boring and fouling communities of Barnegat Bay, New Jersey. Masters Thesis, Rutgers University, New Brunswick, N.J.

Turner, R. 1966. A Survey and Illustrated Catalog of the Teredinidae (Mollusca: Bivalvia). Mus. Comp. Zool., Harvard Univ., Cambridge, Mass. 265 pp.

Turner, R.D. 1973. Report on Marine Borers (Teredinidae) in Oyster Creek, Waretown, New Jersey. Mus. Comp. Zool., Harvard University, Cambridge, Mass. First Report April 3, 1973.

Woodward-Envicon. 1974. The physical behavior of the thermal plume discharge from the Oyster Creek Nuclear Generating Station - Results of the 1974 thermal plume measurements.

APPENDIX A

EXPOSURE PANELS

APPENDIX A

EXPOSURE PANELS

Introduction

Historically, exposure panels have been used by researchers to study the marine borer and fouling communities at specific locations throughout the world (Clapp and Kenk, 1963). The use of untreated softwood panels proved to be a reliable source for the collection of marine borer specimens.

Wooden exposure panels have been used for over 40 years by researchers at the William F. Clapp Laboratories to collect specimens of wood borers to determine the incidence of wood borers and the amount of destruction that the panels undergo. The use of standard-sized panels at all stations provides data that can be compared.

Long- and short-term wood exposure panels were used in this study to aid in the assessment of marine borers and their activity in Barnegat Bay. Short-term exposure panels provide monthly data which is used to determine the borer breeding periods during the year and the amount of borer settlement which takes place. Long-term exposure panels provide data for the speciation, survival, size of the borers, and the amount of destruction to the exposure panel during its exposure period.

Materials and Methods

Exposure panel arrays were installed at seventeen sites (stations) in Barnegat Bay and adjacent waters during the week of June 2, 1975 (Figures A-1 and A-2). The sites were established in the intake and discharge canals within the reaches of the thermal plume and at points not influenced by the thermal plume. Consideration was also given to establishing sites near locations that had been used by earlier investigators of teredinids in the bay (Table A-1).

Each exposure panel array consisted of seven 10-inch by 3.5-inch by 0.75-inch untreated soft pine panels plus two soft pine panels containing a 20-pound per cubic foot treatment of marine grade creosote

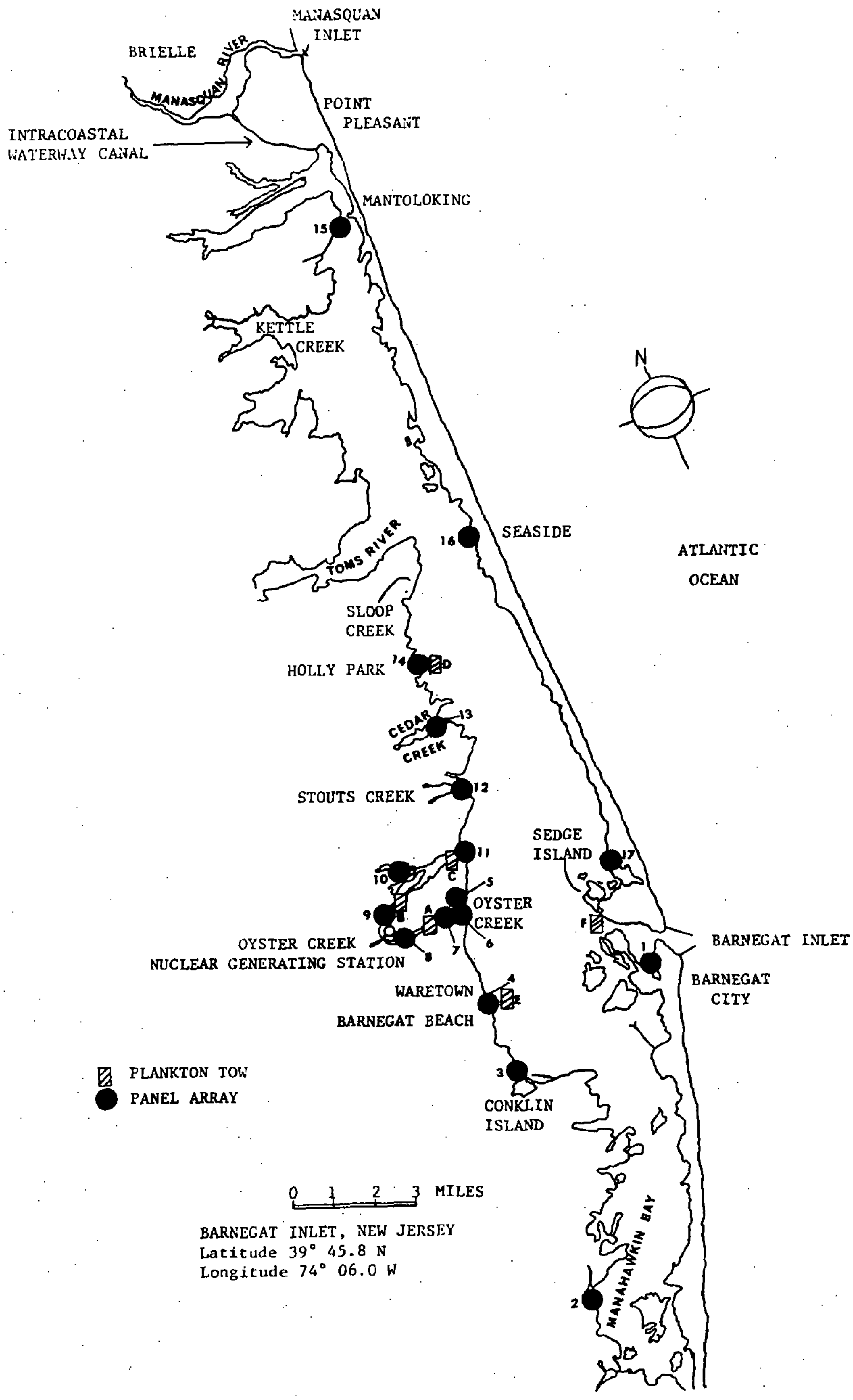
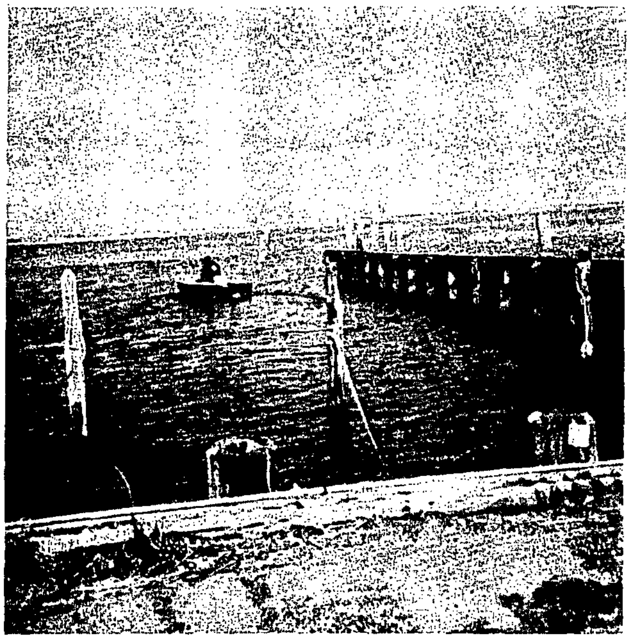


FIGURE A-1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHICAL LOCATION OF EXPOSURE PANELS AND PLANKTON TOWS

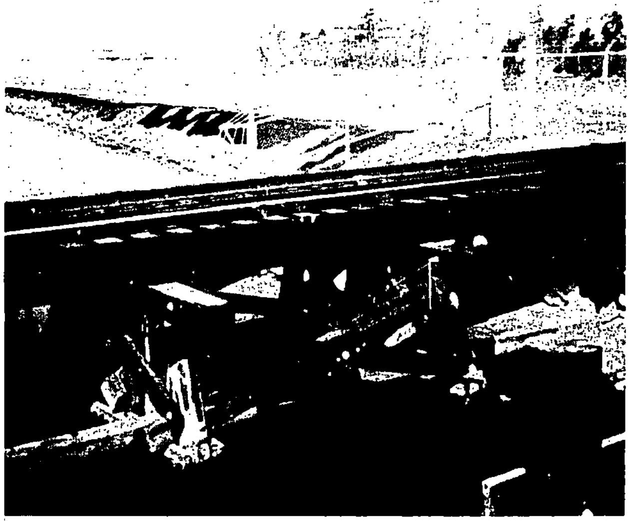


Station 1. Barnegat Inlet. Array suspended off Finger Pier.

Station 6. Inshore end of Oyster Creek. Number 1 lagoon. Array suspended off dock near boat.

Station 11. Mouth of Forked River. Array suspended off bulkhead.

FIGURE A-2. EXPOSURE PANEL LOCATIONS



Station 8. Railroad trestle at Oyster Creek. Panel array suspended underneath crossarms.

Station 13. Cedar Creek. Array suspended from dock.

FIGURE A-2. (continued)

TABLE A-1. GEOGRAPHICAL LOCATIONS OF WILLIAM F. CLAPP LABORATORIES' EXPOSURE PANEL ARRAYS SUBMERGED JUNE, 1975, BARNEGAT BAY, NEW JERSEY

Site No.	Site	Structure to be used for suspension of rack	Nearest previous data stations	Approximate latitude and longitude
1.	Barnegat Coast Guard Station Barnegat Inlet	Finger Pier	WC 1 WFCL 1948-1967	Lat. 39° 45.8'N Long. 74° 06.5'W
2.	Ashton Marina 1450 Bay Ave. Manahawkin, N.J.	Bulkhead	WC 13,14	Lat. 39° 40'N Long. 74° 13'W
3.	Iggie's Marina East Bay Ave. Barnegat, N.J. (Conklin Island)	Bulkhead	WC 16,17,18,19	Lat. 39° 45'N Long. 74° 12.5'W
4.	Liberty Harbor Marina Washington Ave. Waretown, N.J.	Bulkhead	WC 21 R. Turner Rutgers U.	Lat. 39° 47'N Long. 74° 11'W
5.	Mouth of Oyster Creek, Lot 4, Compass Road Offshore End	Dock	WC 29,30 Rutgers U.	Lat. 39° 48.5'N Long. 74° 10.3'W
6.	Oyster Creek #1 Lagoon, Inshore End 37 Capstan Drive	Dock		Lat. 39° 48.5'N Long. 74° 10.35'W
7.	Private Dock Dock Ave. Oyster Creek Sands Pt. Harbor Waretown, N.J.	End of Dock	WC 27,28 R. Turner Rutgers U.	Lat. 39° 48.5'N Long. 74° 11.1'W

TABLE A-1. (continued)

Site No.	Site	Structure to be used for suspension of rack	Nearest previous data stations	Approximate latitude and longitude
8.	Oyster Creek-R.R. Bridge Discharge Canal	Cross Member Bridge	WC 26 Rutgers U.	Lat. 39° 48.7'N Long. 74° 12'W
9.	Forked River South Branch Intake Canal	Cross Member R.R. Bridge	WC 31 Rutgers U.	Lat. 39° 49.2'N Long. 74° 12.2'W
10.	Teds Marina Bay Ave. Forked River	Pier	WC 33,34	Lat. 39° 50.1'N Long. 74° 11.6'W
11.	Forked River (near mouth) 1413 River View Drive	Bulkhead	WC 35 Rutgers U.	Lat. 39° 49.7'N Long. 74° 10'W
12.	Stouts Creek 1273 Capstan Drive	Bulkhead	WC 38,40,41 R. Turner Wurtz Rutgers U.	Lat. 39° 50.5'N Long. 74° 08.8'W
13.	Rocknak's Yacht Basin Seaview Ave. Lanoka Harbor Cedar Creek, N.J.	End of Pier	WC 46	Lat. 39° 52'N Long. 74° 09'W
14.	Dicks Landing Island Drive Bayville, N.J. (Holly Park)	Pier	WC 49 R. Turner Nelson	Lat. 39° 54'W Long. 74° 08.1'W

TABLE A-1. (continued)

Site No.	Site	Structure to be used for suspension of rack	Nearest previous data stations	Approximate latitude and longitude
15.	Winter Yacht Basin Inc. Rt. 528 Mantoloking Bridge W. Mantoloking, N.J.	Pier	WC 57	Lat. 40° 02.5'N Long. 74° 03.5'W
16.	Berkely Yacht Basin J. Street, Seaside	Pier	WC 60,61	Lat. 39° 55.9'N Long. 74° 04.9'W
17.	Island Beach State Park (Sedge Island)	Pier	WC 68	Lat. 39° 47.1'N Long. 74° 05.9'W

All exposure panel racks suspended in a minimum water depth at mean low water of at least three feet. Racks hung with nylon line from existing structures so the bottom panels are close to, but not touching the bottom. Racks at Forked River railroad bridge and Oyster Creek railroad bridge suspended with wire rope.

WC = Woodward-Clyde
WFCL = William F. Clapp Laboratories

(Figure A-3). Before submersion, all untreated panels were seasoned for two weeks in seawater, passed through a Steroline Aquafine Electronic Liquid Sterilizer (Model PVC 6). At each station, the panels were submerged, removed, and replaced monthly in sequence so that after the first six months each long-term panel was exposed for a six-month period. The short-term panels were removed and replaced monthly. The creosoted panels were not removed, but were visually inspected each month for the presence of the crustacean borer, *Limnoria*.

The panels removed from exposure each month were immediately wrapped in newspaper soaked with seawater. They were returned to the laboratory in containers that contained ice in plastic bags.

In the laboratory, the panels were examined macro- and microscopically for the presence of marine borers. Sizes of the specimens, the number present, and the amount of damage to each panel was recorded. Species and sexual determinations were made when possible.

The ratings used for evaluating the prevalence and the destructiveness of marine borers to exposure panels were established by the William F. Clapp Laboratories and have been used for over 40 years. These ratings, adapted to a panel surface area of 85-square inches, are shown in Figure A-4. The end grain of the panels are not included in the surface areas.

<u>Verifications</u>

Dr. Ruth Turner, Harvard University, corroborated Clapp Laboratories identification of the following specimens.

August 21, 1975	-	*Teredo furcifera*	-	Ashton's
		Teredo navalis	-	Forked River*
		Teredo bartschi	-	Oyster Creek*
December 21, 1975	-	*Teredo navalis*	-	Barnegat Inlet

* Specimens received from Woodward-Clyde.

Irene Belmore, William F. Clapp Laboratories, corroborated the following specimens from the William F. Clapp Laboratories' Marine Borer collection:

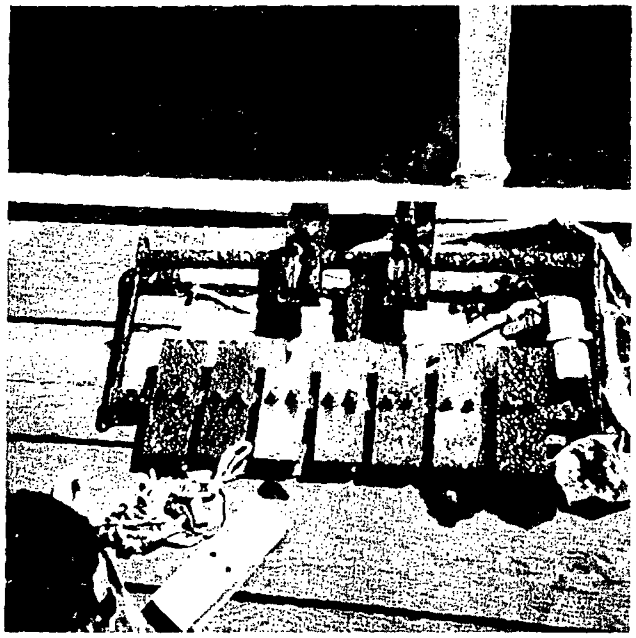


FIGURE A-3. EXPOSURE PANEL ARRAY

FIGURE A-4.

RATING SCALE FOR TEREDINID AND *Limnoria* ATTACK

Teredinidae

No. of tubes per panels	Percent filled*	Attack Rating
1-5	<5	Trace
6-25	5-10	Slight
26-100	11-25	Moderate
101-250	26-50	Medium heavy
251-400	51-75	Heavy
>400+**	76-100	Very heavy

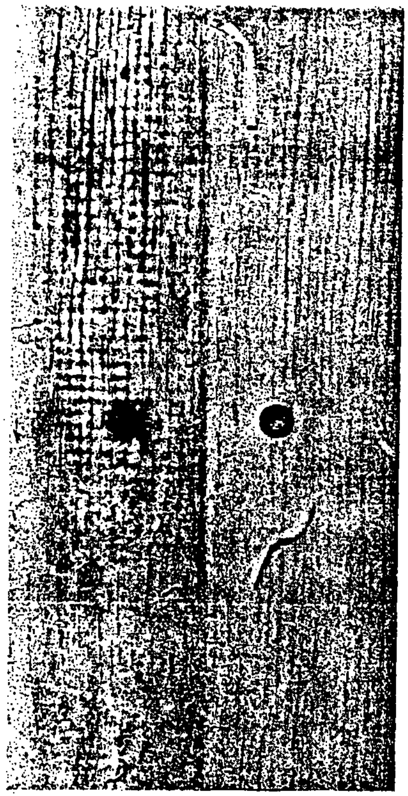
* Percent filled depends upon size of specimens present in panels
** Arbitrary number assigned to panels 76-100 percent filled.

Limnoria

No. of tunnels per sq. inch	Total no. of tunnels	Attack Rating
1	1-85	Trace
10	86-850	Slight
25	851-2125	Moderate
50	2126-4250	Medium heavy
75	4251-6375	Heavy
100*	6375-8500	Very heavy

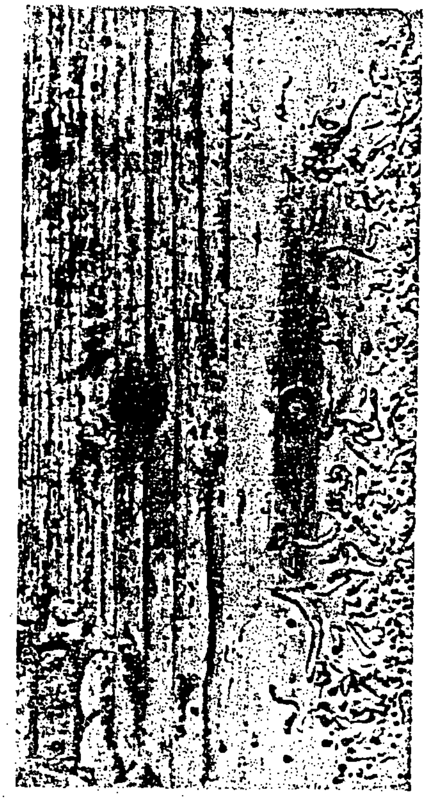
* Ratings of approximately 100 per square inches indicate the maximum density beyond which it is impossible to count

TEREDINIDAE



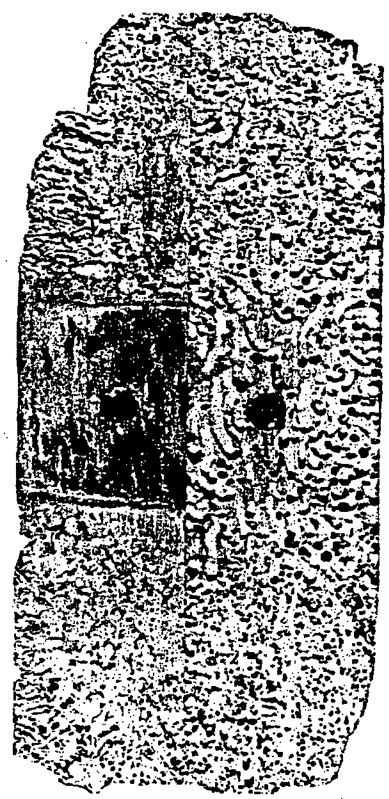
Trace

Slight

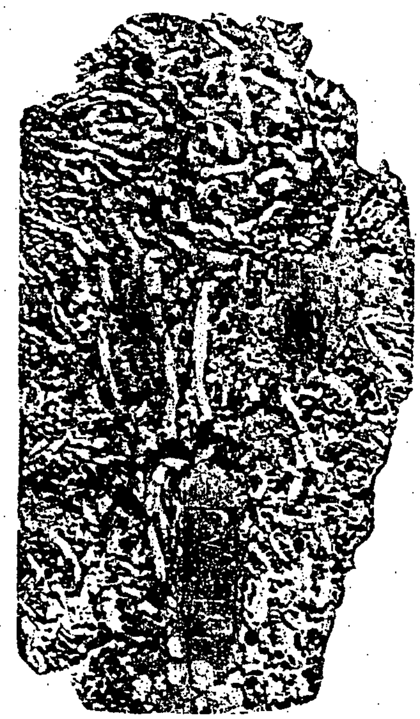


Moderate

Moderately Heavy



Heavy



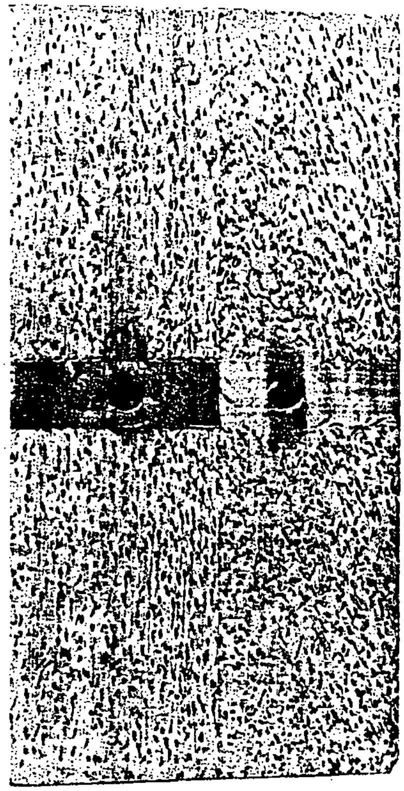
Very Heavy

FIGURE A-4. (continued)

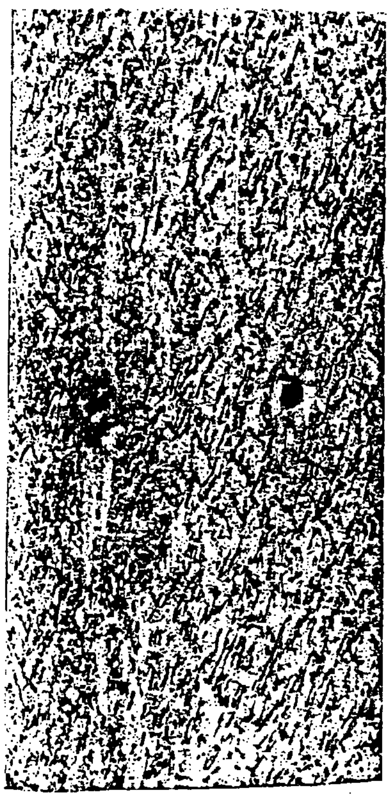
LIMNORIA

Trace

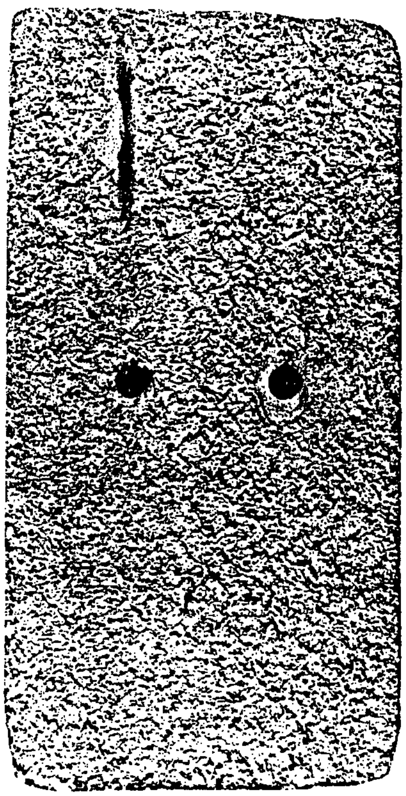
Slight



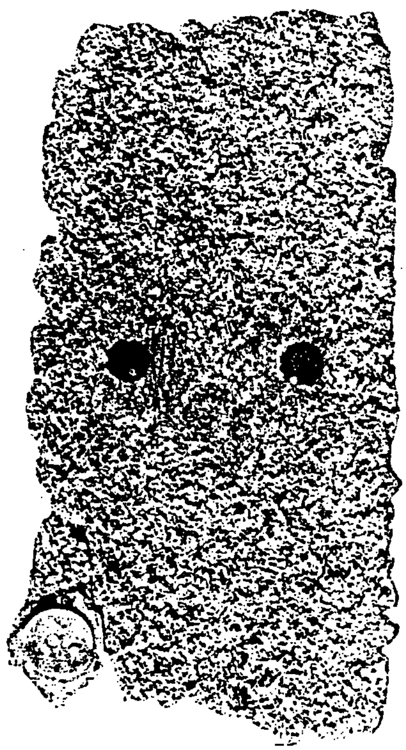
Moderate



Moderately Heavy



Heavy



Very Heavy

FIGURE A-4. (continued)

Barnegat City, New Jersey

May, 1948 - October, 1948	-	*Teredo navalis*
May, 1948 - November, 1948	-	*Teredo navalis*
May, 1948 - December, 1948	-	*Teredo navalis*
February, 1949 - October, 1949	-	*Teredo navalis*
August, 1949 - March, 1950	-	*Teredo navalis*

Barnegat Lightship

August, 1949 - November, 1949	-	*Teredo navalis*

Loss of Exposure Panel Arrays and Individual Panels

Objects of any sort placed in open areas are subject to vandalism. Consequently, it was not unexpected that some vandalism would occur to the arrays placed in Barnegat Bay. The problem areas, all sites near the power plant, were as follows:

- Station 5, Mouth of Oyster Creek. The original installation placed at Jersey Central's bulkhead was missing within 24 hours. A new array was installed June 6, 1975, at the landing dock, Lot 4, Compass Road, offshore end of the last lagoon at Mouth of Oyster Creek.

- Station 7, Barnegat Marine Service, Oyster Creek. Array missing in September, and a new one was installed September 11, 1975.

- Station 8, Railroad Trestle, Oyster Creek. Array was found on the shore in July and replaced in water. Array missing in August and a complete new array was suspended with wire rope on August 13, 1975.

- Station 9, Railroad Trestle, Forked River. Array missing in July and new one was installed. New array installed in July was missing in August. A complete new array was suspended with wire rope on August 13, 1975.

Due to the demolition of the docks at Barnegat Marine, Station 7 was relocated approximately 30 yards upstream to the dock owned by Mr. E.L. Fryling on December 3, 1975.

One creosoted panel at each of five stations was lost as a result of winter ice conditions and new creosoted panels were installed as follows:

March 9, 1976	-	Station 2 (Ashton's) Station 13 (Rocknak's)
April 6, 1976	-	Station 14 (Dick's)
April 7, 1976	-	Station 7 (Fryling's) Station 16 (Liberty)

Results

Summary data for the first twelve months of the exposure panel study (eleven removal periods) are given in Tables A-2 through A-12.

Teredinid Distribution and Dominance at 17 Exposure Panel Stations

Of the four species of teredinids identified during the study *Bankia gouldi* was the most widely distributed. It was found at the 17 exposure panel stations (Figure A-1) and was dominant at all stations except 1, 5, 6, 7, 15, and 17. Stations 5, 6, and 7 are located in Oyster Creek. At Station 15 it was co-dominant with *Teredo navalis* (Table A-13).

Teredo navalis was present at all stations except 5, 6, 7, 14, and 16. It was the dominant species at Stations 1 and 17 (Figure A-1 and Table A-13).

Teredo bartschi and *Teredo furcifera* are considered subtropical species. The former was present and dominant only at Stations 5 and 6. The latter species was found only at Stations 1, 2, 4, 10, 11, 15, and 17. It was never dominant (Figure A-1 and Table A-13).

Teredo spp. contained all species too small to identify or those that did not possess a sufficient number of taxonomic characters. *Teredo* spp. were found at all stations except 9 and 16. *Teredo* spp. was dominant only at Station 7.

TABLE A-2. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR EXPOSURE PANELS REMOVED JULY, 1975

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
1	P	6/3/75	7/8/75	1	12	<1	emb-5	*T. navalis*		1	1	*L. tripunctata*	
	C	6/3/75	7/8/75	1	16	<1	emb-5	*T. navalis*		4	0		
2	P	6/3/75	7/8/75	1	7	2	12-30	*T.* spp.		8	6	*L. tripunctata*	
	C	6/3/75	7/8/75	1	5	2	14-27	*T.* spp.		4	3	*L. tripunctata*	
3	P	6/3/75	7/8/75	1	0					1	2	*L. tripunctata*	
	C	6/3/75	7/8/75	1	0					2	0		
4	P	6/3/75	7/8/75	1	4	<1	emb-2			0			
	C	6/3/75	7/8/75	1	4	<1	emb-2			0			
5	P	6/6/75	7/8/75	1	845	20	emb-5	*T.* spp.		0			
	C	None											
6	P	6/5/75	7/8/75	1	263	20	emb-4	*T.* spp.		0			
	C	6/5/75	7/8/75	1	296	20	emb-4	*T.* spp.		0			
7	P	6/5/75	7/9/75	1	0					0			
	C	6/5/75	7/9/75	1	1	<1	2			0			
8	P	6/4/75	7/9/75	1	0					0			
	C	Control Missing											
9	P	Lost											
	C	Lost											
10	P	6/6/75	7/9/75	1	0					0			
	C	6/6/75	7/9/75	1	0					0			
11	P	6/5/75	7/9/75	1	49	4	emb-5			0			
	C	6/5/75	7/9/75	1	46	4	emb-4			0			
12	P	6/5/75	7/9/75	1	2	<1	2			0			
	C	6/5/75	7/9/75	1	1	<1	1			0			
13	P	6/3/75	7/8/75	1	3	<1	emb-2			0			
	C	6/3/75	7/8/75	1	7	1	emb-5			0			
14	P	6/3/75	7/8/75	1	17	8	emb-12	*B. gouldi*		0			
	C	6/3/75	7/8/75	1	25	10	emb-19			0			
15	P	6/6/75	7/10/75	1	0					0			
	C	6/6/75	7/10/75	1	0					0			
16	P	6/3/75	7/10/75	1	0					0			
	C	6/3/75	7/10/75	1	0					0			
17	P	6/3/75	7/10/75	1	0					0			
	C	6/3/75	7/10/75	1	0					0			

P = long-term exposure panels; C = short-term exposure panels; emb = embryonic

TABLE A-3. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR EXPOSURE PANELS REMOVED AUGUST, 1975

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
1	P	6/3/75	8/12/75	2	5100	50	emb-81	*T. navalis*, *T.* spp.	16 spec. with larvae	5	2	*L. tripunctata*	1 gravid female
	C	7/8/75	8/12/75	1	4250	40	emb-21	*T. navalis*, *T.* spp.		0	0		
2	P	6/3/75	8/12/75	2	19	10	3-75	*T. furcifera*, *T.* spp.	larvae present	14	9	*L. tripunctata*	few juv.
	C	7/8/75	8/12/75	1	6	2	5-34	*T. furcifera*, *T.* spp.		2	0		
3	P	6/3/75	8/12/75	2	5	1	2-22	*B. gouldi*	eggs present	19	3	*L. tripunctata*	juv. present
	C	7/8/75	8/12/75	1	8	1	emb-8	*B. gouldi*		0	0		
4	P	6/7/75	8/12/75	2	16	6	4-52	*B. gouldi*	eggs present	4	1	*L. tripunctata*	
	C	7/8/75	8/12/75	1	2	<1	2-15	*B. gouldi*		0	0		
5	P	6/6/75	8/12/75	2	920	45	emb-90	*B. gouldi*, *T. bartschi*	larvae in umbo stage	0	0		
	C	7/8/76	8/12/75	1	2380	35	emb-57	*B. gouldi*, *T.* spp.		0	0		
6	P	6/5/75	8/12/75	2	420	45	emb-71	*B. gouldi*, *T.* spp.	larvae in umbo stage	0	0		
	C	7/8/75	8/12/75	1	265	15	emb-110	*B. gouldi*		0	0		
7	P	6/5/75	8/14/75	2	15	15	7-142	*B. gouldi*, (1)*T.* spp.		0	0		
	C	7/9/75	8/14/17	1	2	2	40-62	*B. gouldi*, (1)*T.* spp.		0	0		
8	P	Lost (new rack installed)											
	C	Lost (new rack installed)											
9	P	Lost (new rack installed)											
	C	Lost (new rack installed)											
10	P	6/3/75	8/12/75	2	7	2	1-39	*B. gouldi*		0	0		
	C	7/9/75	8/12/75	1	1	<1	2			0	0		
11	P	6/5/75	8/12/75	2	470	65	emb-75	*B. gouldi*, *T.* spp.	90% *Bankia*, eggs present	0	0		
	C	7/9/75	8/12/75	1	320	45	emb-82	*B. gouldi*, *T.* spp.	75% *Bankia*	0	0		
12	P	6/5/75	8/12/75	2	25	10	emb-78	*B. gouldi*	eggs present	0	0		
	C	7/9/75	8/12/75	1	26	8	emb-33	*B. gouldi*		0	0		
13	P	6/3/75	8/12/75	2	118	15	emb-49	*B. gouldi*	eggs present	0	0		
	C	7/8/75	8/12/75	1	127	15	emb-45	*B. gouldi*		0	0		
14	P	6/3/75	8/12/75	2	335	45	emb-62	*B. gouldi*	eggs present	0	0		
	C	7/8/75	8/12/75	1	280	45	emb-55	*B. gouldi*		0	0		
15	P	6/6/75	8/14/75	2	6	5	16-29	(1)*B. gouldi*, *T.* spp.		0	0		
	C	7/10/75	8/14/75	1	2	2	23-55	*B. gouldi*		0	0		
16	P	6/3/75	8/14/75	2	7	3	2-26	*B. gouldi*		0	0		
	C	7/10/75	8/14/75	1	2	<1	emb-8	*B. gouldi*		0	0		
17	P	6/3/75	8/14/75	2	85	15	2-29	*T.* spp.		0	0		
	C	7/10/75	8/14/75	1	110	18	emb-41	(1)*B. gouldi*, *T.* spp.	ripe gonads	0	0		

P = long-term exposure panel; C = short-term exposure panel; emb = embryonic

TABLE A-4. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR EXPOSURE PANELS REMOVED SEPTEMBER, 1975

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
1	P	6/3/75	9/9/75	3	4250	100	emb-48	*B. gouldi, T. navalis T. furcifera*	larvae present	14	9	*L. tripunctata*	
	C	8/12/75	9/9/75	1	3625	20	emb-18	*T.* spp.		8	4	*L. tripunctata*	
2	P	6/3/75	9/10/75	3	29	25	40-155	*T. furcifera*	rack in mud	48	3	*L. tripunctata*	
	C	8/12/75	9/10/75	1	6	<1	1-4	*T.* spp.		6	0		
3	P	6/3/75	9/10/75	3	4	9	62-120	*B. gouldi*		58	39		
	C	8/12/75	9/10/75	1	1	<1	5	*B. gouldi*		0	0		
4	P	6/3/75	9/10/75	3	51	70	6-230	*B. gouldi*	eggs present	18	6		juv. present
	C	8/12/75	9/10/75	1	0								
5	P	6/6/75	9/10/75	3	4000	100	emb-60	*B. gouldi, T. bartschi*	larvae present, 75% *T. bartschi*	0	0		
	C	8/12/75	9/10/75	1	1310	20	emb-6			0	0		
6	P	6/5/75	9/10/75	3	850	80	emb-165	*B. gouldi, T. bartschi*	larvae present, 60% *T. bartschi*	0	0		
	C	8/12/75	9/10/75	1	2125	20	emb-9			0	0		
7	P	Lost (new rack installed)											
	C	Lost (new rack installed)											
8	P	8/13/75	9/11/75	1	6	<1	emb-2		submerged 1 month	0	0		
	C	8/13/75	9/11/75	1	1	<1	emb			0	0		
9	P	8/13/75	9/11/75	1	2	<1	1		submerged 1 month	0	0		
	C	8/13/75	9/11/75	1	0					0	0		
10	P	6/3/75	9/10/75	3	27	65	6-200	*B. gouldi*		0	0		
	C	8/12/75	9/10/75	1	1	<1	12	*B. gouldi*		0	0		
11	P	6/5/75	9/11/75	3	430	99	17-160	*B. gouldi, T. furcifera, T.* spp.	75% *B. gouldi*	0	0		
	C	8/12/75	9/11/75	1	9	2	emb-9	*B. gouldi*		0	0		
12	P	6/5/75	9/11/75	3	45	40	11-210	*B. gouldi*		0	0		
	C	8/12/75	9/11/75	1	7	<1	emb-3	*B. gouldi*		0	0		
13	P	6/3/75	9/11/75	3	340	99	8-25	*B. gouldi*		0	0		
	C	8/12/75	9/11/75	1	7	1	emb-2			0	0		
14	P	6/3/75	9/10/75	3	400	100	14-65	*B. gouldi*		0	0		
	C	8/12/75	9/10/75	1	3	<1	1-3			0	0		
15	P	6/6/75	9/12/75	3	16	25	30-150	8 *T.* spp.		0	0		
	C	8/14/75	9/12/75	1	1	<1	emb			0	0		
16	P	6/3/75	9/11/75	3	3	8	95-100	*B. gouldi*		0	0		
	C	8/14/75	9/11/75	1	0					0	0		
17	P	6/3/75	9/11/75	3	67	45	18-95	*B. gouldi, T. navalis, T. furcifera, T.* spp.		0	0		
	C	8/14/75	9/11/75	1	7	<1	1-2			0	0		

P = long-term exposure panel; C = short-term exposure panel; emb = embryonic

TABLE A-5. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED OCTOBER, 1975

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.	% + Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
1	p	6/3/75	10/7/75	4	3400	100	5-45	*T. navalis*, (*T. furcifera*?, *T. bartschi*?)	majority *T. navalis*	0	0		
	c	9/9/75	10/7/75	1	260	3	emb.-3	*T.* spp.		7	3	*L. tripunctata*	
2	p	6/3/75	10/8/75	4	41	50	38-190	*B. gouldi*, *T. furcifera*	majority *B. gouldi*	62	14	*L. tripunctata*	
	c	9/10/75	10/8/75	1	0					0	0		
3	p	6/3/75	10/8/75	4	3	6	85-125	*B. gouldi*, *T. navalis*		8	0		
	c	9/10/75	10/8/75	1	0					0	0		
4	p	6/3/75	10/8/75	4	49	90	65-215	*B. gouldi*, *T. navalis*, *T. furcifera*	majority *B. gouldi*	1	1	*L. tripunctata*	
	c	9/10/75	10/8/75	1	0					0	0		
5	p	6/6/75	10/8/75	4	900	100	emb.-65	*T. bartschi*	90% tubes empty	0	0		
	c	9/10/75	10/8/75	1	24	1	emb.-2			0	0		
6	p	6/5/75	10/8/75	4	700	100	emb.-95	*T. bartschi*, *B. gouldi*	umbonate larvae present majority *T. bartschi*	0	0		
	c	9/10/75	10/8/75	1	190	2	emb.-2			0	0		
7	p	9/11/75	10/8/75	1	3	<1	emb.-3			0	0		
	c	9/11/75	10/8/75	1	1	<1	emb.			0	0		
8	p	8/13/75	10/8/75	2	3	2	26-70	*B. gouldi*		0	0		
	c	9/11/75	10/8/75	1	0					0	0		
9	p	8/13/75	10/8/75	2	2	2	14-31	*B. gouldi*		0	0		
	c	9/11/75	10/8/75	1	0					0	0		
10	p	6/3/75	10/8/75	4	31	60	30-215	*B. gouldi*, *T. furcifera*	majority *B. gouldi*	0	0		
	c	9/10/75	10/8/75	1	0					0	0		
11	p	6/5/75	10/8/75	4	400	100	14-120	*B. gouldi*, *T. furcifera*	majority *B. gouldi*	0	0		
	c	9/11/75	10/8/75	1	0					0	0		
12	p	6/5/75	10/8/75	4	54	75	40-125	*T.* spp., *B. gouldi*	majority *B. gouldi*	0	0		
	c	9/11/75	10/8/75		0					0	0		
13	p	6/3/75	10/8/75	4	400	100	20-85	*T.* spp., *B. gouldi*	90% tubes empty majority *B. gouldi*	0	0		
	c	9/11/75	10/8/75	1	1		1.5			0	0		

TABLE A-5. (continued)

Site	Panel	Submerged	Removed	Months Exposed	Teredinidae No. of Specs. +	% Filled	Sz. Range in mm.	Species Identification	Remarks	*Limnoria* No. of Tunnels	No. of Specimens	Species Identification	Remarks
14	p	6/3/75	10/7/75	4	400	100	30-95	*B. gouldi*		0	0		
	c	9/10/75	10/7/75	1	0					0	0		
15	p	6/6/75	10/9/75	4	12	30	35-170	*B. gouldi, T. furcifera, T. navalis, T.* spp.		0	0		
	c	9/12/75	10/9/75	1	0					0	0		
16	p	6/3/75	10/9/75	4	4	7	74-135	*B. gouldi*		0	0		
	c	9/11/75	10/9/75	1	0					0	0		
17	p	6/3/75	10/9/75	4	118	70	33-105	*B. gouldi, T. furcifera, T. navalis*	majority *T. navalis*	0	0		
	c	9/11/75	10/9/75	1	0					0	0		

P = long-term exposure panel; C = short-term exposure panel; emb = embryonic

TABLE A-6. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED NOVEMBER, 1975

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.	% + Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
1	p	6/3/75	11/4/75	5	400	100	8-50	*B. gouldi, T. navalis, T.* spp.	majority *T. navalis*	0	0		
	c	10/7/75	11/4/75	1	47	<1	emb.			1	0		
2	p	6/3/75	11/5/75	5	27	60	40-320	*B. gouldi, T. furcifera, T. navalis*	majority *Teredo*	36	7	*L. tripunctata*	
	c	10/8/75	11/5/75	1	0					1	1	*L. tripunctata*	
3	p	6/3/75	11/5/75	5	4	12	90-265	*B. gouldi*		1	0		
	c	10/8/75	11/5/75	1	0					0	0		
4	p	6/3/75	11/5/75	5	76	90	2-165	*B. gouldi, T.* spp.	majority *T.* spp.	41	19	*L. tripunctata*	
	c	10/8/75	11/5/75	1	0					0	0		
5	p	6/6/75	11/5/75	5	400	100	8/40	*B. gouldi, T. bartschi*	majority *T. bartschi* umbonate larvae present	0	0		
	c	10/8/75	11/5/75	1	0					0	0		
6	p	6/5/75	11/5/75	5	400	100	9-105	*B. gouldi, T. bartschi*	majority *T. bartschi* umbonate larvae present	0	0		
	c	10/8/75	11/5/75	1	9	<1	emb.			0	0		
7	p	9/11/75	11/5/75	2	1	<1	4			0	0		
	c	10/8/75	11/5/75	1	0					0	0		
8	p	8/13/75	11/5/75	3	5	13	36-195	*B. gouldi*		0	0		
	c	10/8/75	11/5/75	1	0					0	0		
9	p	8/13/75	11/5/75	3	2	4	80-95	*B. gouldi*		0	0		
	c	10/8/75	11/5/75	1	0					0	0		
10	p	6/3/75	11/5/75	5	17	45	emb.-160	*B. gouldi, T. furcifera, T. navalis*	majority *B. gouldi*	0	0		
	c	10/8/75	11/5/75	1	0					0	0		
11	p	6/5/75	11/5/75	5	400	100	19-150	*B. gouldi, T. furcifera, T.* spp.	majority *B. gouldi*	0	0		
	c	10/8/75	11/5/75	1	0					0	0		
12	p	6/5/75	11/5/75	5	47	95	30-180	*B. gouldi, T. navalis*	majority *B. gouldi*	0	0		
	c	10/8/75	11/5/75	1	0					0	0		

TABLE A-6. (continued)

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.	% + Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
13	p	8/12/75	11/5/75	3	7	15	70-160	*B. gouldi*		0	0		
	c	10/8/75	11/5/75	1	0					0	0		
14	p	6/3/75	11/4/75	5	400	100	20-75	*B. gouldi*, *T.* sp.	majority *B. gouldi*	0	0		
	c	10/7/75	11/4/75	1	0					0	0		
15	p	6/6/75	11/6/75	5	4	9	10-255	*B. gouldi*, *T. navalis*		0	0		
	c	10/9/75	11/6/75	1	0					0	0		
16	p	6/3/75	11/5/75	5	10	40	105-230	*B. gouldi*		0	0		
	c	10/9/75	11/5/75	1	0					0	0		
17	p	6/3/75	11/5/75	5	124	95	30-125	*B. gouldi*, *T. furcifera*, *T. navalis*	majority *T. navalis*	0	0		
	c	10/9/75	11/5/75	1	0					0	0		

P = long-term exposure panel; C = short-term exposure panel; emb = embryonic

TABLE A-7. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED DECEMBER, 1975

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.	% + Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
1	p	6/3/75	12/2/75	6	400	100		*T. navalis*	approx. 3 cu. inches of disintegrated panel received	0	0		
	c	11/4/75	12/2/75	1	1	<1	emb.			0	0		
2	p	6/3/75	12/3/75	6	18	50	85-220	*B. gouldi* *T. navalis*	majority *B. gouldi*	8	6	*L. tripunctata*	
	c	11/5/75	12/3/75		0					0	0		
3	p	6/3/75	12/3/75	6	9	50	110-305	*B. gouldi*		18	11	*L. tripunctata*	
	c	11/5/75	12/3/75	1	0					0	0		
4	p	6/3/75	12/3/75	6	18	50	85-245	*B. gouldi* *T. navalis*	majority *B. gouldi*	5	4	*L. tripunctata*	
	c	11/5/75	12/3/75	1	0					0	0		
5	p	6/6/75	12/3/75	6	400	100	9-130	*B. gouldi* *T. bartschi*	majority *T. bartschi* umbonate larvae present				
	c	11/5/75	12/3/75	1	3	<1	emb.			0	0		
6	p	6/5/75	12/3/75	6	400	100	4-160	*B. gouldi* *T. bartschi*	majority *T. bartschi* umbonate larvae present	0	0		
	c	11/5/75	12/3/75	1	1	<1	emb.			0	0		
7	p	9/11/75	12/3/75	3	4	<1	2-10	*T.* spp.		0	0		
	c	11/5/75	12/3/75	1	0					0	0		
8	p	8/13/75	12/3/75	4	2	5	120-215	*B. gouldi* *T. navalis*		0	0		
	c	11/5/75	12/3/75	1	0					0	0		
9	p	8/13/75	12/3/75	4	1	2	85	*B. gouldi*		0	0		
	c	11/5/75	12/3/75	1	0					0	0		
10	p	6/3/75	12/3/75	6	8	40	110-200	*B. gouldi*		0	0		
	c	11/5/75	12/3/75	1	0					0	0		
11	p	6/5/75	12/3/75	6	400	100	17-165	*B. gouldi* *T. navalis* *T. furcifera*		0	0		
	c	11/5/75	12/3/75	1	0					0	0		
12	p	6/5/75	12/3/75	6	18	75	60-210	*B. gouldi*		0	0		
	c	11/5/75	12/3/75	1	0					0	0		
13	p	6/3/75	12/3/75	6	400	100	17-90	*B. gouldi* *T. navalis*	majority *B. gouldi*	0	0		

TABLE A-7. (continued)

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs. +	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
	p*	6/3/75	12/3/75	6	400	100	9-105	*B. gouldi*		0	0		
	c	11/5/75	12/3/75	1	0					0	0		
14	p	6/3/75	12/3/75	6	400	100	15-75	*B. gouldi*		0	0		
	c	11/4/75	12/3/75	1	0					0	0		
15	p	6/3/75	12/4/75	6	6	20	80-245	*B. gouldi* *T. navalis*		0	0		
	c	11/6/75	12/4/75	1	0					0	0		
16	p	6/3/75	12/4/75	6	1	5	240	*B. gouldi*		0	0		
	c	11/5/75	12/4/75	1	0					0	0		
17	p	6/3/75	12/4/75	6	103	90	32-122	*T. navalis* *T. furcifera*	majority *T. navalis*	0	0		
	c	11/5/75	12/4/75	1	0					0	0		

P = long-term exposure panel; C = short-term exposure panel; emb = embryonic
* = extra panel removed out of sequence

TABLE A-8. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED JANUARY, 1976

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs. ±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
1	p	7/8/75	1/7/76						Panel missing - heavy borer attack				
	c	12/2/75	1/7/76	1	0					0	0		
2	p	7/8/75	1/7/76	6	12	25	6-220 m.	*T. navalis*, *T.* spp.*		38	17	*L. tripunctata*	1 juvenile
	c	12/3/75	1/7/76	1	0					0			
3	p	7/8/75	1/7/76	6	14	75	90-275	*B. gouldi*		39	17	*L. tripunctata*	
	c	12/3/75	1/7/76	1	0					0	0		
4	p	7/8/75	1/7/76	6	10	20	15-240	*B. gouldi*		0	0		
	c	12/3/75	1/7/76	1	0					0	0		
5	p	7/8/75	1/7/76	6	400±	100	12-75	*B. gouldi*, *T. bartschi*	4 *T. bartschi* with umbonate larvae. Lower half panel missing. Severe borer attack. 80% tubes empty.	0	0		
	c	12/3/75	1/7/76	1	0					0	0		
6	p	7/8/75	1/7/76	6	400±	100	12-115	*B. gouldi*, *T. bartschi*	Majority *T. bartschi*. 5 *T. bartschi* with umbonate larvae. Majority tubes empty.				
	c	12/3/75	1/7/76	1	0					0	0		
7	p	12/3/75	1/7/76	1	0				#6 Panel removed in error	0	0		
	c	12/3/75	1/7/76	1	0					0	0		
8	p	8/13/75	1/7/76	5	1	1	60	*B. gouldi*		0	0		
	c	12/3/75	1/7/76	1	0					0	0		
9	p	8/13/75	1/7/76	5	1	5	230	*B. gouldi*		0	0		
	c	12/3/75	1/7/76	1	0					0	0		
10	p	7/9/75	1/7/76	6	5	25	110-205	*B. gouldi*		0	0		
	c	12/3/75	1/7/76	1	0					0	0		
11	p	7/9/75	1/7/76	6	400±	100	12-115	*B. gouldi*, *T. navalis*, *T. furcifera*	40% tubes empty	0	0		
	c	12/3/75	1/7/76	1	0					0	0		

TABLE A-8. (continued)

Site	Panel	Submerged	Removed	Months Exposed	Teredinidae: No. of Specs. ±	Teredinidae: % Filled	Teredinidae: Sz. Range in mm.	Teredinidae: Species Identification	Teredinidae: Remarks	*Limnoria*: No. of Tunnels	*Limnoria*: No. of Specimens	*Limnoria*: Species Identification	*Limnoria*: Remarks
12	p	7/9/75	1/7/76	6	22	90	40-265	*B. gouldi*		0	0		
	c	12/3/75	1/7/76	1	0					0	0		
13	p	7/8/75	1/7/76	6	400±	100	23-95	*B. gouldi*	75% tubes empty	0	0		
	c	12/3/75	1/7/76	1	0					0	0		
14	p	7/8/75	1/7/76	6	400±	100	21-110	*B. gouldi*	50% tubes empty	0	0		
	c	12/3/75	1/7/76	1	0					0	0		
15	p	7/10/75	1/8/76	6	9	45	135-220	*B. gouldi, T. navalis*		0	0		
	c	12/4/75	1/8/76	1	0					0	0		
16	p	7/10/75	1/8/76	6	1	3	145	*B. gouldi*		0	0		
	c	12/4/75	1/8/76	1	0					0	0		
17	p	7/10/75	1/8/76	6	275±	98	19-80	*T. navalis*		0	0		
	c	12/4/75	1/8/76	1	0					0	0		

**Teredo* - not identified to species due to size or condition of pallets.
p = long-term panel
c = short-term panel

TABLE A-9. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED FEBRUARY, 1976

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs. ±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
1	p	8/12/75	2/10/76	6	400±	100	9-43	*T. navalis*	40% panel missing - severe borer attack. 90% specimens were dead.	0	0		
	c	1/7/76	2/10/76	1	0					0	0		
2	p	8/12/75	2/10/76	6	8	15	90-160	*B. gouldi, T. navalis*		3	3		
	c	1/7/76	2/10/76	1	0					0			
3	p	8/12/75	2/10/76	6	1	1	61	*B. gouldi*		0	0		
	c	1/7/76	2/10/76	1	0					0	0		
4	p	8/12/75	2/10/76	6	7	3	6-42	*B. gouldi, T.* spp.*		0	0		
	c	1/7/76	2/10/76	1	0					0	0		
5	p	8/12/75	2/10/76	6	350±	98	20-85	*T. bartschi*	No live specimens. Dead umbonate larvae present.	0	0		
	c	1/7/76	2/10/76	1	0					0	0		
6	p	8/12/75	2/10/76	6	400±	100	17-53	*T. bartschi, B. gouldi*	All *T. bartschi* dead, 9 with dead umbonate larvae				
	c	1/7/76	2/10/76	1	0					0	0		
7	p	9/11/75	2/10/76	5	0					0	0		
	c	1/7/76	2/10/76	1	0					0	0		
8	p	8/13/75	2/10/76	6	2	5	100-170	*T. navalis, B. gouldi*		0	0		
	c	1/7/76	2/10/76	1	0					0	0		
9	p	8/13/75	2/10/76	6	2	4	80-130	*B. gouldi, T. navalis*		0	0		
	c	1/7/76	2/10/76	1	0					0	0		
10	p	8/12/75	2/10/76	6	0					0	0		
	c	1/7/76	2/10/76	1	0					0	0		
11	p	8/12/75	2/10/76	6	68	75	23-165	*B. gouldi, T. navalis, T.* spp.*		0	0		
	c	1/7/76	2/10/76	1	0					0	0		
12	p	8/12/75	2/10/76	6	8	10	21-90	*B. gouldi*		0	0		
	c	1/7/76	2/10/76	1	0					0	0		

TABLE A-9. (continued)

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs. ±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
13	p								Panel removed in November				
	c	1/7/76	2/10/76	1	0					0	0		
14	p	8/12/75	2/10/76	6	8	10	37-75	*B. gouldi*		0	0		
	c	1/7/76	2/10/76	1	0					0	0		
15	p	8/14/75	2/13/76	6	7	20	47-180	*T. navalis*		0	0		
	c	1/8/76	2/13/76	1	0					0	0		
16	p	8/14/75	2/10/76	6	0					0	0		
	c	1/8/76	2/10/76	1	0					0	0		
17	p	8/14/75	2/10/76	6	33	30	30-110			0	0		
	c	1/8/76	2/10/76	1	0					0	0		

*Teredo - not identified to species due to size or condition of pallets.
p = long-term panel
c = short-term panel

TABLE A-10. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED MARCH, 1976

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs. ±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
1	p	9/9/75	3/9/76	6	400±	100	7-40	*T. navalis*		0	0		
	c	2/10/76	3/9/76	1	0					0	0		
2	p	9/10/75	3/9/76	6	0					1	1	*L. tripunctata*	
	c	2/10/76	3/9/76	1	0					0	0		
3	p	9/10/75	3/9/76	6	0					0	0		
	c	2/10/76	3/9/76	1	0					0	0		
4	p	9/10/75	3/9/76	6	0					0	0		
	c	2/10/76	3/9/76	1	0					0	0		
5	p	9/10/75	3/9/76	6	77	15	1-45	*T. bartschi*, *T.* spp.*	Tubes empty	0	0		
	c	2/10/76	3/9/76	1	0					0	0		
6	p	9/10/75	3/9/76	6	70	5	<1-23	*T. bartschi*	Tubes empty	0	0		
	c	2/10/76	3/9/76	1	0					0	0		
7	p	9/11/75	3/9/76	6	2	<1	8-11	*T.* spp.*		0	0		
	c	2/10/76	3/9/76	1	0					0	0		
8	p	9/11/75	3/10/76	6	1	<1	8	*T.* spp.*		0	0		
	c	2/10/76	3/10/76	1	0					0	0		
9	p	9/11/75	3/10/76	6	0					0	0		
	c	2/10/76	3/10/76	1	0					0	0		
10	p	9/10/75	3/9/76	6	0					0	0		
	c	2/10/76	3/9/76	1	0					0	0		
11	p	9/11/75	3/9/76	6	1	<1	2			0	0		
	c	2/10/76	3/9/76	1	0					0	0		
12	p	9/11/75	3/9/76	6	0					0	0		
	c	2/10/76	3/9/76	1	0					0	0		
13	p	9/11/75	3/9/76	6	0					0	0		
	c	2/10/76	3/9/76	1	0					0	0		
14	p	9/10/75	3/9/76	6	0					0	0		
	c	2/10/76	3/9/76	1	0					0	0		
15	p	9/12/75	3/12/76	6	0					0	0		
	c	2/13/76	3/12/76	1	0					0	0		

TABLE A-10. (continued)

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs. ±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
16	p	9/11/75	3/9/76	6	0					0	0		
	c	2/10/76	3/9/76	1	0					0	0		
17	p	9/11/75	3/9/76	6	0					0	0		
	c	2/10/76	3/9/76	1	0					0	0		

*Teredo - not identified to species due to size or condition of pallets.
p = long-term panel
c = short-term panel

TABLE A-11. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED APRIL, 1976

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Spec.+	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
1	P	10/7/75	4/6/76	6	128	3	0.5-7	*Teredo* spp.		1	0		
	C	3/9/76	4/6/76	1						0	0		
2	P	10/8/75	4/6/76	6	0					0	0		
	C	3/9/76	4/6/76	1	0					0	0		
3	P	10/8/75	4/6/76	6	0					0	0		
	C	3/9/76	4/6/76	1	0					0	0		
4	P	10/8/75	4/6/76	6	0					0	0		
	C	3/9/76	4/6/76	1	0					0	0		
5	P	10/8/76	4/6/76	6	9	<1	0.5-1			0	0		
	C	3/9/76	4/6/76	1	0					0	0		
6	P	10/8/76	4/6/76	6	43	<1	0.5-2			0	0		
	C	3/9/76	4/6/76	1						0	0		
7	P	9/11/75	4/7/76	7	0					0	0		
	C	3/9/76	4/7/76	1	0					0	0		
8	P	10/8/75	4/7/76	6	0					0	0		
	C	3/10/76	4/7/76	1	0					0	0		
9	P	10/8/76	4/7/76	6	0					0	0		
	C	3/10/76	4/7/76	1	0					0	0		
10	P	10/8/76	4/6/76	6	0					0	0		
	C	3/9/76	4/6/76	1	0					0	0		
11	P	10/8/76	4/6/76	6	1	<1	2	*Teredo* spp.		0	0		
	C	3/9/76	4/6/76	1	0					0	0		
12	P	10/8/76	4/6/76	6	0					0	0		
	C	3/9/76	4/6/76		0					0	0		
13	P	10/8/76	4/6/76	6	0					0	0		
	C	3/9/76	4/6/76	1	0					0	0		
14	P	10/7/76	4/6/76	6	0					0	0		
	C	3/9/76	4/6/76		0					0	0		
15	P	10/9/76	4/8/76	6	0					0	0		
	C	3/12/76	4/8/76	1	0					0	0		
16	P	10/9/76	4/7/76	6	0					0	0		
	C	3/9/76	4/7/76	1	0					0	0		
17	P	10/9-76	4/7/76	6	1	<1	1			0	0		
	C	3/9/76	4/7/76	1	0					0	0		

P = long-term exposure panel; C = short-term exposure panel

TABLE A-12. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED MAY, 1976

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.+	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
1	P	11/4/75	5/6/76	6	0					0			
	C	4/6/76	5/6/76	1	0					0			
2	P	11/5/75	5/4/76	6	0					2	2	*L. tripunctata*	
	C	4/6/76	5/4/76	1	0					0			
3	P	11/5/75	5/4/76	6	0					0			
	C	4/6/76	5/4/76	1	0					1	0		
4	P	11/5/75	5/4/76	6	0					0			
	C	4/6/76	5/4/76	1	0					0			
5	P	11/5/75	5/4/76	6	0					0			
	C	4/6/76	5/4/76	1	0					0			
6	P	11/5/75	5/4/76	6	0					0			
	C	4/6/76	5/4/76	1	0					0			
7	P	11/5/75	5/4/76	6	0					0			
	C	4/7/76	5/4/76	1	0					0			
8	P	11/5/75	5/5/76	6	0					0			
	C	4/7/76	5/5/76	1	0					0			
9	P	11/5/75	5/5/76	6	0					0			
	C	4/7/76	5/5/76	1	0					0			
10	P	11/5/75	5/4/76	6	0					0			
	C	5/4/76	5/4/76	1	0					0			
11	P	11/5/75	5/4/76	6	0					0			
	C	4/6/76	5/4/76	1	0					0			
12	P	11/5/75	5/4/76	6	0					0			
	C	4/6/76	5/4/76	1	0					0			
13	P	11/5/75	5/4/76	6	0					0			
	C	4/6/76	5/4/76	1	0					0			
14	P	11/4/75	5/4/76	6	0					0			
	C	4/6/76	5/4/76	1	0					0			
15	P	11/6/75	5/6/76	6	0					0			
	C	4/8/76	5/6/76	1	0					0			
16	P	11/5/75	5/5/76	6	0					0			
	C	4/7/76	5/5/76	1	0					0			
17	P	11/5/76	5/5/76	6	0					0			
	C	4/7/76	5/5/76	1	0					0			

P = long-term exposure panel; C = short-term exposure panel

TABLE A-13. DOMINANCE OF SPECIES OF TEREDINIDAE IN LONG-TERM PANELS

Location	*Bankia gouldi*	*Teredo navalis*	*Teredo bartschi*	*Teredo furcifera*	*Teredo* spp*
1	✓	✓ dominant		✓	✓
2	✓ dominant	✓		✓	✓
3	✓ dominant	✓			✓
4	✓ dominant	✓		✓	✓
5	✓		✓ dominant		✓
6	✓		✓ dominant		✓
7	✓				✓ dominant
8	✓ dominant	✓			✓
9	✓ dominant	✓			
10	✓ dominant	✓		✓	✓
11	✓ dominant	✓		✓	✓
12	✓ dominant	✓			✓
13	✓ dominant	✓			✓
14	✓ dominant				✓
15	✓ dominant	✓ dominant		✓	✓
16	✓ dominant				
17	✓	✓ dominant		✓	✓

* = Specimens too small or too poor condition for speciating
/ = Species present

Teredinid Reproduction

August, 1975, was the first month when adult teredinids were found containing eggs or larvae. Teredinids in a reproductive condition were present at all stations except 7, 10, 15, and 16. At Station 1, 16 specimens of *Teredo* spp. were found with larvae. *Teredo furcifera* with larvae were present in the long-term panels removed from Station 2. *Bankia gouldi* was the only teredinid found at the remaining stations in a reproductive state. The specimens were found with either eggs or ripe gonads (Table A-3).

In September teredinids in a reproductive condition were present only at Stations 1, 4, 5, and 6 (Table A-4). The species taken from Station 1 with larvae were *Teredo navalis* and *Teredo furcifera*. The long-term panel removed from Station 4 contained specimens of *Bankia gouldi* with eggs. At Stations 5 and 6, 75 percent of the *Teredo bartschi* examined contained larvae.

After September, 1975, only specimens of *T. bartschi* were found with eggs or larvae. They were found only in the Oyster Creek lagoons at Stations 5 and 6.

Monthly, from August, 1975, to February, 1976, adult *Teredo bartschi* containing embryos at the umbonate stage were found in the long-term panels removed from Stations 5 and 6. The adults and embryos removed from the panels at Stations 5 and 6 in February were dead. Their death can probably be attributed to their inability to survive the low water temperatures they were exposed to as a result of the power plant shut-down from December 26, 1975, to March 11, 1976.

Teredinid Larval Settlement on Short-term Panels

Survival of teredinid larvae is measured by the amount of successful settlement on the exposure panels.

Of the 17 short-term panels removed in July, only nine had borer entrances. The panel removed from Station 6 contained the largest number, 296. The number present in the other panels ranged from 1 to 46, the latter number being recorded from Station 11 (Table A-14).

TABLE A-14. NUMBERS* OF TEREDINIDS IN SHORT-TERM PANELS EXPOSED DURING 1975-1976

Location	July	August	September	October	November	December	January	February	March	April	May
1	16	4250	3625	260	47	1	0	0	0	0	0
2	5	6	6	0	0	0	0	0	0	0	0
3	0	8	1	0	0	0	0	0	0	0	0
4	4	2	0	0	0	0	0	0	0	0	0
5	(845)**	2380	1310	24	0	3	0	0	0	0	0
6	296	265	2125	190	9	1	0	0	0	0	0
7	1	2	--	1	0	0	0	0	0	0	0
8	--	--	1	0	0	0	0	0	0	0	0
9	--	--	0	0	0	0	0	0	0	0	0
10	0	1	1	0	0	0	0	0	0	0	0
11	46	320	9	0	0	0	0	0	0	0	0
12	1	26	7	0	0	0	0	0	0	0	0
13	7	127	7	1	0	0	0	0	0	0	0
14	25	280	3	0	0	0	0	0	0	0	0
15	0	2	1	0	0	0	0	0	0	0	0
16	0	2	0	0	0	0	0	0	0	0	0
17	0	110	7	0	0	0	0	0	0	0	0

* - Numbers over 400 given when majority of specimens were embryonic or juvenile and actual count could be made.
** - Short-term panel missing. Count from long-term panel which had been exposed one month.
-- - No panel.

Teredinid larvae settlement was heaviest during the second month of the study. This agrees with the 1972-73 results of Shafto (1974) and Turner (1973). This was reflected in the number of entrances present in the short-term panels removed in August, 1975. Settlement was greatest at Stations 1 and 5. The panel from the former station contained 4,250 entrances, the latter 2,380. The following stations also contained large numbers of entrances: Station 11 (320), Station 14 (280), Station 6 (265), Station 13 (127), and Station 17 (110). The short-term panels from the remaining stations contained from 1 to 26 entrances (Table A-14).

In September, the short-term panels removed from Stations 1, 6, and 5 contained large numbers of borer entrances, 3,625, 2,125, and 1,310, respectively. The panels from the remaining 14 stations contained from 0 to 9 entrances (Table A-14).

There was a marked decline in the number of borer entrances in the short-term panels removed after September, 1975. The October short-term panels at Stations 1 and 6 had 260 and 190 entrances, respectively. The panel at Station 5 contained 24 entrances, and Stations 7 and 13 contained one entrance each. The short-term panels removed from the remaining 12 stations did not contain any borer entrances.

Stations 1 and 6 were the only two stations that had borer entrances in the short-term panels in November. The former station had 47, the latter 9.

Only three of the 17 short-term panels collected in December had borer entrances. The panel from Station 5 had three entrances, and the panels from Stations 1 and 6 each had one entrance.

Short-term panels removed from January through May, 1976, were free of borer entrances.

Percent Destruction of Short-term Panels by Teredinids

The percent to which the short-term panels at each station were filled (destroyed) by teredinids each month from July through

December, 1975, is presented in Table A-15. The short-term panels collected from January through May, 1976, were free of teredinids.

Of the 14 short-term panels collected in July, only nine had come under attack by teredinids. The panel from Station 6 had received the heaviest infestation and was 20 percent destroyed. The other eight panels were from less than 1 to 10 percent filled (Table A-15).

Teredinid attack on short-term panels was heaviest in August (panels submerged in July). The panels retrieved from Stations 1, 5, 11, and 14 had sustained a medium-heavy attack and were from 35 to 45 percent destroyed (Table A-15).

Three of the 16 short-term panels removed in September were 20 percent filled. They were taken from Stations 1, 5, and 6. The panels from 10 other stations were from less than 1 to 2 percent filled (Table A-15).

Of the 17 short-term panels removed in October, only five contained teredinids. The percent of destruction ranged from less than 1 to 3 (Table A-15).

In November, only two short-term panels from Stations 1 and 6 contained teredinids. Each panel was less than 1 percent filled.

The short-term panels retrieved in December from Stations 1, 5, and 6 contained teredinids, and each was less that 1 percent filled. The panels from the remaining 14 stations were free of teredinids.

Teredinids were not found in any of the short-term panels from January through May, 1976.

<u>Percent Destruction of Long-term Panels by Teredinids</u>

The percent to which each long-term panel was destroyed (filled) with teredinids and the number present by month is presented in Tables A-16 and A-17).

The long-term exposure panels removed in July, 1975, were submerged for just over 30 days. Each of the panels removed from Stations

TABLE A-15. PERCENT OF SHORT-TERM PANELS FILLED WITH TEREDINIDAE, JULY THROUGH DECEMBER, 1975

Location	July	August	September	October	November	December
1	1	40	20	3	<1	<1
2	2	2	<1	0	0	0
3	0	1	<1	0	0	0
4	<1	<1	0	0	0	0
5	No panel	35	20	1	0	<1
6	20	15	20	2	<1	<1
7	<1	2	No panel	<1	0	0
8	No panel	No panel	<1	0	0	0
9	No panel	No panel	0	0	0	0
10	0	<1	<1	0	0	0
11	4	40	2	0	0	0
12	<1	8	<1	0	0	0
13	1	15	1	<1	0	0
14	10	45	<1	0	0	0
15	0	2	<1	0	0	0
16	0	<1	0	0	0	0
17	0	18	<1	0	0	0

No borers present in short-term panels January through May

TABLE A-16. PERCENT OF LONG-TERM PANELS FILLED WITH TEREDINIDAE, SUBMERGED JUNE TO DECEMBER, 1975, AND REMOVED SEQUENTIALLY JULY, 1975, THROUGH JUNE, 1976

	Submerged	June						July	August	September	October	November	December		
Location	Removed	July	August	September	October	November	December	January	February	March	April	May	June	$\bar{X}$*	S
1		1	50	90	100	100	100	Panel Missing	100	100	3	0	0	74.4	41.17
2		2	10	25	50	60	50	25	15	0	0	0	0	23.7	22.51
3		0	1	9	6	12	50	75	1	0	0	0	0	15.4	25.86
4		<1	6	70	90	90	50	20	3	0	0	0	0	33.0	38.23
5		20	45	90	100	100	100	100	98	15	<1	0	0	66.9	41.63
6		20	45	80	100	100	100	100	100	5	<1	0	0	65.1	42.78
7		0	15	**Lost	<1	<1	<1	0	0	<1	0	0	0	2.1	4.86
8				<1	2	13	5	1	5	<1	0	0	0	3.5	4.28
9				<1	2	4	2	5	4	0	0	0	0	2.3	1.91
10		0	2	65	60	45	40	25	0	0	0	0	0	23.7	26.80
11		4	65	90	100	100	100	100	75	<1	<1	0	0	63.6	44.12
12		<1	10	40	75	95	75	90	10	0	0	0	0	39.6	40.13
13		<1	15	90	100	15	100	100	**No Panel	0	0	0	0	46.8	48.55
14		8	45	100	100	100	100	100	20	0	0	0	0	57.3	46.73
15		0	5	25	30	9	20	45	0	0	0	0	0	13.4	15.85
16		0	3	8	7	40	5	3	0	0	0	0	0	6.6	12.11
17		0	15	45	70	95	90	98	30	0	<1	0	0	44.4	40.92

Locations 8 and 9 submerged 8/13/75.
Location 7 submerged 9/11/75.
* Mean derived from data obtained from July through April, since there was no settlement on long-term panels submerged after October.
** Used the row mean for missing values.

TABLE A-17. NUMBERS* OF TEREDINIDS IN LONG-TERM PANELS EXPOSED DURING 1975-1976

Location	July 1	August 2	September 3	October 4	November 5	December 6	January 6	February 6	March 6	April 6	May 6
1	12	5100	4250	3400	>400(1)	>400	**	>400(2)	>400(1)	125	0
2	7	19	29	41	27	18	12	8	0	0	0
3	0	5	4	3	4	9	14	1	0	0	0
4	4	16	51	49	76	18	10	7	0	0	0
5	845	920	4000	900	>400(1)	>400(1)	>400(1)	350(3)	77(4)	9	0
6	263	420	850	700	>400(1)	>400(1)	>400(1)	>400(1)	70(4)	43	0
7	0	15	--	3	1	4	0	0	2	0	0
8	0	--	6	3	5	2	1	2	1	0	0
9	--	--	2	2	2	1	1	2	6	0	0
10	0	7	27	31	17	8	0	0	2	0	0
11	49	470	430	>400(1)	>400(1)	>400(1)	>400(1)	68	1	1	0
12	2	25	45	54	47	18	22	8	0	0	0
13	3	118	340	>400(1)	7(5)	>400(1)	>400(1)	--	0	0	0
14	17	335	>400(1)	>400(1)	>400(1)	>400(1)	>400(1)	8	0	0	0
15	0	6	16	12	4	6	9	7	0	0	0
16	0	7	3	4	10	1	1	0	0	0	0
17	0	85	67	118	124	103	6	33	0	1	0

Number following month indicates months exposed

Notes:
- * - Numbers over 400 given when majority of specimens were embryonic or juvenile and actual count could be made
- ** - Board riddled and missing
- (1) - >400 estimated count, panel 75-100 percent riddled
- (2) - 40 percent panel missing, 40 percent of specimens dead
- (3) - No live specimens
- (4) - Tubes empty
- (5) - Submerged two months
- -- - No panel

5 and 6 was 20 percent filled with teredinids. The panels removed from Stations 3, 7, 10, 15, 16, and 17 were free of teredinids. The percent to which the panels from the remaining stations were filled with teredinids ranged from less than 1 to 8 percent.

By the end of the second removal period, August, 1975, the percent to which the long-term panels were filled with teredinids varied from 1 to 65 percent (Table A-16). The panel from Station 11 had sustained the heaviest attack and was 65 percent filled. The panels from Stations 1, 5, 6, and 14 had received a moderately heavy attack and were from 45 to 50 percent filled. The panels from the remaining stations were from 1 to 15 percent filled with teredinids.

The long-term panels removed in September, 1975, (3 months' exposure) from Stations 1, 5, 6, 11, 13, and 14 were 90 percent filled with teredinids. The panels from Stations 4, 10, 12, and 17 were from 40 to 70 percent filled. Data on these stations and the remainder of the stations where panels were collected are presented in Table A-16.

By October, 1975, (4 months' exposure) the long-term panels at Stations 1, 5, 6, 11, 13, and 14 were 100 percent filled with teredinids. The panels removed from Station 4 were 90 percent filled. At Stations 12, 17, 10, and 2, the panels were from 50 to 75 percent filled. The percent destruction each long-term panel sustained is given in Table A-16.

Of the 17 long-term exposure panels removed in November, 1975, (5 months' exposure) 5 were 100 percent filled with teredinids. The panels were located at Stations 1, 5, 6, 11, and 14. The panels from Stations 4, 12, and 17 were 90 to 95 percent filled. Percent filled data for each of the 17 stations are given in Table A-16.

In December, 1975, (6 months' exposure) the long-term panels removed from Stations 1, 5, 6, 11, 13, and 14 were 100 percent filled with teredinids. The panels from Stations 12 and 17 were 75 and 90 percent filled, respectively. At Stations 2, 3, and 4 the panels were each 50 percent filled. Percent filled data for each of the remaining stations are presented in Table A-16.

In January, 1976, (6 months' exposure) the long-term panel at Station 1 was missing. It can be assumed that the panel had been so weakened by the activity of teredinids that it broke up and fell from the exposure panel rack. The panels removed from Stations 5, 6, 11, 13, and 14 were 100 percent filled with teredinids. At Stations 3, 12, and 17 the percent of each panel filled with teredinids was respectively 75, 90, and 95. Table A-16 gives percent filled data for the remaining stations.

In February, 1976, (6 months' exposure) only two of the 17 long-term panels were 100 percent filled with teredinids; they were removed from Stations 1 and 6. The long-term panel from Station 5 was 98 percent filled, and the one from Station 11 was 75 percent filled. The panels removed from Stations 7, 10, 15, and 16 were free of teredinids. Table A-16 gives the percent to which the long-term panels from the remaining stations were filled.

In March, 1976, (6 months' exposure) 11 of the 17 long-term panels retrieved were free of teredinids. The panel removed from Station 1 was 100 percent filled. Panel destruction at Stations 7, 8, and 11 was less than one percent. The panels from Stations 5 and 6 were 15 and 5 percent filled, respectively.

Only five of the 17 long-term panels removed in April, 1976, (6 months' exposure) contained teredinids. The panel from Station 1 was 3 percent filled; the remaining Stations (5, 6, 11, and 17) were each less than one percent filled.

The long-term exposure panels removed in May, 1976, (6 months' exposure, submerged November, 1975) from each of the 17 stations were free of teredinids.

A two-factor analysis of variance using Tukey's test was performed to determine if there were significant differences in the percent destruction sustained by the long-term panels at 15 of the 17 exposure panel stations. Stations 8 and 9 were not included in the analysis. During July and August, 1975, the exposure panel arrays were lost due to vandalism. The losses occurred during the peak periods of teredinid larval settlement.

The results of the analysis showed (Table A-18, Figure A-5) that the destruction of long-term panels at Station 1 was significantly greater ($\alpha = 0.05$) than at Stations 2, 3, 4, 7, 10, 15, and 16.

At Stations 5 and 6, long-term panel destruction was significantly greater ($\alpha = 0.05$) than at Stations 2, 3, 10, 15, and 16. Long-term panel destruction at Station 11 was significantly greater ($\alpha = 0.05$) than Stations 2, 3, 7, 10, 15, and 16. At Station 7 the long-term panel destruction was significantly less ($\alpha = 0.05$) than at Stations 1, 5, 6, 11, 12, 13, 14, and 17. This can be attributed to the loss of the exposure panel array in September due to vandalism. There was not a significant difference ($\alpha = 0.05$) between the long-term panel destruction at Stations 2, 3, 4, 10, 12, 13, and 15.

Teredinid Mortality

From September, 1975, through March, 1976, 70 to 100 percent of the teredinids contained in the long-term panels removed from Stations 1, 5, 6, and 13 were dead. Ninety percent of the teredinids in the long-term panels removed from Station 14 in December, 1975, were dead. The January, 1976, long-term panel contained 50 percent dead.

The death of the teredinids occupying the long-term panels removed from January through March, 1976, may have resulted from the low winter seawater temperature and would not be considered abnormal in view of the exceptionally cold winter. Of greater interest, however, is the death of the teredinids in the long-term panels that were removed from September through December, 1975, at Stations 1, 5, 6, and 13. The seawater temperature from July through October (at the time of panel removal) was high enough for *Teredo navalis* and *Bankia gouldi* to reproduce. The seawater temperatures recorded in Barnegat Bay in December, when the panels were removed, were still above the lower lethal limit for *B. gouldi* and *T. navalis*.

Stations 5 and 6 are located in Oyster Creek. The seawater temperatures recorded did not exceed the upper lethal limits for any of the teredinid species found in Barnegat Bay. Ambient seawater temperatures prevailed at Stations 1 and 13 during the period in question.

TABLE A-18. TWO-FACTOR ANALYSIS OF VARIANCE OF THE MEAN PERCENT DESTRUCTION OF LONG-TERM PANELS BY MONTHS AND STATIONS

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	182490.153	23	7934.354	16.006	<.001
Station Effects	78010.760	14	5572.197	11.241	<.001
Month Effects	104479.393	9	11608.821	23.419	<.001
Residual	62459.107	126	495.707		
TOTAL	244949.260	149			

*Exposure panel arrays were lost during July and August, 1975. Therefore, Stations 8 and 9 were not included in the analysis of variance.

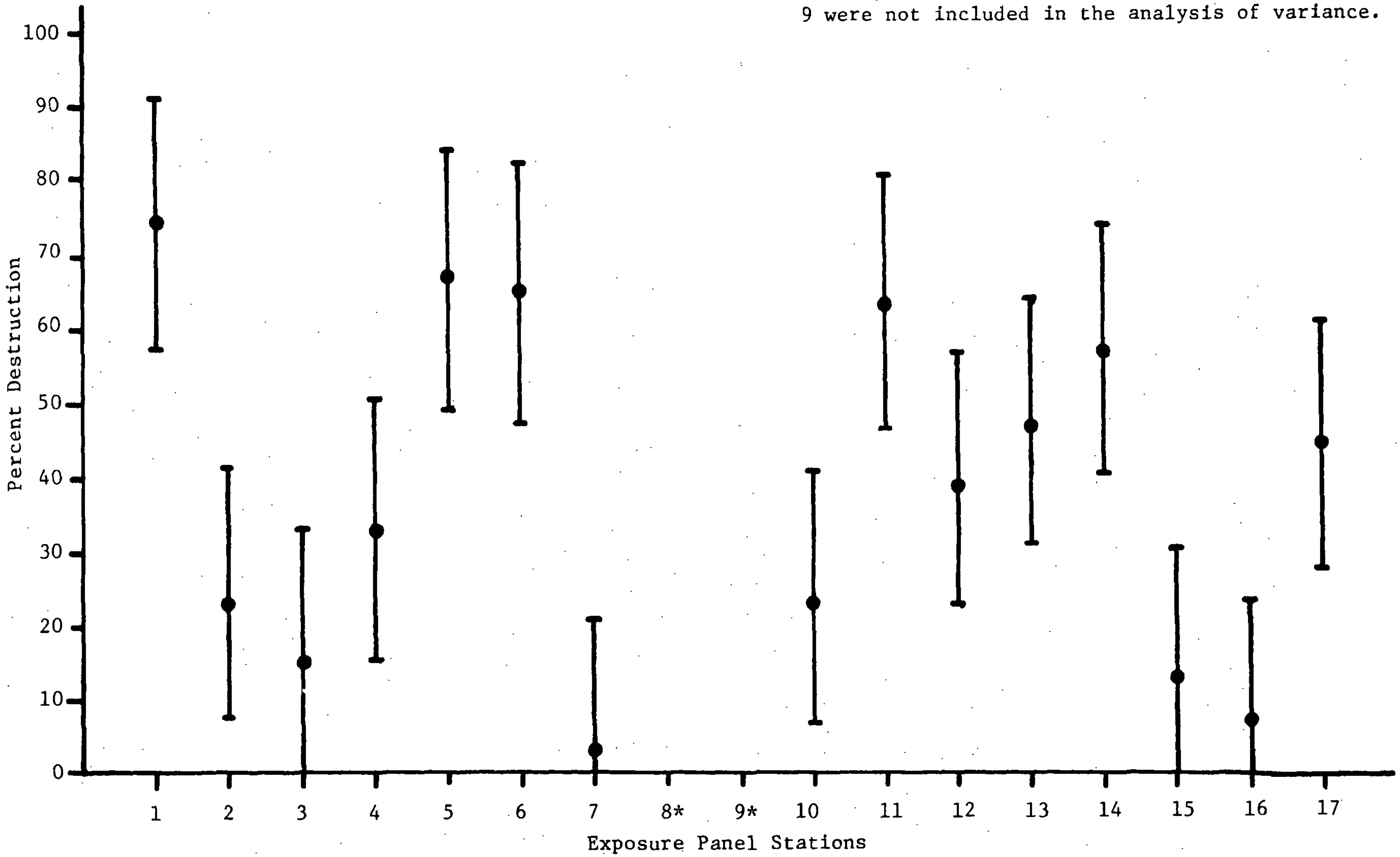


FIGURE A-5. MEAN PERCENT DESTRUCTION OF LONG-TERM PANELS AND INTERVAL OF SIGNIFICANT DIFFERENCE AT $\alpha = 0.05$, AT 15 EXPOSURE PANEL STATIONS IN BARNEGAT BAY

The salinity and seawater temperature limits are not known for *Teredo bartschi* and *T. furcifera*. However, from the available seawater temperature data, it does not appear that their upper thermal limit could have been exceeded, since they are both considered subtropical species.

It is not known what caused the death of the adult teredinids at these stations. It is also unknown if the agent(s) that affected the adult teredinids also acted on the larvae, and if so to what extent, because the short-term panels removed each month from September through December at Stations 1, 5, and 6 contained shipworms. After October, 1975, teredinids were absent from the short-term panels removed from Station 13. The number of teredinids found in the short-term panels each month by station is presented in Table A-15.

The larvae that settled on the short-term panels at Stations 5 and 6 may have been released by adult teredinids in the vicinity of the exposure panel racks within Oyster Creek, or they may have originated elsewhere, became entrained with the intake water and passed through the dilution pumps.

The larvae that settled on the short-term panels at Stations 1 and 13 may have originated from near the panels (i.e., trash wood, untreated pilings), or they may have drifted in.

Lenths of Teredinids

The size of the teredinid specimens collected varied considerably depending, in part, upon the number of specimens settling on the panels. When large numbers of larvae settle successfully at the same time, the size of each specimen may be restricted, although its final length is not related to maturation of the adult specimen and reproduction takes place normally. The amount of reproduction can be increased as the numbers of mature specimens increase. The restricted size condition is known as stenomorphism and the stunted organisms are called stenomorphs. In the long-term panels, the size of the specimens ranged from less than 1 millimeter to 320 millimeters. Specimens attained lengths up to 110 millimeters in one month (August) in the short-term panels removed from Station 6, Oyster Creek. This growth rate is similar to that reported by Turner (1973) (Table A-19).

Limnoria

Limnoria were found only at Stations 1, 2, 3, and 4. *Limnoria tripunctata* was the only species identified. Gravid females and junveiles were present in the panels removed in August. The *Limnoria* attack rates were minimal (Table A-20, Figure A-6).

The creosoted exposure panels remained free of *Limnoria* attack. However, the existing inshore pilings and bulkheading at Station 2 had a heavy *Limnoria* attack. But, it is not known what type of preservative treatment, if any, these wooden structures received.

TABLE A-19. LONGEST (Millimeter) TEREDINID RECORDED EACH MONTH

	Long-Term Panels										Short-Term Panels					
Location	July	August	September	October	November	December	January	February	March	April	July	August	September	October	November	December
1	5	81	48	45	50	des. by attack		43	40	7	5	21	18	3	1	e
2	30	75	155	190	320	220	220	160	-	-	27	34	4	-	-	-
3	-	22	120	215	265	305	275	61	-	-	-	8	5	-	-	-
4	2	52	230	215	165	245	240	42	-	-	1	15	-	-	-	-
5	5	90	60	65	40	130	75	85	45	1	-	57	6	2	-	e
6	4	71	165	95	105	160	115	53	23	2	4	110	9	2	e	e
7	-	142	-	3	4	10	-*	-*	11	-	2	62	-	e	-	-
8	Array Lost		2	70	195	215	60**	170	8	-	-	-	e	-	-	-
9	Array Lost		1	31	95	85	230**	130	-	-	-	-	-	-	-	-
10	-	39	200	215	160	200	205	-	-	-	-	2	12	-	-	-
11	5	75	160	120	150	165	115	165	2	2	4	82	9	-	-	-
12	2	78	210	125	180	210	265	90	-	-	1	33	3	-	-	-
13	2	49	85	85	160	90	95	No Panel	-	-	5	45	2	1.5	-	-
14	12	62	65	95	75	75	110	75	-	-	9	55	3	-	-	-
15	-	29	150	170	255	245	220	180	-	-	-	35	e	-	-	-
16	-	26	100	135	230	240	145	-	-	-	-	8	-	-	-	-
17	-	29	95	70	125	122	80	110	-	1	-	41	2	-	-	-

* = 1 month exposure
** = 5 months exposure
e = embryonic
\- = no borers
No borers were recorded in May or June removals
No borers were recorded from short-term panels removed after December

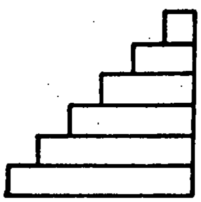
TABLE A-20. NUMBER OF *Limnoria* TUNNELS IN PANELS EXPOSED DURING 1975-1976

Month	Barnegat Light		Manahawkin		Conklin Island		Waretown	
	P	C	P	C	P	C	P	C
July	1	4	8	4	1	2	0	0
August	5	0	14	2	19	0	4	0
September	14	8	48	0	58	0	18	0
October	0	7	62	0	8	0	1	0
November	0	1	36	1	1	0	41	0
December	0	0	8	0	18	0	5	0
January	–	0	38	0	39	0	0	0
February	0	0	3	0	0	0	0	0
March	0	0	1	0	0	0	0	0
April	1	0	0	0	0	0	0	0
May	0	0	2	0	0	1	0	0

P = Long-term panel
C = Short-term panel
– = Panel lost, severe shipworm attack

No *Limnoria* at other panel exposure locations

KEY

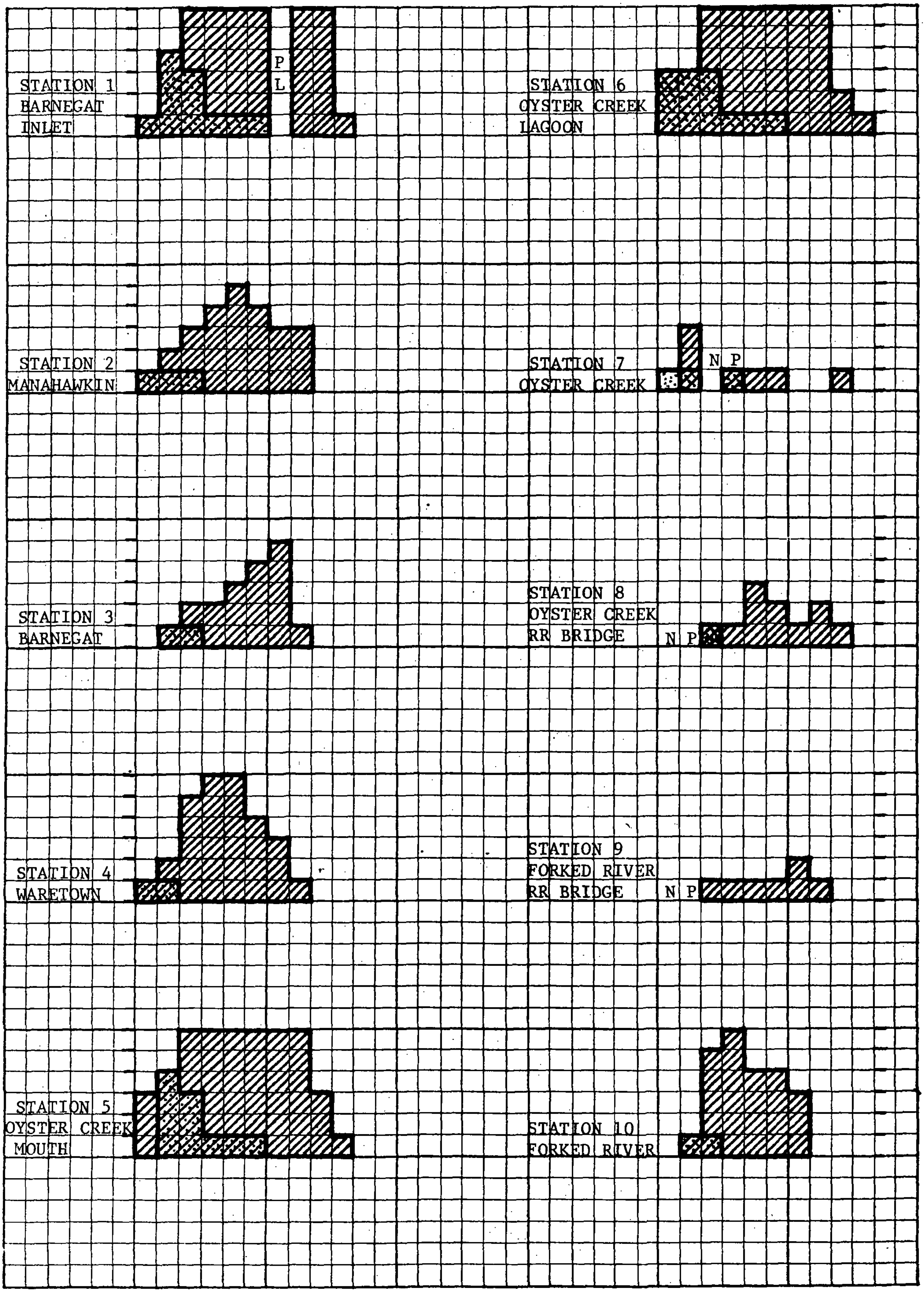


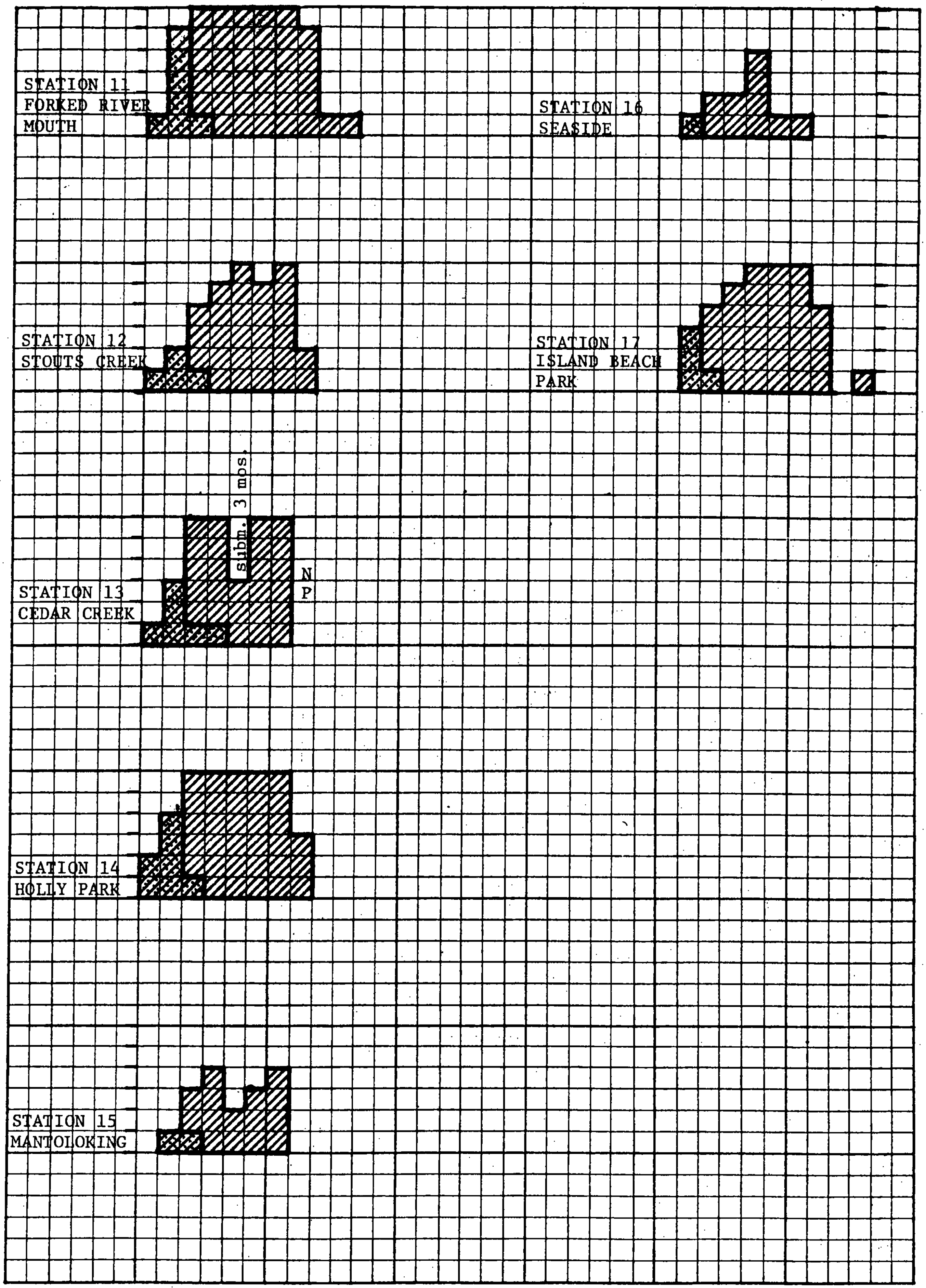
76-100% Very Heavy
51-75 Heavy
26-50 Moderately Heavy
11-25 Moderate
5-10 Slight
5 Trace

Long-term Panel
Short-term Panel

N.P. No Panel
P.L. Panel Lost - Severe Attack

FIGURE A-6. RATE OF PANEL DESTRUCTION BY TEREDINIDAE FROM JUNE, 1975 THROUGH MAY, 1976


STATION 1
BARNEGAT
INLET
P
L
STATION 6
OYSTER CREEK
LAGOON
STATION 2
MANAHAWKIN
STATION 7
OYSTER CREEK
N P
STATION 3
BARNEGAT
STATION 8
OYSTER CREEK
RR BRIDGE
N P
STATION 4
WARETOWN
STATION 9
FORKED RIVER
RR BRIDGE
N P
STATION 5
OYSTER CREEK
MOUTH
STATION 10
FORKED RIVER


STATION 11
FORKED RIVER
MOUTH
STATION 16
SEASIDE
STATION 12
STOUTS CREEK
STATION 17
ISLAND BEACH
PARK
subm. 3 mos.
N
P
STATION 13
CEDAR CREEK
STATION 14
HOLLY PARK
STATION 15
MANTOLOKING

Literature Cited

Bartsch, Paul. 1908. A New Shipworm from the United States. Proc. Biol. Soc. Washington 21(34):211-212.

Clapp, William F. 1923. A New Species of *Teredo* from Florida. Proc. Bos. Soc. Nat. Hist. 37(2):37-38.

Clapp, William F. and R. Kenk. 1963. Marine Borers: An Annotated Bibliography. ACR-74, Office of Naval Research, Dept. of the Navy, Washington, D.C. 1136 pp.

Menzies, R.J. 1951. A New Species of *Limnoria* (Crustacea:Isopoda) from Southern California. Bull. So. Calif. Acad. Sci. 50(2):86-88.

Purushotham, A. and K. Satyanaroyana Rao. ca. 1971. The First Progress Report of the Committee for the Protection of Timber Against Marine Organisms Attack in the Indian Coastal Waters for the Period 1953 - 70. Jour. Timber Development Assoc. (India), Vol. XVII (3):1-74.

Shafto, S.S. 1974. The boring and fouling community of Barnegat Bay, New Jersey. Masters Thesis, Rutgers Univ., New Brunswick, N.J. 235 pp.

Turner, R.D. 1966. A Survey and Illustrated Catalogue of the Teredinidae. Mus. of Comp. Zoo. Harvard Univ., Cambridge, Mass. 265 pp.

Turner, R.D. 1973. Report on Marine Borers (Teredinidae) in Oyster Creek, Waretown, New Jersey. Mus. Comp. Zoo. Harvard Univ., Cambridge, Mass. First Report, April 3, 1973, 30 pp.

Wallour, D.B. 1960. Marine Borer Activity in Test Boards Operated During 1959. 13th Progress Report, William F. Clapp Laboratories, Duxbury, Massachusetts, 1-XXXX, 1-59.

APPENDIX B

MARINE BORER LARVAE

APPENDIX B

MARINE BORER LARVAE

Introduction

Water temperature is a major factor controlling the distribution, reproduction, and growth rate of organisms inhabitating the marine environment (Gunther, 1957). The thermal effluent from the Oyster Creek Nuclear Electric Generating Station is discharged into Oyster Creek. Because of this, marine organisms inhabiting Oyster Creek are, at times, exposed to temperatures that are higher than at other areas in the Barnegat Bay system.

As a result of this increase in water temperature a number of studies were initiated to determine to what extent the thermal effluent from the Oyster Creek station is affecting the reproductive behavior of the resident marine borer population in Oyster Creek and other areas in Barnegat Bay. This study addresses the distribution and density of teredinid larvae collected in the plankton at six locations in Barnegat Bay.

Materials and Methods

Field Procedures

Six stations were established in Barnegat Bay (Figure B-1). Each station designation and its location is as follows:

	Location	Approximate latitude and longitude
A.	Mouth of Oyster Creek	Lat. 39° 48.5'N Long. 74° 10.2'W
B.	South branch Forked River	Lat. 39° 49.2'N Long. 74° 12.2'W
C.	Mouth of Forked River	Lat. 39° 49.7'N Long. 74° 10'W
D.	Holly Park	Lat. 39° 53.2'N Long. 74° 08'W
E.	Barnegat Beach	Lat. 39° 47'N Long. 74° 11'W
F.	Between Barnegat Inlet and Oyster Creek Channel	Lat. 39° 46.2'N Long. 74° 06.5'W

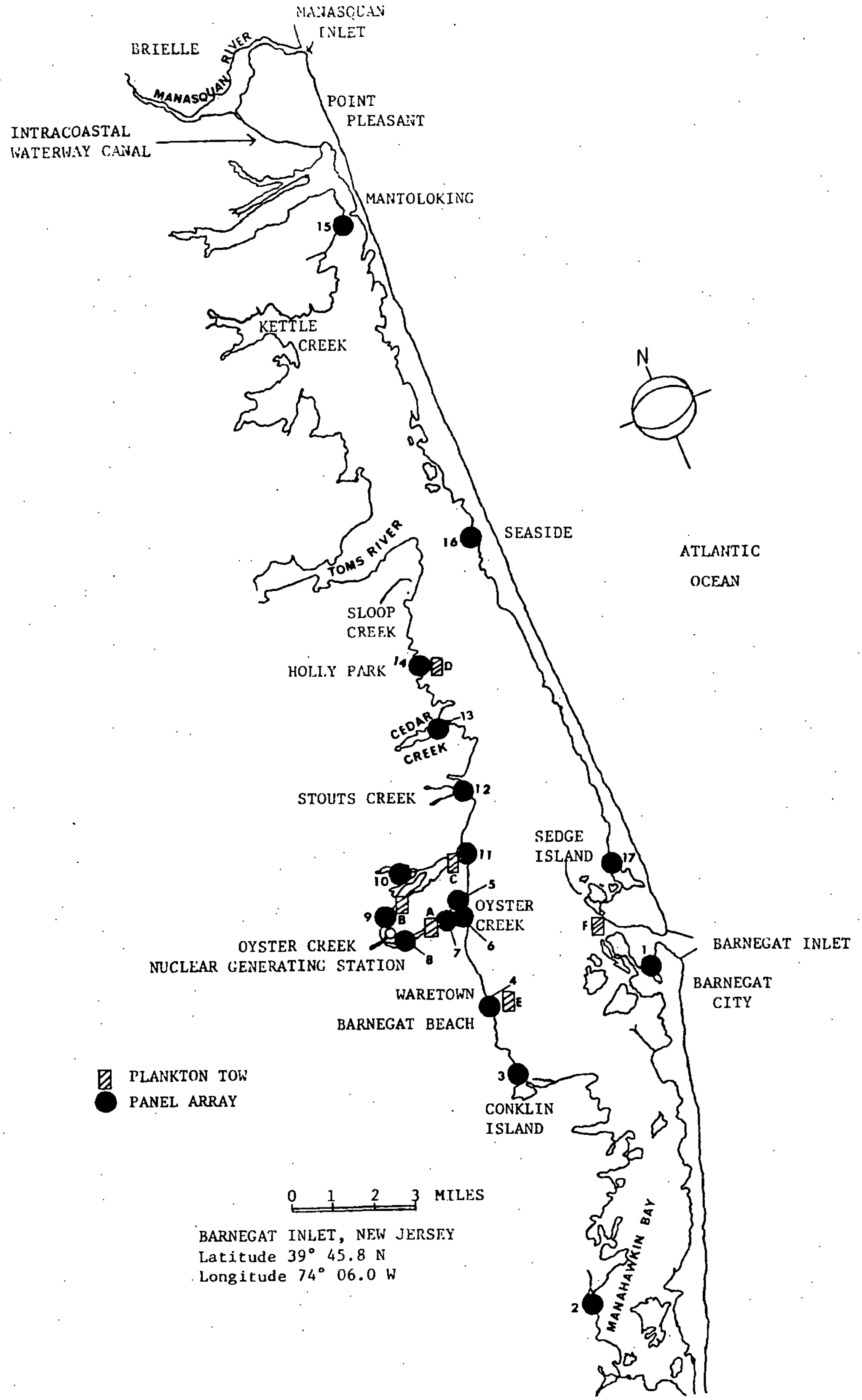


FIGURE B-1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHICAL LOCATIONS OF EXPOSURE PANELS AND PLANKTON TOWS

Sampling techniques conformed to the standard procedures established by MARMAP whenever possible. All tows were ten minutes in duration. Step oblique tows were conducted by paying out the nets so that they gradually sank toward the bottom as the boat proceeded. When the nets approached the bottom they were raised to just below the surface. This process was repeated for the duration of the tow.

In June, 1975, six individual tows were made at each station with a Clarke-Bumpus sampler with a 156 micrometer-mesh-net. The sampler was equipped with the General Oceanics Model 2030 flowmeter. For the remainder of the study sampling was conducted with a 20 centimeter Bongo frame. From July to September, 1975, the nets used had a mesh of 153 micrometers; from October, 1975, to May, 1976, 80 micrometer mesh nets were employed. It was felt that by using nets with an 80 micrometer mesh, a greater number of teredinid larvae over a broader size range would be captured. Three tows were made at each station when the Bongo's were used. Flowmeters, General Oceanics Model 2030, were attached inside the mouth of each net frame. The tow speed for all boat tows was between one and one and one-half knots.

As a result of the breakdown of the boat during the February sampling period it was not possible to sample all stations. Samples were taken from the dock at the Coast Guard Station and Dick's Landing, and from the railroad bridge that extends across Oyster Creek. At the Coast Guard Station and Dick's Landing sampling was conducted by lowering the nets into the water and pulling them along parallel to the dock. The step oblique procedure was followed and the duration of each of the three tows was ten minutes. At the Oyster Creek railroad bridge the nets were lowered into the water and allowed to sink gradually. When the nets approached bottom they were gradually raised toward the surface, then lowered again. This procedure was conducted during each of the three ten minute tows.

When the nets were retrieved after each tow they were thoroughly washed so that all organisms clinging to the nets passed to the cod end. Each net sample was poured into a 1-liter polyethylene jar(s) and fixed with buffered formalin to a final concentration between 5 and 10 percent.

For each sample the flowmeter revolutions were recorded. Each sample was labelled with the appropriate field information and placed in a container for shipment to the laboratory.

Water Quality. Water temperature, salinity, pH, and dissolved oxygen were measured at each plankton station with a Hydrolab Model II B. The Hydrolab was calibrated prior to each days use.

Laboratory Procedures

Plankton Samples. Each field sample was poured into a graduated beaker to obtain the volume of the sample. The sample was stirred to obtain a homogenous mixture of the sample. Immediately after stirring, a 10-milliliter aliquot was removed for inspection. The 10-milliliter aliquot was placed in a rafting cell and inspected using a Bausch and Lomb Stero Zoom dissecting microscope.

All teredinid larvae observed were removed from the rafting cell and placed in a small screw top vial and the vial labelled. The above procedure was repeated until five 10-milliliter aliquots had been withdrawn from the sample and inspected.

The number of teredinid larvae found in the aliquots was used to calculate the number present in each sample. The number thus obtained was used to calculate the number of teredinid larvae per cubic meter of seawater filtered as determined from flowmeter data.

After each field sample was inspected it was returned to the field sample jar and stored.

Results

The mean number of teredinid larvae captured per cubic meter of seawater filtered at each of the six plankton stations from June, 1975, to May, 1976, is presented in Table B-1. The catch data suggests that the results of the year's sampling effort can be divided into two broad categories based on the presence or absence of teredinid larvae in the plankton. Except for September, 1975, teredinid larvae were captured each month from June through November, 1975. From the available data it is not possible to determine why teredinid larvae were not present in September.

TABLE B-1. THE MEAN NUMBER, STANDARD DEVIATION, AND RANGE OF TEREDINID LARVAE COLLECTED PER CUBIC METER OF SEAWATER FILTERED AT SIX PLANKTON STATIONS IN BARNEGAT BAY FROM JUNE, 1975, THROUGH MAY, 1976

	Stations					
	A	B	C	D	E	F
1975						
Jun 4-6	$\bar{X}^a = 0.17$ $\sigma^b = 0.42$ R*, 0-1.02	0**	0	0	0	0
Jul 8-9	$\bar{X}^a = 0.17$ $\sigma^b = 0.41$ R*, 0-1	$\bar{X}^a = 6.84$ $\sigma^b = 6.52$ R*, 2.28-19.39	$\bar{X}^a = 3.19$ $\sigma^b = 1.97$ R*, 0.98-5.16	$\bar{X}^a = 1.42$ $\sigma^b = 2.29$ R*, 0-5.26	$\bar{X}^a = 0.36$ $\sigma^b = 0.89$ R*, 0-2.19	$\bar{X}^a = 5.56$ $\sigma^b = 2.92$ R*, 2.56-10.67
Aug 12-13	$\bar{X}^a = 1.24$ $\sigma^b = 0.92$ R*, 0-2.49	$\bar{X}^a = 0.17$ $\sigma^b = 0.42$ R*, 0-104	$\bar{X}^a = 0.28$ $\sigma^b = 0.43$ R*, 0-0.85	0	0	$\bar{X}^a = 0.42$ $\sigma^b = 0.48$ R*, 0-1.05
Sep 9-10	0	0	0	0	0	0
Oct 7-8	0	$\bar{X}^a = 2.01$ $\sigma^b = 1.73$ R*, 0-3.71	$\bar{X}^a = 0.26$ $\sigma^b = 0.41$ R*, 0-0.89	$\bar{X}^a = 0.17$ $\sigma^b = 0.19$ R*, 0-0.35	$\bar{X}^a = 0.16$ $\sigma^b = 0.18$ R*, 0-0.34	$\bar{X}^a = 0.57$ $\sigma^b = 0.98$ R*, 0-2.19
Nov 4	0	0	$\bar{X}^a = 0.50$ $\sigma^b = 0.48$ R*, 0.39-1.42	$\bar{X}^a = 0.84$ $\sigma^b = 1.15$ R*, 0-1.18	$\bar{X}^a = 0.19$ $\sigma^b = 0.22$ R*, 0-0.46	$\bar{X}^a = 0.99$ $\sigma^b = 2.41$ R*, 0-5.9
Dec 2	0	0	0	0	0	0
1976						
Jan*** No Samp.	-	-	-	-	-	-
Feb 12	0	****	****	0	****	0
Mar 10-11	0	0	0	0	0	0
Apr 6	0	0	0	0	0	0
May 5-6	0	0	0	0	0	0

a = mean
b = standard deviation
* = range
** = no teredinid larvae captured
*** = Barnegat Bay frozen over. It was not possible to collect samples.
**** = no samples taken, boat inoperable.

Of the five months when teredinid larvae were captured, July, 1975, was the only month when they were taken at each of the six plankton stations. During this sampling period the larvae were present in greatest numbers at Stations B, C, and F, the lowest numbers per cubic meter were taken at Station A, mouth of Oyster Creek (Table B-1).

In June, teredinid larvae were captured only at Station A. They were taken at Stations A, B, C, and F in August; at Stations B through F in October; and at Stations C through F in November, 1975. The mean number of larvae captured per cubic meter at each station is presented in Table B-1.

Several of the exposure panel stations are in the vicinity of the teredinid plankton stations. The number of larvae captured each month at these plankton stations and the number that settled on the short-term exposure panels are presented in Table B-2. Because of the nearness of some of the plankton stations to the exposure panel stations it was felt that a relationship might be present between the number of teredinid larvae taken in the plankton and the number settling on the short-term panels. However, an analysis of the data showed that sufficient information was not available to show that relationship.

The absence of teredinid larvae in the plankton from December, 1975, through May, 1976, can probably be attributed to lower water temperatures and the natural reproductive cycle of the adult teredinids.

The Oyster Creek power plant was not releasing a thermal effluent into Oyster Creek during a shut-down from December 26, 1975, to March 11, 1976. Thus, the organisms inhabiting this body of water were subjected to normal winter-spring water temperatures for the area. As a result it was not possible from plankton sampling to determine if the thermal effluent from the power station operations was causing an extension of the normal breeding season of teredinid populations occupying wooden structures in Oyster Creek.

The use of 80 micrometer mesh nets from October, 1975, through May, 1976, did not have an effect on the number of teredinids captured.

TABLE B-2. MEAN NUMBER OF TEREDINID LARVAE CAPTURED/M^3 in PLANKTON* COMPARED WITH SETTLEMENT ON SHORT-TERM PANELS**, 1975

	Jun***	Jul	Aug	Sep	Oct	Nov	Dec
Oyster Creek							
Station A	0.17	0.17	1.24	0	0	0	0
Station 5		845	2380	1310	24	0	3
South Branch, Forked River							
Station B		6.84	0.17	0	2.01	0	0
Station 10	0	0	1	1	0	0	0
Forked River Mouth							
Station C	0	3.19	0.28	0	0.26	0.50	0
Station 11		46	320	9	0	0	0
Holly Park							
Station D	0	1.42	0	0	0.17	0.84	0
Station 14	0	25	280	3	0	0	0
Waretown							
Station E	0	0.36	0	0	0.16	0.19	0
Station 4		4	2	0	0	0	0
Inlet							
Station F	0	5.56	0.42	0	0.57	0.99	0
Station 1		16	4250	3625	260	47	1

* Lettered Stations - Plankton Larvae
** Numbered Stations - Settlement on Short-Term Panels
*** Panels were first placed in the water in June. Therefore, teredinid larval settlement data were not available for the month.

From December, 1975, through May, 1976, teredinids were not taken with the 80 micrometer or 153 micrometer nets.

Water quality data are presented in Appendix D.

Literature Cited

Gunther, G. 1957. Temperature. pp. 159-184. In Treatise on Marine ecology and paleoecology. Vol. 1. 1296 p. J.W. Hedgepth (ed.). The Geological Society of America Memoir 67. The Geological Society of America, New York, N.Y.

APPENDIX C

HISTOLOGICAL STUDIES

APPENDIX C

HISTOLOGICAL STUDIES

Introduction

The role of temperature in regulating reproductive cycles in marine invertebrates is well-known (e.g., Loosanoff, 1942). The thermal plume from the Oyster Creek generating station, therefore, could have an effect on the normal reproductive cycles of the teredinid borers in those areas influenced by the plume.

Alteration of the normal cycles theoretically could occur in one or more ways. Initiation of gonadal development could be earlier than expected in the thermally-affected areas, resulting in earlier than normal spawning. Given the short time necessary for newly settled larvae to become sexually mature (Turner, 1966), some could settle and spawn within one season. Should the waters in a given area be warmer than those of surrounding areas not affected by the thermal plume, the breeding period might be extended well into the fall, and in addition, an extended breeding season might lead to two spawning peaks within a given year - one in the spring and one in the fall.

Such alterations in the normal reproductive cycles can be ascertained qualitatively through examination of the various stages of gonad development in the borers. Histological studies of gonads of the various teredine borers were begun, therefore, to assess the developmental stages of the gonads from borers in the areas affected by the thermal plume and compare those stages with those of gonads from borers in non-affected areas.

Materials and Methods

Teredine borers were removed from exposure panels in the laboratory, placed in Bouin's solution for 24 to 48 hours and rinsed with 70 percent denatured ethanol. Portions of the shipworms containing the gonads were excised, placed in 70 percent denatured ethanol, and sent to the histological processing section of Battelle's Columbus Laboratories. There, the tissues were further dehydrated in alcohol, and then placed in two changes of methyl benozate and cleared in three changes of benzene. They were embedded in

Paraplast and sectioned at six microns. The slides were stained in Harris' hematoxylin and eosin and returned to Duxbury for analysis of gonad development.

The slides were examined microscopically to determine the stage of gonad development at the time the exposure panels were removed from the water. Because the Teredinidae are bivalve mollusks, the characteristics of gonad development are similar to those of other bivalves and a classification of developmental stages used by other investigators examining gonads of various bivalves (e.g., Rope and Stickney, 1965; Ropes, 1968; Holland and Chew, 1974) was suitable. The various phases of gonad development were characterized as follows:

Female Gonads

1. Early active phase - Ovogonia occurred at the periphery and within the alveolar walls; nuclei of ovogonia contained basophilic nuclei. The alveolar walls were not completely contracted and lumina were evident in most gonads.
2. Late active phase - Large ovocytes were attached to the alveolar wall and protruded into the alveolar lumen. The ovocyte nucleus was large and contained a basophilic nucleolus (Figure C-1).
3. Ripe phase - The shipworm was considered ripe when the number of ovocytes that had become detached from the alveolar wall and were free in the lumen of the alveolus exceeded the number still attached to the alveolar wall.
4. Partially spawned phase - A few ovocytes were still attached to the thickened alveolar wall, and some residual ripe ova remained in the alveolar lumen (Figure C-2).
5. Spent phase - Alveoli were usually empty of ripe ovocytes and those that remained were undergoing cytolysis.

Male Gonads

1. Early active phase - Shipworms in the early active phase contained darkly staining spermatogonia in the thickened alveolar wall (Figure C-3).
2. Late active phase - This phase was characterized by the proliferation and maturation of spermatocytes, most of which had migrated toward the center of the alveolus. A central lumen was present in the alveolus and occasionally a small number of spermatozoa were present in the lumen.
3. Ripe phase - In the ripe phase, the alveolar lumen was crowded with darkly stained spermatozoa (Figure C-4).

FIGURE C-1. *Bankia gouldi*. Late active ovary.

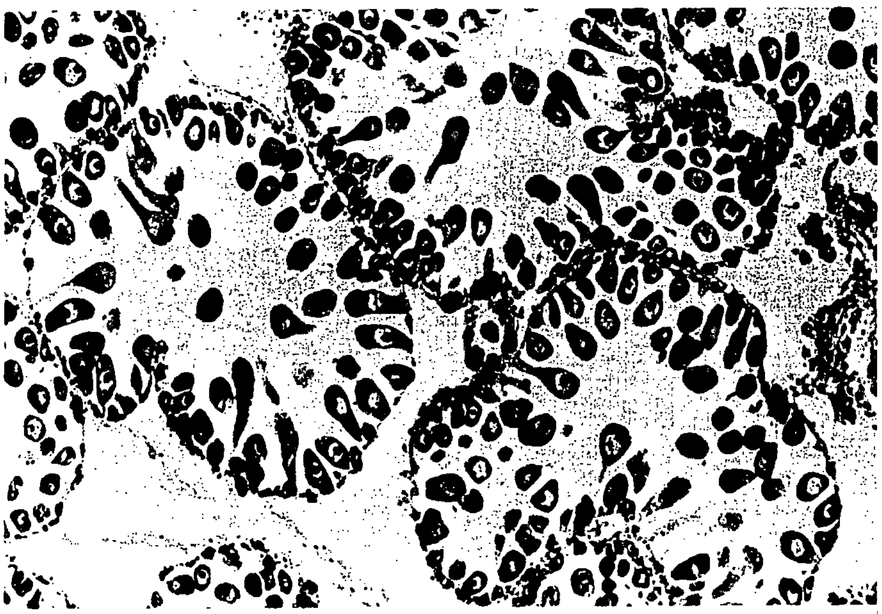


FIGURE C-2. *Bankia gouldi*. Partially spawned ovary.

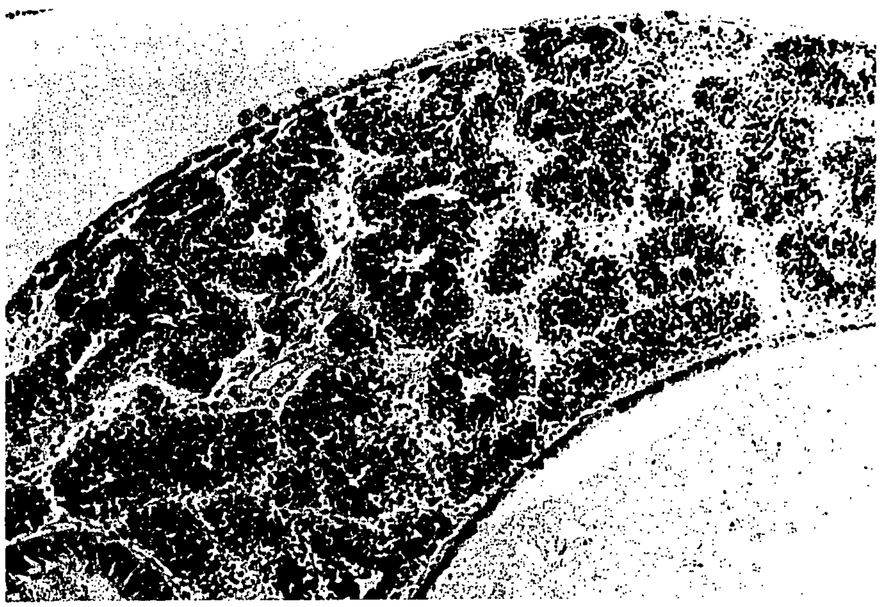


FIGURE C-3. *Bankia gouldi.* Early active testis.

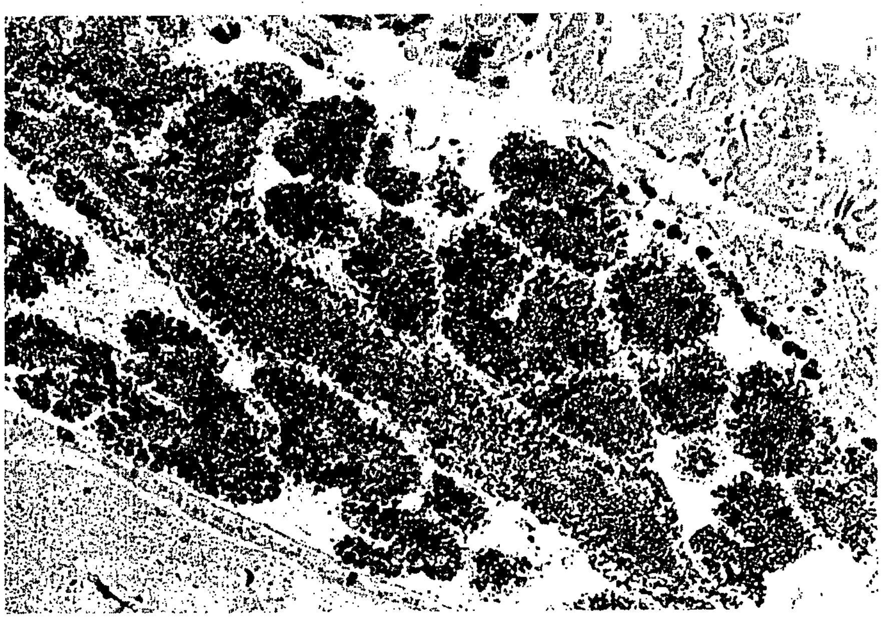


FIGURE C-4. *Bankia gouldi.* Ripe testis.

4. Partially spawned phase - A small number of spermatozoa remained in the alveolar lumen.
5. Spent phase - Alveoli in the spent phase contained very few or no spermatozoa.

Hermaphroditic gonads were characterized according to the condition of both the ovocytes and spermatocytes within the various alveoli. The slides were numbered consecutively according to sample number, and gonad condition was noted for each sample. The phase designations of the gonads were correlated with the species and station designations only after the gonads were characterized. This tended to eliminate any possible bias for station or season.

Results and Discussion

A total of 347 marine borer specimens was removed from the exposure panels and prepared for histological studies of the gonad.

The developmental phases for each species at each station are summarized on a monthly basis in Table C-1, and are discussed below by species.

Bankia gouldi

As expected, the gonads were generally in the late active through spent phases in summer and early fall. By fall, many of the young shipworms that had entered the panels in the summer were undergoing gonad development, and the gonads were primarily in the early active to late active phases.

From November through February, almost all of the samples showed some gonad development, but it was generally limited to early active phases. In January and February, some of the alveoli appeared to be undergoing cytolysis and resorption. Apparently, as the water temperatures cooled, gonad development was arrested, and the gonads rarely proceeded past the early active phases.

Teredo navalis

Where *Teredo navalis* was found, the gonads almost always were in late active through spawning phases. Ripe gonads were found at Stations 2, 9, and 15 as late as February (Figure C-5).

TABLE C-1. BREEDING CONDITION OF GONADS OF TEREDINE BORERS FOUND IN EXPOSURE PANELS FROM THE BARNEGAT BAY AREA, AUGUST, 1975, THROUGH MARCH, 1976

EA = Early active phase; LA = Late active phase; R = Ripe; PS = Partially spent; S = Spent; IN = inactive; * = Indicates section did not have any gonad material; Number in ( ) indicates number of specimens examined.

		Stations								
		1	2	3	4	5	6	7	8	9
Bankia gouldi	Aug			PS (2)	LA-PS (3)	LA-R (1)	LA-PS (6)	R-PS (8)		
	Sep			LA-R (4)	PS-S (5)		LA (1)			
	Oct		LA (2)	LA (1)	EA-LA (4)				LA-R (3)	* (2)
	Nov	IN (1)	EA (1)	EA (4)	EA-LA (4)	LA (2)	EA-LA (1)		EA (4)	EA (2)
	Dec		EA (2)	EA (4)	EA-LA (3)	EA (1)	EA (6)		EA (1)	EA (1)
	Jan		EA (2)	EA (4)	EA (4)	EA (1)	EA-LA (3)		EA (1)	
	Feb		EA-LA (2)	LA (1)	EA (2)		LA (1)			PS (1)
	Mar									
Teredo navalis	Aug									
	Sep									
	Oct									
	Nov		LA (1)							
	Dec				PS (1)				LA (1)	
	Jan		R (2)							
	Feb	R (2)	LA-R (3)						LA-S (1)	R (1)
	Mar	LA (2)								
Teredo furcifera	Aug									
	Sep		S (3)							
	Oct		LA-R (2)							
	Nov		LA (1)							
	Dec									
	Jan		LA (1)							
	Feb									
	Mar									
Teredo bartschi	Aug						PS-S (3)			
	Sep						R-PS (2)			
	Oct									
	Nov									
	Dec									
	Jan						IN (1)			
	Feb									
	Mar									
Teredo spp.	Aug	EA-LA (9)	R-S (4)			LA (4)		S (1)		
	Sep	LA-R (1)								
	Oct	* (4)								
	Nov				LA (1)					
	Dec							R (2)		
	Jan									
	Feb									
	Mar									

TABLE C-1. (continued)

Species	Month	Stations 10	11	12	13	14	15	16	17
Bankia gouldi	Aug	R-PS (2)	LA-PS (3)	R-PS (6)	R-PS (5)	R-PS (10)	R-PS (1)	EA (3)	
	Sep	LA-S (6)	PS-S (4)	R (5)	LA-PS (6)	R (1)	R-S (5)	S (3)	PS (2)
	Oct	EA-LA (4)	EA-LA (4)	LA (3)	PS-S (3)		LA-R (3)	LA (4)	
	Nov		EA (3)	EA-LA (12)	EA (2)	EA (4)	EA (1)	EA (4)	EA (1)
	Dec	EA (3)	EA (2)	EA-LA (3)	EA-LA (2)	IN (2)	LA (2)	EA (1)	
	Jan	EA-LA (3)	EA (3)	LA (3)	EA (1)	EA-LA (2)	LA (1)		
	Feb		EA-LA (4)	EA (4)		EA-LA (3)			
	Mar								
Teredo navalis	Aug								
	Sep								R (3)
	Oct								LA-R (3)
	Nov	LA-R (1)		LA (1)			LA (2)		LA (2)
	Dec						R (2)		LA (4)
	Jan		PS (2)				R (3)		R-PS (3)
	Feb						LA-R (4)		LA (4)
	Mar								
Teredo furcifera	Aug								
	Sep		LA (2)						R-S (3)
	Oct	LA (1)	LA (1)						R-PS (1)
	Nov		LA (2)						
	Dec								
	Jan								
	Feb								
	Mar								
Teredo bartschi	Aug								
	Sep								
	Oct								
	Nov								
	Dec								
	Jan								
	Feb								
	Mar								
Teredo spp.	Aug		R-PS (2)	LA-R (3)			PS-S (3)		R-PS (6)
	Sep						PS (3)		
	Oct						LA (3)		
	Nov								
	Dec								
	Jan								
	Feb								
	Mar								

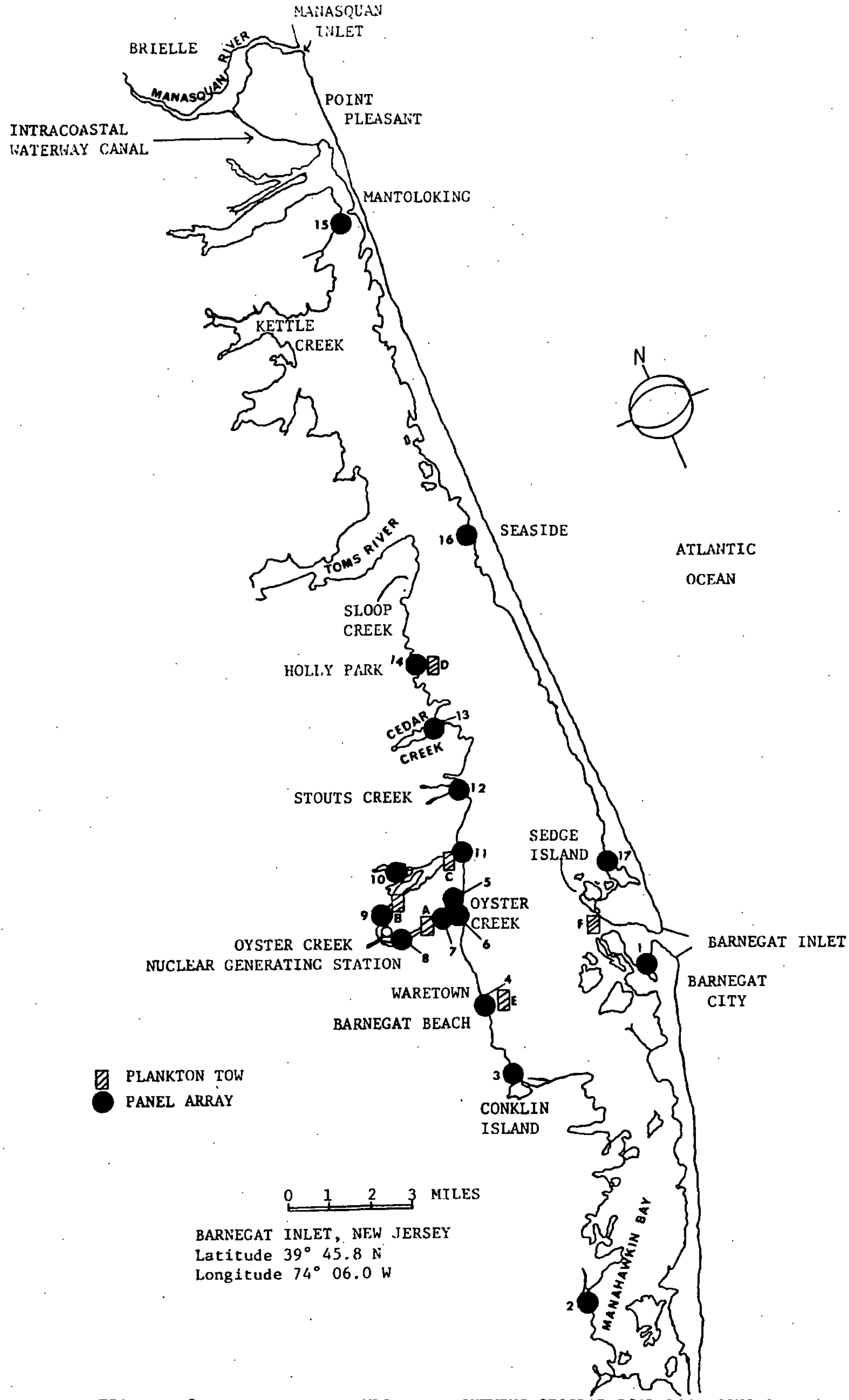


FIGURE C-5. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHICAL LOCATIONS OF EXPOSURE PANELS AND PLANKTON TOWS

Teredo furcifera

Where this species was found, gonad developmental patterns were similar to those of *T. navalis*. Shipworms with late active and partially spend gonads occurred at Stations 2 and 11 as late as January.

Teredo bartschi

Very few *T. bartschi* were among those species studied. They were found only at Station 6 and were ripe and spawning in August and September. One specimen was found in January, and showed no signs of alveolar formation.

Teredo spp.

These were probably *T. navalis* for the most part, and were collected only during the earlier months of the study. Like *T. navalis*, they were generally in late active to spawning stages. Two specimens, one male and one female, were found at Station 7 in December and both were ripe.

The number of males, females, and hermaphrodites found each month are shown in Table C-2. It was often difficult to distinguish sexes during the early active phases. The principal distinguishing characteristic used was the size of the sex cell and its staining characteristics, the male cells being smaller and more darkly stained. It is possible that some of the females were incorrectly characterized as males during the early active phases. On the other hand, most of the specimens appeared to be relatively young; and since these species are usually protandrous (e.g., see Nair and Saraswathy, 1971), that is, they become males first and latter change to females, it is quite possible that there would be a preponderance of males in the samples.

No real differences among stations relative to gonad condition of any of the borers could be ascertained. If there were plant-induced effects, active gonads might be expected in borers at those stations where there was a thermal influence. This was not in evidence from any of the specimens studied.

TABLE C-2. NUMBERS OF MALES, FEMALES, AND HERMAPHRODITES AMONG SPECIMENS OF TEREDINE BORERS FOUND IN EXPOSURE PANELS FROM THE BARNEGAT BAY AREA FROM AUGUST, 1975, THROUGH FEBRUARY, 1976

	Bankia gouldi			*Teredo navalis*			*Teredo furcifera*			*Teredo bartschi*			*Teredo* spp.		
	Male	Female	Hermaph.	Male	Female	Hermaph.	Male	Female	Hermaph.	Male	Female	Hermaph.	Male	Female	Hermaph.
Aug	31	17	2	0	0	0	0	0	0	0	3	0	8	16	8
Sep	33	8	0	3	0	0	7	1	0	2	0	0	4	0	0
Oct	27	3	0	1	0	0	5	0	0	0	0	0	5	1	0
Nov	30	10	0	0	3	4	2	0	1	0	0	0	1	0	0
Dec	24	5	0	4	3	1	0	0	0	0	0	0	1	0	1
Jan	25	6	1	1	5	3	0	1	0	0	1	0	0	0	0
Feb	17	0	0	1	7	4	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0

The "active" conditions of the *Bankia gouldi* gonads throughout the winter (Table C-1) are not necessarily indicative of active development. They are probably the result of development being initiated in the late summer and early fall, and then being arrested as the water cooled during the late fall and winter. Sections of shipworms collected in the winter showed evidence of gonad resorption.

Teredo navalis was not as widely distributed as *B. gouldi*, but did show evidence of spawning as late as February at the discharge (Station 8), and imminent spawning at Stations 2, 9, and 15. Stations 2 and 15 are well outside of any plant influence, and the power plant was not operating from December through March, so it is unlikely that the spawning of *T. navalis* in February at Station 8 was due to the thermal effects of the power station.

Teredo furcifera, *T. bartschi*, and the immature specimens of *Teredo* which were too small to identify to species (*Teredo* spp.) were not numerous enough or widely distributed enough to use them for determining any possible power station-induced effects.

It was mentioned earlier that settlement and development to maturity can be accomplished in a relatively short time. Thus the exposure panels can contain populations of shipworms that are not uniform with respect to age. For example, if the panels were first installed in June, they would contain young but mature specimens by the end of July, most of them being males. Settlement would continue throughout July with maturation by August. Panels removed in August therefore could contain many newly-matured males as well as some "older" mature females ready to spawn, with some possibly having already spawned. This pattern would continue throughout the months when spawning and settling were taking place, resulting in panels with populations of varied ages. The sex ratios shown in Table C-2, therefore, are not necessarily indicative of the ratios found in normal populations. They are really only reflecting the high proportion of males that would be expected in newly matured shipworms.

Literature Cited

Holland, D.A. and K.K. Chew. 1974. Reproductive cycle of the Manila clam (*Venerupis japonica*), from Hood Canal, Washington. Proc. Natl. Shellf. Assoc. 64:53-58.

Loosanoff, V.L. 1942. Seasonal gonadal changes in the adult oysters, *Ostrea virginica*, of Long Island Sound. Biol. Bull. 82:195-206.

Nair, N.B. and M. Saraswathy. 1971. The biology of wood-boring teredinid molluscs. Adv. Mar. Biol. 9:335-509.

Ropes, J.W. 1968. Reproductive cycle of the surf clam, *Spisula solidissima*, in offshore New Jersey. Biol. Bull. 135:349-365.

Ropes, J.W. and A.P. Stickney. 1965. Reproductive cycle of *Mya arenaria* in New England. Biol. Bull. 128:315-327.

Turner, R.D. 1966. *A Survey and Illustrated Catalog of the Teredinidae (Mollusca:Bivalvia)*. Mus. Comp. Zool., Harvard Univ., Cambridge, Mass. 265 pp.

APPENDIX D

WATER QUALITY

APPENDIX D

WATER QUALITY

Introduction

Various water quality parameters were used to describe the physical-chemical environment at the exposure panel and plankton stations. These parameters, particularly water temperature and salinity, were used to define the minimum/maximum limits for the marine borers found in Barnegat Bay.

Materials and Methods

Water quality data were taken every sampling period at each of the seventeen exposure panel stations and at each of the six plankton sampling stations (Figure D-1). The water temperature, salinity, pH, and dissolved oxygen were measured with a Hydrolab Model II B (Figures D-2 and D-3). The Hydrolab was calibrated prior to each day's use, as described in the User's Manual.

Results

The water quality values recorded each month are presented in Tables D-1 through D-23. Tables D-24 through D-46 give the water quality values recorded from June, 1975, through May, 1976, by station.

The oxygen and pH values recorded during the course of the study were within the range to support teredinids (Table D-47). The mean salinity values and the range recorded for each station from June, 1975, through May, 1976, are presented in Table D-48. Salinity did not appear to be a limiting factor at any of the exposure panel and plankton stations.

Table D-49 presents the minimum/maximum temperature range from June-November at exposure panel and plankton stations.

Figure D-4 shows the average water temperature at the Oyster Creek Railroad Bridge plotted at five day intervals. These temperature data were provided by Jersey Central Power & Light Company.

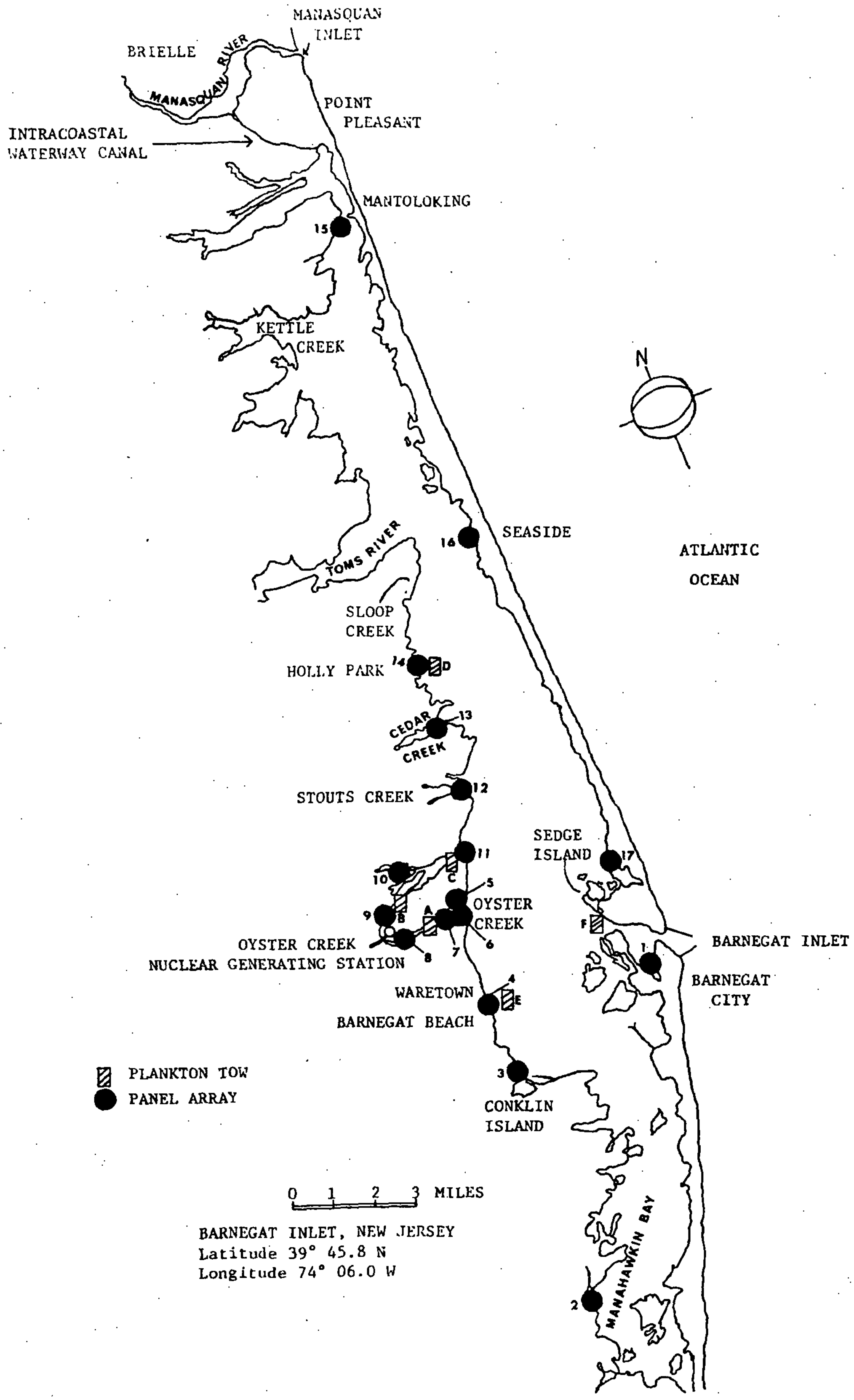


FIGURE D-1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHICAL LOCATIONS OF EXPOSURE PANELS AND PLANKTON TOWS

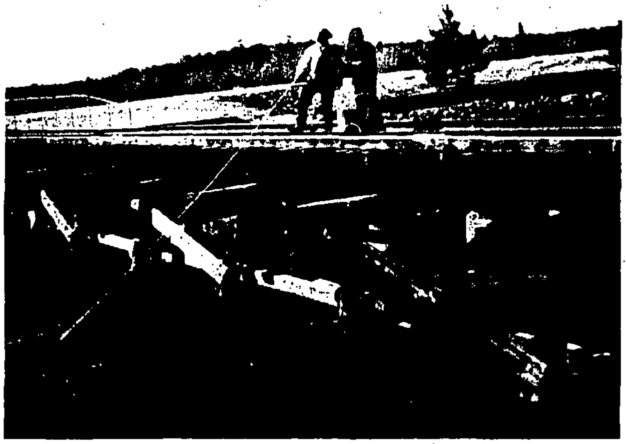


FIGURE D-2. OBTAINING WATER QUALITY DATA FROM OYSTER CREEK RAILROAD BRIDGE

FIGURE D-3. CALIBRATING HYDROLAB

TABLE D-1. WATER QUALITY DATA AT EXPOSURE PANEL STATIONS, JUNE, 1975

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
1	6/6/75	1150	18"	30.6	17.0	8.1	7.7
			8'	30.6	17.0	8.5	7.7
2	6/3/75	1130	18"	22.7	22.5	8.5	7.9
3	6/3/75	1205	3'	22.7	22.5	6.7	7.9
4	6/3/75	1330	3'	23.4	22.5	7.5	7.9
5	6/4/75	1055	3'	20.6	25.0	7.1	7.8
6	6/6/75	1320	12"	19.2	24.5	5.3	7.7
7	6/4/75	1015	3'	20.6	25.0	7.1	7.8
8	6/4/75	1220	18"	21.2	25.1	7.5	7.7
			13'	21.2	25.1	7.6	7.7
9	6/4/75	1615	6'	21.3	22.3	8.5	7.7
10	6/3/75	1350	3'	10.0	23.5	8.0	7.9
11	6/5/75	1740	5'	20.6	22.5	8.6	7.7
12	6/6/75	1500	2'	19.2	22.5	5.9	7.4
13	6/3/75	1425	18"	14.8	24.0	6.9	7.9
14	6/3/75	1510	2'	17.2	23.5	8.1	7.4
15	6/6/75	1640	4'	15.8	21.0	7.4	7.7
16	6/3/75	1550	4'	13.0	23.5	8.0	7.9
17	6/3/75	1625	18"	26.3	22.5	9.5	7.9

TABLE D-2. WATER QUALITY DATA AT EXPOSURE PANEL STATIONS, JULY, 1975

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
1	7/8/75	1107	18"	19.2	26.7	7.0	8.0
			10'	28.5		7.2	8.1
2	7/9/75	1735	18"	21.3	27.2	4.5	6.1
3	7/9/75	1750	18"	21.3	27.8	5.8	6.2
4	7/9/75	1805	18"	22.1	28.3	2.9	6.2
5	7/8/75	1525	3'	20.6	28.9	9.0	8.0
6	7/9/75	1145	3'	19.9	28.9	7.4	6.0
7	7/9/75	1135	18"	22.1	28.9	6.2	6.0
8	7/9/75	1100	3'	20.6	28.9	5.8	6.0
9	7/9/75	1020	18"	20.8	26.7	6.0	4.0
			6'	20.8		6.0	4.0
10	7/9/75	0912	18"	13.9	24.4	5.6	6.2
			8'	17.2		4.6	6.2
11	7/9/75	1305	3'	22.8	26.7	7.0	6.3
12	7/9/75	1820	18"	19.2	27.8	7.4	6.2
13	7/9/75	1835	18"	13.8	27.8	6.5	6.2
14	7/9/75	1847	18"	17.2	27.8	6.1	6.2
15	7/10/75	1003	3'	15.9	26.7	4.6	6.2
16	7/10/75	0825	18"	12.5	24.4	5.1	6.2
17	7/10/75	0900	18"	23.5	25.6	4.4	6.2

TABLE D-3. WATER QUALITY DATA AT EXPOSURE PANEL STATIONS, AUGUST, 1975

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
1	8/12/75	1033	18"	27.0	24.0	8.3	8.1
			8'	27.0	23.5	8.1	8.1
2	8/14/75	1000	12"	22.7	25.2	4.7	8.0
3	8/14/75	1025	2'	22.0	25.0	5.5	8.0
4	8/14/75	1038	3'	23.4	25.5	5.0	8.0
5	8/12/75	1625	18"	22.0	29.5	8.1	8.1
			10'	22.0	27.5	6.1	8.1
6	8/14/75		18"	20.6	27.5	4.3	8.0
7	8/12/75	1610	18"	22.0	29.5	9.0	8.1
			5'	21.6	29.5	8.7	8.1
8	8/14/75		12"	22.7	27.5	5.5	8.0
9	8/13/75	1410	18"	21.7	26.5	9.7	7.7
			8'	21.7	26.5	9.5	7.7
10	8/14/75	1107	2'	17.6	25.0	5.0	8.0
11	8/13/75	1450	18"	21.3	26.5	9.7	7.8
12	8/14/75	1130	2 1/2'	19.2	25.3	7.4	8.0
13	8/14/75	1137	18"	10.4	24.5	7.0	8.0
14	8/13/75	1000	2'	18.5	25.5	7.5	7.9
15	8/14/75	1415	18"	17.2	26.0	8.5	7.9
			6'	18.5	25.5	6.0	7.9
16	8/14/75	1242	3'	13.1	25.5	5.5	8.0
17	8/14/75	1330	12"	24.1	25.5	8.7	8.0

TABLE D-4. WATER QUALITY DATA AT EXPOSURE PANEL STATIONS, SEPTEMBER, 1975

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2*	pH
1	9/9/75	1110	18"	25.6	21.5		8.1
2	9/10/75	1415	2'	25.6	20.5		7.5
3	9/10/75	1455	18"	24.9	21.0		7.8
4	9/10/75	1520	4'	25.6	21.0		7.7
5	9/10/75	1555	18"	22.7	23.5		7.5
6	9/10/75		18"	23.5	23.5		7.5
7	9/9/75	1600	3'	23.4	25.0		8.1
8	9/9/75		18"	23.4	25.0		8.1
			13'	23.1	25.0		8.1
9	9/9/75	1800	3'	24.3	22.0		6.2
10	9/10/75	1330	18"	18.5	20.5		7.2
11	9/9/75	1810	3'	24.1	22.0		6.2
12	9/11/75	1035	2'	22.0	20.0		7.3
13	9/11/75	1115	18"	17.9	22.0		7.2
14	9/10/75	1000	2'	17.2	18.0		7.7
15	9/12/75	0900	4'	17.2	20.0		7.1
16	9/11/75	1200	2'	15.8	20.0		7.4
17	9/11/75	1300	18"	25.6	20.5		7.3

* Malfunction of Hydrolab, unable to obtain oxygen readings for September, 1975.

TABLE D-5. WATER QUALITY DATA AT EXPOSURE PANEL STATIONS, OCTOBER, 1975

tation	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
1	10/7/75	0840	18"	22.7	17.5	4.9	8.0
			8'	24.9	17.5	6.6	8.0
2	10/8/75	1003	18"	22.0	17.0	5.4	8.0
3	10/8/75	1030	3'	19.9	17.5	9.9	6.0
4	10/8/75	1110	3'6"	22.7	18.5	6.3	6.0
5	10/8/75	1135	4'	17.9	19.5	7.5	8.0
6	10/8/75	1215	18"	19.2	20.5	6.9	8.0
7	10/8/75	1235	10'	18.5	20.5	8.5	8.0
8	10/8/75	1400	18"	19.5	20.5	8.8	8.0
			8'	19.5	20.5	8.8	8.0
9	10/8/75	1430	3'	19.5	18.5	9.5	8.0
			10'	19.5	18.5	9.5	8.0
10	10/8/75	0925	2'	17.9	18.0	6.9	8.0
11	10/8/75	-----*	18"	19.2	18.0	9.5	8.0
12	10/8/75	1535	3'	19.2	19.3	7.3	8.0
13	10/8/75	1600	18"	17.2	20.0	8.5	8.0
14	10/7/75	1340	18"	13.1	17.5	5.1	8.0
			3'	16.9	17.5	5.1	8.0
15	10/9/75	0945	18"	17.9	17.5	8.4	8.0
16	10/9/75	0825	3'	9.8	18.5	6.9	8.0
17	10/9/75	0900	18"	15.2	18.0	9.3	8.0

Time not recorded.

TABLE D-6. WATER QUALITY DATA AT EXPOSURE PANEL STATIONS, NOVEMBER, 1975

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
1	11/4/75	0815	18"	24.9	14.0	8.8	7.8
			10'	28.4	15.0	8.5	7.8
2	11/5/75	0730	12"	17.2	14.0	7.6	7.7
3	11/5/75	0755	2'6"	11.1	13.5	8.7	7.7
4	11/5/75	0815	3'	19.2	14.0	7.3	7.7
5	11/5/75	0840	18"	3.5	17.5	7.4	7.7
6	11/5/75	0855	18"	14.5	15.5	7.6	7.7
7	11/5/75	0915	12"	19.9	17.5	9.0	7.7
8	11/5/75	0945	18"	19.2	18.0	9.7	7.7
			10'	19.2	18.0	9.7	7.7
9	11/5/75	1015	18"	19.9	13.5	N.R.*	7.7
			8'	19.9	13.5	N.R.*	7.7
10	11/5/75	1120	3'	<1.0**	14.0	8.8	7.7
11	11/5/75	1050	3'	21.4	14.5	9.6	7.7
12	11/5/75	1140	4'	19.9	14.5	8.4	7.7
13	11/5/75	1205	18"	11.8	14.0	8.5	7.7
14	11/5/75	1340	18"	17.2	14.0	9.7	7.8
15	11/6/75	0815	4'	17.2	13.5	9.0	7.7
16	11/5/75	1250	4'	13.1	14.5	8.4	7.7
17	11/5/75	1330	18"	<1.0***	17.0	9.3	7.7

* No reading, malfunction of Hydrolab oxygen component.

** The low salinity may have resulted from freshwater runoff.

*** The low salinity may have resulted from the formation of a layer of fresh water during a period of precipitation.

TABLE D-7. WATER QUALITY DATA AT EXPOSURE PANEL STATIONS, DECEMBER, 1975

tation	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
1	12/2/75	0845	18"	23.4	7.0	9.5	8.0
			8'	27.7	9.0	9.5	8.0
2	12/3/75	0755	18"	19.9	5.5	N.R.*	N.R.*
3	12/3/75	0830	18"	21.3	7.0	9.2	N.R.*
4	12/3/75	0905	2'	17.9	9.0	9.5	N.R.*
5	12/3/75	0925	2'	17.9	8.0	9.5	N.R.*
6	12/3/75	0940	2'	15.2	9.5	9.8	N.R.*
7	12/3/75	1014	12"	20.6	9.0	N.R.*	N.R.*
8	12/3/75	1120	18"	19.9	9.0	9.5	N.R.*
			12'	19.9	9.0	9.5	N.R.*
9	12/3/75	1147	18"	21.3	7.0	N.R.*	N.R.*
10	12/3/75	1335	2'	13.1	9.0	9.6	N.R.*
11	12/3/75	1210	18"	21.3	6.5	N.R.*	N.R.*
12	12/3/75	1400	2'	19.2	6.5	N.R.*	N.R.*
13	12/3/75	1430	18"	12.5	7.0	N.R.*	N.R.*
14	12/3/75	1450	12"	15.8	7.5	N.R.*	N.R.*
15	12/4/75	0925	2'	8.7	4.0	N.R.*	N.R.*
16	12/4/75	0810	3'	9.8	3.0	N.R.*	N.R.*
17	12/4/75	0840	2'	22.0	4.0	N.R.*	N.R.*

No reading, malfunction of Hydrolab oxygen and pH components.

TABLE D-8. EXPOSURE PANEL STATIONS WATER QUALITY DATA, JANUARY, 1976

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
1	1/7/76	0910	18"	4.0	2.0	13.0	7.7
			12'	3.0	5.0	12.6	7.7
2	1/7/76	0953	12"	9.2	0.0	12.2	7.7
3	1/7/76	1035	2'	6.9	1.0	13.2	7.7
4	1/7/76	1100	4'	9.8	1.0	13.0	7.7
5	1/7/76	1150	12"	9.2	1.5	11.0	7.7
6	1/7/76	1207	12"	16.5	0.9	12.2	7.7
7	1/7/76	1130	5'	5.0	1.5	13.6	7.7
8	1/7/76	1305	18"	8.7	1.5	14.0	7.7
			14'	8.7	1.5	14.0	7.7
9	1/7/76	1237	18"	13.1	0.5	13.0	7.7
			15'	13.1	0.5	13.0	7.7
10	1/7/76	1520	3'	14.5	2.5	10.6	7.7
11	1/7/76	1455	2'	16.5	1.0	13.0	7.7
12	1/7/76	1545	3'	17.9	1.5	12.8	7.7
13	1/7/76	1625	18"	2.0	0.5	10.8	7.7
14	1/7/76	1645	18"	2.0	0.0	10.8	7.7
15	1/8/76	1045	2'	16.5	0.50	12.6	7.7
16	1/8/76	0930	2'	14.5	1.0	9.8	7.7
17	1/8/76	1000	3'	22.6	1.0	14.0	7.6

TABLE D-9. EXPOSURE PANEL STATIONS WATER QUALITY DATA, FEBRUARY, 1976

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
1	2/10/76	0810	2'	12.0	1.0	15.2	7.5
			12'	12.0	1.5	13.0	7.5
2	2/10/76	0855	18"	16.5	0.5	12.6	7.5
3	2/10/76	0925	18"	17.9	1.0	12.4	7.5
4	2/10/76	0950	2'	12.5	1.5	12.0	7.5
5	2/10/76	1010	2'	14.5	1.0	13.4	7.5
6	2/10/76	1030	18"	15.2	0.5	12.2	7.5
7	2/10/76	1100	3'	15.2	1.0	13.4	7.5
8	2/10/76	1315	18"	16.5	1.0	16.8	7.5
			12'	16.5	1.0	16.8	7.5
9	2/10/76	1350	18"	16.5	1.0	16.8	7.5
			8'	16.5	1.0	16.8	7.5
10	2/10/76	1200	3'	9.8	1.5	16.2	7.5
11	2/10/76	1135	18"	2.9	1.5	14.2	7.5
12	2/10/76	1425	3 1/2'	15.8	1.0	17.6	7.5
13	2/10/76	1500	12"	5.8	1.5	15.0	7.5
14	2/10/76	1530	12"	5.8	2.0	15.6	7.5
15	2/13/76	0830	4'	12.5	1.0	14.6	7.4
16	2/10/76	1700	2 1/2'	0.0*	1.0	15.0	7.5
17	2/10/76	1630	2'	0.0*	2.0	14.8	7.5

* The zero readings probably resulted from the presence of ice melting.

TABLE D-10. EXPOSURE PANEL STATIONS WATER QUALITY DATA, MARCH, 1976

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
1	3/11/76	0855	2'	24.9	4.0	15.0	7.5
			8'	24.9	4.0	15.0	7.5
2	3/9/76	0850	18"	18.5	5.5	15.2	7.9
3	3/9/76	0920	3'	22.0	6.0	12.0	7.5
4	3/9/76	0940	4'	19.2	6.5	15.2	7.9
5	3/9/76	1000	2'	13.1	5.0	10.2	7.5
6	3/9/76	1020	12"	19.9	6.0	11.0	7.5
7	3/9/76	1100	3'	22.0	4.0	14.4	7.5
8	3/9/76	1040	3'	22.0	4.0	14.4	7.5
			12'	22.0	4.0	14.4	7.5
9	3/9/76	1240	3'	22.0	4.0	14.4	7.5
			11'	22.0	4.0	14.4	7.5
10	3/9/76	1140	3'	7.5	6.5	11.4	7.5
11	3/10/76	1205	4'	22.0	4.0	14.2	7.5
12	3/9/76	1200	4'	20.6	6.0	10.4	7.5
13	3/10/76	1605	2'	9.8	4.0	11.4	7.5
14	3/9/76	1300	12"	11.8	3.5	15.4	7.5
15	3/12/76	0840	3'	17.2	4.0	13.0	7.5
16	3/9/76	1340	18"	13.1	6.5	15.2	7.5
17	3/9/76	1410	18"	24.1	3.0	12.6	7.5

TABLE D-11. EXPOSURE PANEL STATIONS WATER QUALITY DATA, APRIL, 1976

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
1	4/6/76	0820	2'	24.2*	8.5	10.8	8.0
			7'	24.2	8.5	11.0	8.5
2	4/7/76	0750	12"	25.6	11.0	10.4	8.0
3	4/7/76	0810	2'	23.5	11.0	9.4	7.9
4	4/7/76	0825	3'	18.6	11.0	8.0	10.0
5	4/6/76	1130	2'	19.9	13.5	11.0	8.0
			6'	19.9	13.5	10.2	8.0
6	4/7/76	0840	12"	19.9	12.5	9.0	8.0
7	4/7/76	0855	5'	22.0	13.5	9.8	8.0
8	4/7/76	0940	10'	22.0	13.5	11.0	8.0
9	4/7/76	1510	18"	22.0	11.0	11.6	8.0
			8'	22.0	11.0	11.6	8.0
10	4/6/76	1535	3'	19.9	11.0	10.8	8.0
11	4/6/76	1420	4'	22.7	11.0	11.4	8.0
12	4/7/76	1230	3'	21.3	12.5	10.2	8.0
13	4/7/76	1245	12"	13.9	12.5	10.0	8.0
14	4/6/76	1310	7'	23.5	10.0	12.2	8.0
15	4/8/76	0852	2'	13.2	12.5	10.0	8.4
16	4/7/76	1420	2'	8.1	12.5	10.4	8.0
17	4/7/76	1345	2'	24.9	15.0	11.2	8.0

* Salinity recorded at Station F.

TABLE D-12. EXPOSURE PANEL STATIONS WATER QUALITY DATA, MAY, 1976

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
1	5/6/76	0920	4'	23.5	12.0	10.2	7.5
2	5/4/76	1453	1 1/2'	18.6	15.0	8.1	7.5
3	5/4/76	1510	3'	24.2	15.5	8.4	7.5
4	5/4/76	1538	4'	21.3	15.3	10.0	7.5
5	5/4/76	1550	6'	23.6	21.5	9.8	7.5
6	5/4/76	1605	12"	22.8	20.5	8.4	7.5
7	5/4/76	1625	4'	21.3	16.0	8.9	7.5
8	5/5/76	1105	2'	22.0	16.5	10.2	7.5
			12'	22.8	16.5	10.2	7.5
9	5/5/76	1410	2'	23.5	16.0	10.0	7.5
			10'	23.5	16.0	10.0	7.5
10	5/4/76	1400	3'	15.2	16.5	8.0	7.5
11	5/4/76	1645	3'	17.2	16.0	10.2	7.5
12	5/4/76	1705	4'	22.0	16.0	8.2	7.5
13	5/5/76	1735	12"	13.2	15.5	8.8	7.5
14	5/5/76	1800	6"	18.6	16.0	9.6	7.5
15	5/6/76	1640	4'	13.9	17.0	8.5	7.5
16	5/6/76	0845	18"	13.2	13.0	10.0	7.5
17	5/6/76	0925	2'	26.3	11.5	10.0	7.5

TABLE D-13. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE, JUNE, 1975, AT THE SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{x}$ # Teredinid larvae per M^3*
A	6/4/75	1045	12"	20.6	25.0	7.1	7.8	1.05
			6'	20.6	25.0	7.2	7.8	
B	6/4/75	1500	12"	21.7	22.5	8.8	7.7	0.00
			6'	21.7	22.5	8.8	7.7	
C	6/5/75	1740	5'	20.6	22.5	8.6	7.7	0.00
D	6/5/75		18"	18.4	22.0	8.6	7.7	0.00
E	6/5/75	1535	3 1/2'	23.4	22.0	8.6	7.7	0.00
F	6/6/75	1012	18"	29.2	17.5	9.2	7.7	0.00
			12'	29.2	17.5	9.1	7.7	

* The mean number of Teredinid larvae collected per M^3 of water filtered.

TABLE D-14. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE, JULY, 1975, AT THE SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{x}$ # Teredinid larvae per M^3*
A	7/8/75	1515	18"	20.6	28.9	9.0	8.0	0.17
			5'	20.6	28.9	9.0	8.0	
B	7/9/75	1418	18"	22.0	26.7	7.3	6.2	6.84
			6'	22.0		7.3	6.2	
C	7/9/75	1305	3'	22.8	26.7	7.0	6.3	3.19
D	7/9/75	1847	18"	17.2	26.7	6.1	6.2	1.42
E	7/8/75	1400	18"	22.0	27.2	9.4	7.9	0.37
			5'	22.0		9.4	7.9	
F	7/8/75	1135	18"	27.8	26.7	8.2	8.0	5.56
			12'	27.8		8.3	7.9	

* The mean number of Teredinid larvae collected per M^3 of water filtered.

TABLE D-15. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE, AUGUST, 1975, AT THE SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{x}$ # Teredinid larvae per M^3*
A	8/12/75	1600	18"	22.0	29.5	8.8	8.1	1.24
			8'	22.00	29.5	9.1	8.1	
B	8/13/75	1420	18"	21.3	26.5	9.7	7.8	0.17
			8'	21.3	26.5	9.7	7.8	
C	8/13/75		18"	21.3	26.0	9.7	7.8	0.28
			8'	21.3	25.5	9.7	7.8	
D	8/13/75	1115	2'	16.5	26.0	8.6	7.8	0.00
			7'	18.5	25.5	8.6	7.8	
E	8/12/75	1435	18"	24.9	26.5	9.0	8.0	0.00
			7'	24.9	26.0	9.0	8.0	
F	8/12/75	1220	18"	31.3	22.5	7.5	8.0	0.42
			10'	31.3	22.5	7.3	8.0	

* The mean number of Teredinid larvae collected per M^3 of water filtered.

TABLE D-16. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE, SEPTEMBER, 1975, AT THE SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2**	pH	$\bar{x}$ # Teredinid larvae per M^3*
A	9/9/75	1635	18"	23.4	25.0		8.1	0.00
			15'	24.1	25.0		8.1	
B	9/10/75	1115	18"	24.9	20.0		7.6	0.00
			11'	24.9	19.5		7.6	
C	9/9/75	1800	18"	24.1	22.0		6.2	0.00
			6 1/2'	27.0				
D	9/10/75	1045	18"	17.2	18.0		7.7	0.00
			6'	16.5	17.0			
E	9/9/75	1400	18"	26.3	22.0		8.1	0.00
			6'	26.3	22.0			
F	9/9/75	0745	18"	24.1	18.5		7.6	0.00
			15'	24.9	18.5			

* The mean number of Teredinid larvae collected per M^3 of water filtered.
** Malfunction of Hydrolab, unable to obtain oxygen readings for September, 1975.

TABLE D-17. WATER QUALITY AND THE INCIDENCE OF TEREDINID LARVAE, OCTOBER, 1975, AT THE SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{x}$ # Teredinid larvae per M^3*
A	10/7/75	1525	18"	19.9	20.0	5.0	7.9	0.00
			10'	19.9	20.0	5.0	7.9	
B	10/8/75	0720	18"	19.5	18.5	9.5	8.0	2.01
			10'	19.5	18.5	9.5	8.0	
C	10/7/75	1700	18"	19.2	18.0	5.1	7.9	0.26
			6'	19.9	18.0	5.1	7.9	
D	10/7/75	1350	18"	13.5	18.0	4.9	7.9	0.17
			3'	14.5	18.0	4.9	7.9	
E	10/7/75	1200	18"	22.0	17.5	5.1	7.9	0.16
			6'	21.3	17.0	5.1	7.9	
F	10/7/75	1025	18"	29.1	18.0	7.0	8.0	0.57
			10'	29.5	18.0	7.0	8.0	

* The mean number of Teredinid larvae captured per M^3 of water filtered.

TABLE D-18. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE, NOVEMBER, 1975, AT THE SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{x}$ # Teredinid larvae per M^3**
A	11/4/75	1250	18"	19.9	17.5	9.7	7.8	0.00
			15'	20.6	17.5	9.6	7.8	
B	11/4/75	1745	18"	19.9	13.5	N.R.*	7.7	0.00
			8'	19.9	13.5	N.R.*	7.7	
C	11/4/75	1635	18"	22.0	14.0	8.9	7.8	0.50
			6'	23.4	14.0	7.9	7.8	
D	11/4/75	1510	18"	17.2	13.5	9.9	7.8	0.84
			7'	17.2	13.5	9.9	7.8	
E	11/4/75	1055	18"	22.7	13.5	9.4	7.8	0.19
			8'	24.9	13.5	8.4	7.8	
F	11/4/75	0925	18"	28.4	15.0	8.9	7.8	0.99
			10'	28.4	15.0	8.7	7.8	

* No reading, malfunction of Hydrolab oxygen component.
** The mean number of Teredinid larvae captured per M^3 of water filtered.

TABLE D-19. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE, DECEMBER, 1975, AT THE SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{x}$ # Teredinid larvae per M^3**
A	12/2/75	1130	18"	19.2	10.0	N.R.*	8.0	0.00
			15'	18.5	10.0	N.R.*	8.0	
B	12/2/75	1425	18"	21.3	7.0	N.R.*	8.0	0.00
			8'	21.3	7.0	N.R.*	8.0	
C	12/2/75	1325	18"	21.3	6.5	N.R.*	8.0	0.00
			7'	21.3	6.5	N.R.*	8.0	
D	12/2/75	1300	18"	15.8	7.5	N.R.*	8.0	0.00
			3'	15.8	7.5	N.R.*	8.0	
E	12/2/75	1030	18"	22.0	7.5	N.R.*	8.0	0.00
			6'	22.0	7.5	N.R.*	8.0	
F	12/2/75	0915	18"	27.0	9.5	9.3	8.0	0.00
			12'	28.4	10.0	9.3	8.0	

* No reading, malfunction of Hydrolab oxygen component.
** The mean number of Teredinid larvae captured per M^3 pf water filtered.

TABLE D-20. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE, FEBRUARY, 1976, AT THE SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{x}$ # Teredinid Larvae per M^3
A*	2/12/76	1315	18"	16.5	1.0	16.8	7.5	0.00
			12'	16.5	1.0	16.8	7.5	
B	2/76	No Sample, Boat Inoperable						
C	2/76	No Sample, Boat Inoperable						
D**	2/10/76	1530	12"	5.8	2.0	15.6	7.5	0.00
E	2/76	No Sample Boat, Inoperable						
F***	2/10/76	0810	2'	12.0	1.0	15.2	7.5	0.00
			12'	12.0	1.5	15.3	7.5	

* Samples and water quality were taken from Oyster Creek railroad bridge. Boat inoperable.
** Samples and water quality taken off dock at Dick's Landing. Boat inoperable.
*** Samples and water quality taken off dock at Coast Guard Station. Boat inoperable.

TABLE D-21. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE, MARCH, 1976, AT THE SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{x}$ # Teredinid Larvae per M^3
A	3/10/76	1100	2'	22.0	4.0	14.8	7.5	0.00
			15'	22.0	4.0	14.8	7.5	
B	3/10/76	1240	2'	19.9	4.0	11.8	7.5	0.00
			6'	19.9	4.0	11.8	7.5	
C	3/10/76	1205	2'	22.0	4.0	14.8	7.5	0.00
			6'	22.0	4.0	14.8	7.5	
D	3/10/76	0900	18"	11.8	3.5	15.4	7.5	0.00
			3'	11.8	3.5	15.4	7.5	
E	3/11/76	1045	2'	29.1	4.0	13.0	7.5	0.00
			8'	29.1	4.0	13.0	7.5	
F	3/11/76	0915	2'	24.9	4.0	15.0	7.5	0.00
			8'	24.9	4.0	15.0	7.5	

TABLE D-22. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE, APRIL, 1976, AT THE SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{x}$ # Teredinid Larvae per M^3
A	4/6/76	*	2'	22.7	13.5	12.0	8.0	0.00
			6'	24.2	12.0	11.8	8.0	
B	4/6/76	1420	4'	22.7	11.0	11.4	8.0	0.00
C	4/6/76	1510	8'	22.0	11.0	11.6	8.0	0.00
D	4/6/76	1310	7'	23.5	10.0	12.2	8.0	0.00
E	4/6/76	1010	2'	25.6	10.5	12.2	8.0	0.00
			7'	25.6	10.5	12.2	8.0	
F	4/6/76	0945	2'	24.2	9.0	12.2	8.0	0.00
			20'	25.6	8.5	12.2	8.0	

* Time not recorded.

TABLE D-23. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE, MAY, 1976, AT THE SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{x}$ # Teredinid Larvae per M^3
A	5/6/76	1145	6'	23.6	21.5	9.8	7.5	0.00
B	5/5/76	1410	2'	23.5	16.0	10.0	7.5	0.00
			10'	23.5	16.0	9.6	7.5	
C	5/5/76	1300	5'	19.9	17.0	9.8	7.5	0.00
D	5/5/76	1800	6"	18.6	16.0	9.6	7.5	0.00
E	5/6/76	1000	4'	26.3	15.0	9.8	7.5	0.00
F	5/4/76	0815	6'	24.9	13.0	13.0	7.5	0.00

TABLE D-24. EXPOSURE PANEL STATION 1, WATER QUALITY DATA FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
6/6/75	1150	18"	30.6	17.0	8.1	7.7
		8'	30.6	17.0	8.5	7.7
7/8/75	1107	18"	19.2	26.7	7.0	8.0
		10'	28.5	-	7.2	8.1
8/12/75	1033	18"	27.0	24.00	8.3	8.1
		8'	27.0	23.00	8.1	8.1
9/9/75	1110	18"	25.6	21.50	*	8.1
10/7/75	0840	18"	22.7	17.50	4.9	8.0
		8'	24.9	17.00	6.6	8.0
11/4/75	0815	18"	24.9	14.00	8.8	7.8
		10'	28.4	15.00	8.5	7.8
12/2/75	0845	18"	23.4	7.0	9.5	8.0
		8'	27.7	9.0	9.5	8.0
1/7/76	0910	18"	4.0 **	2.0	13.0	7.7
		12'	3.0 **	5.0	12.6	7.7
2/10/76	0810	2'	12.0	1.0	15.2	7.5
		12'	12.0	1.5	13.0	7.5
3/11/76	0855	2'	24.9	4.0	15.0	7.5
		8'	24.9	4.0	15.0	7.5
4/6/76	0820	2'	24.2***	8.5	10.8	8.0
		7'	24.2	8.5	11.0	8.5
5/6/76	0920	4'	23.5	12.0	10.2	7.5

* No reading, malfunction of Hydrolab oxygen component.

** Possible malfunction of Hydrolab salinity component.

*** Salinity value recorded at Station F.

TABLE D-25. EXPOSURE PANEL STATION 2, WATER QUALITY DATA FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
6/3/75	1130	18"	22.7	22.5	8.5	7.9
7/9/75	1735	18"	21.3	27.2	4.5	6.1
8/14/75	1000	12"	22.7	25.2	4.7	8.0
9/10/75	1415	2'	25.6	20.5	*	7.5
10/8/75	1003	18"	22.0	17.0	5.4	8.0
11/5/75	0730	12"	17.2	14.0	7.6	7.7
12/3/75	0755	18"	19.9	5.5	*	**
1/7/76	0953	12"	9.2	0.0	12.2	7.7
2/10/76	0855	18"	16.5	0.5	12.6	7.5
3/9/76	0850	18"	18.5	5.5	15.2	7.9
4/7/76	0750	12'	25.6	11.0	10.4	8.0
5/4/76	1453	1 1/2'	18.6	15.0	8.1	7.5

* No reading, malfunction of Hydrolab oxygen component.
** No reading, malfunction of Hydrolab pH component.

TABLE D-26. EXPOSURE PANEL STATION 3, WATER QUALITY DATA FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
6/3/75	1205	3'	22.7	22.5	6.7	7.9
7/9/75	1750	18"	21.3	27.8	5.8	6.2
8/14/75	1025	2'	22.0	25.0	5.5	8.0
9/10/75	1455	18"	24.9	21.0	*	7.8
10/8/75	1030	3'	19.9	17.5	9.9	6.0
11/5/75	0755	2 1/2'	11.1	13.5	8.7	7.7
12/3/75	0830	18"	21.3	7.0	9.2	**
1/7/76	1035	2'	6.9	1.0	13.2	7.7
2/10/76	0925	18"	17.9	1.0	12.4	7.5
3/9/76	0920	3'	22.0	6.0	12.0	7.5
4/7/76	0810	2'	23.5	11.0	9.4	7.9
5/4/76	1510	3'	24.2	15.5	8.4	7.5

* No reading, malfunction of Hydrolab oxygen component.
** No reading, malfunction of Hydrolab pH component.

TABLE D-27. EXPOSURE PANEL STATION 4, WATER QUALITY DATA, FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
6/3/75	1330	3'	23.4	22.5	7.5	7.9
7/9/75	1805	18"	22.1	28.3	2.9	6.2
8/14/75	1038	3'	23.4	25.5	5.0	8.0
9/10/75	1520	4'	25.6	21.0	*	7.7
10/8/75	1110	3 1/2'	22.7	18.5	6.3	6.0
11/5/75	0815	3'	19.2	14.0	7.3	7.7
12/3/75	0905	2'	17.9	9.0	9.5	**
1/7/76	1100	4'	9.8	1.0	13.0	7.7
2/10/76	0950	2'	12.5	1.5	12.0	7.5
3/9/76	0940	4'	19.2	6.5	15.2	7.9
4/7/76	0825	3'	18.6	11.0	8.0	10.0
5/4/76	1538	4'	21.3	15.3	10.0	7.5

* No reading, malfunction of Hydrolab oxygen component.
** No reading, malfunction of Hydrolab pH component.

TABLE D-28. EXPOSURE PANEL STATION 5, WATER QUALITY DATA FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
6/4/75	1055	3'	20.6	25.0	7.1	7.8
7/8/75	1525	3'	20.6	28.9	9.0	8.0
8/12/75	1625	18"	22.0	29.5	8.1	8.1
		10'	22.0	27.5	6.1	8.1
9/10/75	1555	18"	22.7	23.5	*	7.5
10/8/75	1135	4'	17.9	19.5	7.5	7.9
11/5/75	0840	18"	3.5	17.5	7.4	7.7
12/3/75	0925	2'	17.9	8.0	9.5	**
1/7/76	1150	12"	9.2	1.5	11.0	7.7
2/10/76	1010	2'	14.5	1.0	13.4	7.5
3/9/76	1000	2'	13.1	5.0	10.2	7.5
4/6/76	1130	2'	19.9	13.5	11.0	8.0
		6'	19.9	13.5	10.2	8.0
5/4/76	1550	6'	23.6	21.5	9.8	7.5

* No reading, malfunction of Hydrolab oxygen component.

** No reading, malfunction of Hydrolab pH component.

TABLE D-29. EXPOSURE PANEL STATION 6, WATER QUALITY DATA FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
6/6/75	1320	12"	19.2	24.5	5.3	7.7
7/9/75	1145	3'	19.9	28.9	7.4	6.0
8/14/75	*	18"	20.6	27.5	4.3	8.0
9/10/75	*	18"	23.5	23.5	**	7.5
10/8/75	1215	18"	19.2	20.5	6.9	8.0
11/5/75	0855	18"	14.5	15.5	7.6	7.7
12/3/75	0940	2'	15.2	9.5	9.8	***
1/7/76	1207	12"	16.5	0.9	12.2	7.7
2/10/76	1030	18"	15.2	0.5	12.2	7.5
3/9/76	1020	12"	19.9	6.0	11.0	7.5
4/7/76	0840	12"	19.9	12.5	9.0	8.0
5/4/76	1605	12"	22.8	20.5	8.4	7.5

* Time not recorded.
** No reading, malfunction of Hydrolab oxygen component.
*** No reading, malfunction of Hydrolab pH component.

TABLE D-30. EXPOSURE PANEL STATION 7, WATER QUALITY DATA FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
6/4/75	1015	3'	20.6	25.0	7.1	7.8
7/9/75	1135	18"	22.1	28.9	6.2	6.0
8/12/75	1610	18"	22.0	29.5	9.0	8.1
		5'	21.6	29.5	8.7	8.1
9/9/75	1600	3'	23.4	25.0	*	8.1
10/8/75	1235	10'	18.5	20.5	8.5	8.0
11/5/75	0915	12"	19.9	17.5	9.0	7.7
12/3/75	1014	12"	20.6	9.0	*	**
1/7/76	1130	5'	5.0	1.5	13.6	7.7
2/10/76	1100	3'	15.2	1.0	13.4	7.5
3/9/76	1100	3'	22.0	4.0	14.4	7.5
4/7/76	0855	5'	22.0	13.5	9.8	8.0
5/4/76	1625	4'	21.3	16.0	8.9	7.5

* No reading, malfunction of Hydrolab oxygen component.
** No reading, Malfunction of Hydrolab pH component.

TABLE D-31. EXPOSURE PANEL STATION 8, WATER QUALITY DATA FROM JUNE, 1975, TO MAY, 1976

Data	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
6/4/75	1220	18"	21.2	25.1	7.5	7.7
		13'	21.2	25.1	7.6	7.7
7/9/75	1100	3'	20.6	28.9	5.8	6.0
8/14/75	*	12"	22.7	27.5	5.5	8.0
9/9/75	*	18"	23.4	25.0	**	8.1
		13'	23.1	25.0	**	8.1
10/8/75	1400	18"	19.5	20.5	8.8	8.0
		8'	19.5	20.5	8.8	8.0
11/5/75	0945	18"	19.2	18.0	9.7	7.7
		10'	19.2	18.0	9.7	7.7
12/3/75	1120	18"	19.9	9.0	9.5	***
		12'	19.9	9.0	9.5	***
1/7/76	1305	18"	8.7	1.5	14.0	7.7
		14'	8.7	1.5	14.0	7.7
2/10/76	1315	18"	16.5	1.0	16.8	7.5
		12'	16.5	1.0	16.8	7.5
3/9/76	1040	3'	22.0	4.0	14.4	7.5
		12'	22.0	4.0	14.4	7.5
4/7/76	0940	10'	22.0	13.5	11.0	8.0
5/5/76	1105	2'	22.0	16.5	10.2	7.5
		12'	22.8	16.5	10.2	7.5

* Time not recorded.
** No reading, malfunction of Hydrolab oxygen component.
*** No reading, malfunction of Hydrolab pH component.

TABLE D-32. EXPOSURE PANEL STATION 9, WATER QUALITY DATA FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
6/9/75	1615	6'	21.3	22.3	8.5	7.7
7/9/75	1020	18"	20.8	26.7	6.0	4.0
		6'	20.8	-	6.0	4.0
8/13/75	1410	18"	21.7	26.5	9.7	7.7
		8'	21.7	26.5	9.5	7.7
9/9/75	1800	3'	24.3	22.0	*	6.2
10/8/75	1430	3'	19.5	18.5	9.5	8.0
		10'	19.5	18.5	9.5	8.0
11/5/75	1015	18"	19.9	13.5	*	7.7
		8'	19.9	13.5	*	7.7
12/3/75	1147	18"	21.3	7.0	*	**
1/7/76	1237	18"	13.1	0.5	13.0	7.7
		15'	13.1	0.5	13.0	7.7
2/10/76	1350	18"	16.5	1.0	16.8	7.5
		8'	16.5	1.0	16.8	7.5
3/9/76	1240	3'	22.0	4.0	14.4	7.5
		11'	22.0	4.0	14.4	7.5
4/7/76	1510	18"	22.0	11.0	11.6	8.0
		8'	22.0	11.0	11.6	8.0
5/5/76	1410	2'	23.5	16.0	10.0	7.5
		10'	23.5	16.0	10.0	7.5

* No recording, malfunction of Hydrolab oxygen component.
** No recording, malfunction of Hydrolab pH component.

TABLE D-33. EXPOSURE PANEL STATION 10, WATER QUALITY DATA FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
6/3/75	1350	3'	10.0	23.5	8.0	7.9
7/9/75	0912	18"	13.9	24.4	5.6	6.2
		8'	17.2	-	4.6	6.2
8/14/75	1107	2'	17.6	25.0	5.0	8.0
9/10/75	1330	18"	18.5	20.5	*	7.2
10/8/75	0925	2'	17.9	18.0	6.9	8.0
11/5/75	1120	3'	<1.0	14.0	8.8	7.7
12/3/75	1335	2'	13.1	9.0	9.6	**
1/7/76	1520	3'	14.5	2.5	10.6	7.7
2/10/76	1200	3'	9.8	1.5	16.2	7.5
3/9/76	1140	3'	7.5	6.5	11.4	7.5
4/6/76	1535	3'	19.9	11.0	10.8	8.0
5/4/76	1400	3'	15.2	16.5	8.0	7.5

* No reading, malfunction of Hydrolab oxygen component.
** No reading, malfunction of Hydrolab pH component.

TABLE D-34. EXPOSURE PANEL STATION 11, WATER QUALITY DATA FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
6/5/75	1740	5'	20.6	22.5	8.6	7.7
7/9/75	1305	3'	22.8	26.7	7.0	6.3
8/13/75	1450	18"	21.3	26.5	9.7	7.8
9/9/75	1810	3'	24.1	22.0	**	6.2
10/8/75	*	18"	19.2	18.0	9.5	8.0
11/5/75	1050	3'	21.4	14.5	9.6	7.7
12/3/75	1210	18"	21.3	6.5	**	***
1/7/76	1455	2'	16.5	1.0	13.0	7.7
2/10/76	1135	18"	2.9	1.5	14.2	7.5
3/10/76	1205	4'	22.0	4.0	14.2	7.5
4/6/76	1420	4'	22.7	11.0	11.4	8.0
5/4/76	1645	3'	17.2	16.0	10.2	7.5

* Time not recorded.
** No reading, malfunction of Hydrolab oxygen component.
*** No reading, malfunction of Hydrolab pH component.

TABLE D-35. EXPOSURE PANEL STATION 12, WATER QUALITY DATA FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
6/6/75	1500	2'	19.2	22.5	5.9	7.4
7/9/75	1820	18"	19.2	27.8	7.4	6.2
8/14/75	1130	2 1/2'	19.2	25.3	7.4	8.0
9/11/75	1035	2'	22.0	20.0	*	7.3
10/8/75	1535	3'	19.2	19.3	7.3	7.9
11/5/75	1140	4'	19.9	14.5	8.4	7.7
12/3/75	1400	2'	19.2	6.5	*	**
1/7/76	1545	3'	17.9	1.5	12.8	7.7
2/10/76	1425	3 1/2'	15.8	1.0	17.6	7.5
3/9/76	1200	4'	20.6	6.0	10.4	7.5
4/7/76	1230	3'	21.3	12.5	10.2	8.0
5/4/76	1705	4'	22.0	16.0	8.2	7.5

* No reading, malfunction of Hydrolab oxygen component.
** No reading, malfunction of Hydrolab pH component.

TABLE D-36. EXPOSURE PANEL STATION 13, WATER QUALITY DATA FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
6/3/75	1425	18"	14.8	24.0	6.9	7.9
7/9/75	1835	18"	13.8	27.8	6.5	6.2
8/14/75	1137	18"	10.4	24.5	7.0	8.0
9/11/75	1115	18"	17.9	22.0	*	7.2
10/8/75	1600	18"	17.2	20.0	8.5	8.0
11/5/75	1205	18"	11.8	14.0	8.5	7.7
12/3/75	1430	18"	12.5	7.0	*	**
1/7/76	1625	18"	2.0	0.5	10.8	7.7
2/10/76	1500	12"	5.8	1.5	15.0	7.5
3/10/76	1605	2'	9.8	4.0	11.4	7.5
4/7/76	1245	12"	13.9	12.5	10.0	8.0
5/5/76	1735	12"	13.2	15.5	8.8	7.5

* No reading, malfunction of Hydrolab oxygen component.
** No reading, malfunction of Hydrolab pH component.

TABLE D-37. EXPOSURE PANEL STATION 14, WATER QUALITY DATA FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
6/3/75	1510	2'	17.2	23.5	8.1	7.4
7/9/75	1847	18"	17.2	27.8	6.1	6.2
8/13/75	1000	2'	18.5	25.5	7.5	7.9
9/10/75	1000	2'	17.2	18.0	*	7.7
10/7/75	1340	18"	13.1	17.5	5.1	8.0
		3'	16.9	17.5	5.1	8.0
11/5/75	1340	18"	17.2	14.0	9.7	7.8
12/3/75	1450	12"	15.8	7.5	*	**
1/7/76	1645	18"	2.0	0.0	10.8	7.7
2/10/76	1530	12"	5.8	2.0	15.6	7.5
3/9/76	1300	12"	11.8	3.5	15.4	7.5
4/6/76	1310	7'	23.5	10.0	12.2	8.0
5/5/76	1800	6"	18.6	16.0	9.6	7.5

* No reading, malfunction of Hydrolab oxygen component.
** No reading, malfunction of Hydrolab pH component.

TABLE D-38. EXPOSURE PANEL STATION 15, WATER QUALITY DATA FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
6/6/75	1640	4'	15.8	21.0	7.4	7.7
7/10/75	1003	3'	15.9	26.7	4.6	6.2
8/14/75	1415	18"	17.2	26.0	8.5	7.9
		6'	18.5	25.5	6.0	7.9
9/12/75	0900	4'	17.2	20.0	*	7.1
10/9/75	0945	18"	17.9	17.5	8.4	7.9
11/6/75	0815	4'	17.2	13.5	9.0	7.7
12/4/75	0925	2'	8.7	4.0	*	**
1/8/76	1045	2'	16.5	0.5	12.6	7.7
2/13/76	0830	4'	12.5	1.0	14.6	7.4
3/12/76	0840	3'	17.2	4.0	13.0	7.5
4/8/76	0852	2'	13.2	12.5	10.0	8.4
5/6/76	1640	4'	13.9	17.0	8.5	7.5

* No reading, malfunction of Hydrolab oxygen component.
** No reading, malfunction of Hydrolab pH component.

TABLE D-39. EXPOSURE PANEL STATION 16, WATER QUALITY DATA FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
6/3/75	1550	4'	13.0	23.5	8.0	7.9
7/10/75	0825	18"	12.5	24.4	5.1	6.2
8/14/75	1242	3'	13.1	25.5	5.5	8.0
9/11/75	1200	2'	15.8	20.0	*	7.4
10/9/75	0825	3'	9.8	18.5	6.9	8.0
11/5/75	1250	4'	13.1	14.5	8.4	7.7
12/4/75	0810	3'	9.8	3.0	*	**
1/8/76	0930	2'	14.5	1.0	9.8	7.7
2/10/76	1700	2 1/2'	0.0***	1.0	15.0	7.5
3/9/76	1340	1.5'	13.1	6.5	15.2	7.5
4/7/76	1420	2'	8.1	12.5	10.4	8.0
5/6/76	0845	18"	13.2	13.0	10.0	7.5

* No reading, malfunction of Hydrolab oxygen component.
** No reading, malfunction of Hydrolab pH component.
*** The zero salinity reading can probably be attributed to the presence of freshwater as a result of ice and melting.

TABLE D-40. EXPOSURE PANEL STATION 17, WATER QUALITY DATA FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH
6/3/75	1625	18"	26.3	22.5	9.5	7.9
7/10/75	0900	18"	23.5	25.6	4.4	6.2
8/14/75	1330	12"	24.1	25.5	8.7	8.0
9/11/75	1300	18"	25.6	20.5	*	7.3
10/9/75	0900	18"	15.2	18.0	9.3	8.0
11/5/75	1330	18"	<1.0***	17.0	9.3	7.7
12/4/75	0840	2'	22.0	4.0	*	**
1/8/76	1000	3'	22.6	1.0	14.0	7.6
2/10/76	1630	2'	0.0****	2.0	14.8	7.5
3/9/76	1410	18"	24.1	3.0	12.6	7.5
4/7/76	1345	2'	24.9	15.0	11.2	8.0
5/6/76	0925	2'	26.3	11.5	10.0	7.5

* No reading, malfunction of Hydrolab oxygen component.

** No reading, malfunction of Hydrolab pH component.

*** The low salinity probably resulted from the layering of fresh water after precipitation.

**** The zero salinity reading can probably be attributed to the presence of fresh water as a result of ice and melting.

TABLE D-41. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE AT PLANKTON STATION A, FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{x}$ # Teredinid Larvae per M^3
6/4/75	1045	12"	20.60	25.0	7.1	7.8	0.17
		6'	20.60	25.0	7.2	7.8	
7/8/75	1515	18"	20.60	29.0	9.0	8.0	0.17
		5'	20.60	-	9.0	8.0	
8/12/75	1600	18"	22.00	29.50	8.8	8.1	1.24
		8'	22.00	29.50	9.1	8.1	
9/9/75	1635	18"	23.40	25.00	*	8.1	0.00
		15'	24.10	25.00	*	8.1	
10/7/75	1525	18"	19.90	20.00	5.0	7.9	0.00
		10'	19.90	20.00	5.0	7.9	
11/4/75	1250	18"	19.9	17.5	9.7	7.8	0.00
		15'	20.6	17.5	9.6	7.8	
12/2/75	1130	18"	19.2	10.0	*	8.0	0.00
		15'	18.5	10.0	*	8.0	
1/76	No Sample - Barnegat Bay Frozen Over						
2/12/76	1315	18"	16.5	1.0	16.8	7.5	0.00
		12'	16.5	1.0	16.8	7.5	
3/10/76	1100	2'	22.00	4.0	14.8	7.5	0.00
		15'	22.00	4.0	14.8	7.5	
4/6/76		2'	22.7	13.5	12.0	8.0	0.00
		8'	24.2	12.0	11.8	8.0	
5/6/76	1145	6'	23.6	21.5	9.8	7.5	0.00

* No recording, malfunction of Hydrolab oxygen component.

TABLE D-42. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE AT PLANKTON STATIONS B, FROM JUNE, 1975 TO MAY, 1976

Date	Time	Depth	Salinity -o/oo	Temperature - C°	O_2	pH	$\bar{x}$ # Teredinid Larvae per M^3
6/4/75	1500	12"	21.7	22.5	8.8	7.7	0.00
		6'	21.7	22.5	8.8	7.7	
7/9/75	1418	18"	22.0	27.0	7.3	6.2	6.84
		6'	22.0	-	7.3	6.2	
8/13/75	1420	18"	21.30	26.50	9.7	7.8	0.17
		8'	21.30	26.50	9.7	7.8	
9/10/75	1115	18"	24.90	20.00	*	7.6	0.00
		11'	24.90	19.50	*	7.6	
10/8/75	0720	18"	19.9	18.5	9.5	8.0	2.01
		10'	19.9	18.5	9.5	8.0	
11/4/75	1745	18"	19.9	13.5	*	7.7	0.00
		8'	19.9	13.5	*	7.7	
12/2/75	1425	18"	21.3	7.0	*	8.0	0.00
		8'	21.3	7.0	*	8.0	
1/76	No samples - Barnegat Bay Frozen Over						
2/76	No samples - Boat Inoperable						
3/10/76	1240	2'	19.9	4.0	11.8	7.5	0.00
		6'	19.9	4.0	11.8	7.5	
4/6/76	1420	4'	22.7	11.0	11.4	8.0	0.00
5/5/76	1410	2'	23.5	16.0	10.0	7.5	0.00
		10'	23.5	16.0	9.6	7.5	

* No reading, malfunction of Hydrolab oxygen component.

TABLE D-43. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE AT PLANKTON STATION C, FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{x}$ # Teredinid Larvae per M^3
6/5/75	1740	5'	20.6	22.5	8.6	7.7	0.00
7/9/75	1305	3'	22.8	27.0	7.0	6.3	3.19
8/13/75		18"	21.30	26.00	9.7	7.8	0.28
		8'	21.30	25.00	9.7	7.8	
9/9/75	1800	18"	24.10	22.00	*	6.2	0.00
		6 1/2'	27.00	-	*	**	
10/7/75	1700	18"	19.20	18.00	5.1	7.9	0.26
		6'	19.90	18.00	5.1	7.9	
11/4/75	1635	18"	22.0	14.0	8.9	7.8	0.50
		6'	23.4	14.0	7.9	7.8	
12/2/75	1325	18"	21.3	6.5	*	8.0	0.00
		7'	21.3	6.5	*	8.0	
1/76	No Samples, Barnegat Bay Frozen Over						
2/76	No Sample, Boat Inoperable						
3/10/76	1205	2'	22.0	4.0	14.8	7.5	0.00
		6'	22.0	4.0	14.8	7.5	
4/6/76	1510	8'	22.0	11.0	11.6	8.0	0.00
5/5/76	1300	5'	19.9	17.0	9.8	7.5	0.00

* No reading, malfunction of Hydrolab oxygen component.

** No reading, malfunction of Hydrolab pH component.

TABLE D-44. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE AT PLANKTON STATION D, FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{x}$ # Teredinid Larvae per M^3
6/5/75		18"	18.4	22.0	8.6	7.7	0.00
7/9/75	1847	18"	17.20	27.0	6.1	6.2	1.42
8/13/75	1115	2'	16.50	26.0	8.6	7.8	0.00
		7'	18.50	25.50	8.6	7.8	
9/10/75	1045	18"	17.20	18.00	*	7.7	0.00
		6'	16.50	17.00	*	**	
10/7/75	1350	18"	13.50	18.00	4.9	7.9	0.17
		3'	14.50	18.00	4.9	7.9	
11/4/75	1510	18"	17.20	13.5	9.9	7.8	0.84
		7'	17.2	13.5	9.9	7.8	
12/2/75	1300	18"	15.8	7.5	*	8.0	0.00
		3'	15.8	7.5	*	8.0	
1/76	No Samples, Barnegat Bay Frozen Over						
2/10/76	1530	12"	5.8	2.0	15.6	7.5	0.00
3/10/76	0900	18"	11.8	3.5	15.4	7.5	0.00
		3'	11.8	3.5	15.4	7.5	
4/6/76	1310	7'	23.5	10.0	12.2	8.0	0.00
5/5/76	1800	6"	18.6	16.0	9.6	7.5	0.00

* No recording, malfunction of Hydrolab oxygen component.

** No recording, malfunction of Hydrolab pH component.

TABLE D-45. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE AT PLANKTON STATION E, FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{x}$ # Teredinid Larvae per M^3
6/8/75	1535	3 1/2'	23.4	22.0	8.6	7.7	0.00
7/8/75	1400	18"	22.0	28.0	9.4	7.9	0.36
		5'	22.0		9.4	7.9	
8/12/75	1435	18"	24.90	26.50	9.0	8.0	0.00
		7'	24.90	26.00	9.0	8.0	
9/9/75	1400	18"	26.30	22.00	*	8.1	0.00
		6'	26.30	22.00	*		
10/7/75	1330	18"	22.00	17.50	5.1	7.9	0.16
		6'	21.30	17.00	5.1	7.9	
11/4/75	1055	18"	22.7	13.5	9.4	7.8	0.19
		8'	24.9	13.5	8.4	7.8	
12/2/75	1030	18"	22.0	7.5	*	8.0	0.00
		6'	22.0	7.5	*	8.0	
1/76	No Samples, Barnegat Bay Frozen Over						
2/76	No Sample, Boat Inoperable						
3/11/76	1045	2'	29.1	4.0	13.0	7.5	0.00
		8'	29.1	4.0	13.0	7.5	
4/6/76	1010	2'	25.6	10.5	12.2	8.0	0.00
		7'	25.6	10.5	12.2	8.0	
5/6/76	1000	4'	26.3	15.0	9.8	7.5	0.00

* No reading, malfunction of Hydrolab oxygen component.

TABLE D-46. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE AT PLANKTON STATION F, FROM JUNE, 1975, TO MAY, 1976

Date	Time	Depth	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{x}$ # Teredinid Larvae per M^3
6/6/75	1012	18"	29.2	17.5	9.2	7.7	0.00
		12'	29.2	17.5	9.1	7.7	
7/8/75	1135	18"	27.80	27.0	8.2	8.0	5.56
		12'	27.80		8.3	7.9	
8/12/75	1220	18"	31.30	22.50	7.5	8.0	0.42
		10'	31.30	22.50	7.3	8.0	
9/9/75	0745	18"	24.1	18.50	*	7.6	0.00
		15'	24.9	18.50	*	**	
10/7/75	1025	18"	29.1	18.00	7.0	8.0	0.57
		10'	29.5	18.00	7.0	8.0	
11/4/75	0925	18"	28.4	15.0	8.9	7.8	0.99
		10'	28.4	15.0	8.7	7.8	
12/2/75	0915	18"	27.0	9.5	9.3	8.0	0.00
		12'	28.4	10.0	9.3	8.0	
1/76	No Samples, Barnegat Bay Frozen Over						
2/10/76	0810	2'	12.0	1.0	15.2	7.5	0.00
		12'	12.0	1.5	13.0	7.5	
	(Sample taken at the Coast Guard Station docks; boat was inoperable.)						
3/11/76	0915	2'	24.9	4.0	15.0	7.5	0.00
		8'	24.9	4.0	15.0	7.5	
4/6/76	0945	2'	24.2	9.0	12.2	8.0	0.00
		20'	25.6	8.5	12.2	8.0	
5/4/76	0815	6'	24.9	13.0	13.0	7.5	0.00

* No reading, malfunction of Hydrolab oxygen component.
** No reading, malfunction of Hydrolab pH component.

TABLE D-47. KNOWN WATER QUALITY RANGES FOR TEREDINIDS PRESENT IN BARNEGAT BAY

Species	Temperature - C	Salinity - o/oo	O_2	pH	Reference
Teredo navalis					
Adult	2-35	5-32	-	-	Turner, 1973
release larvae	13-30	-	-	-	Turner, 1973
Adults				4-5	Mawatari, 1950
			Lab 0.98 mg/l Natural 9.59-10.30 mg/l		Roch, F., 1932
Bankia gouldi					
Adult	5-23	10-35			Turner, 1973
spawn	17.5-30 16-20				Turner, 1973 Scheltema and Truitt, 1954
Adult		14-35	>2-3		Allen, 1924
Teredo furcifera					
Adult	24-33	15			Karande, 1968
Teredo bartschi					
No information found in literature.					

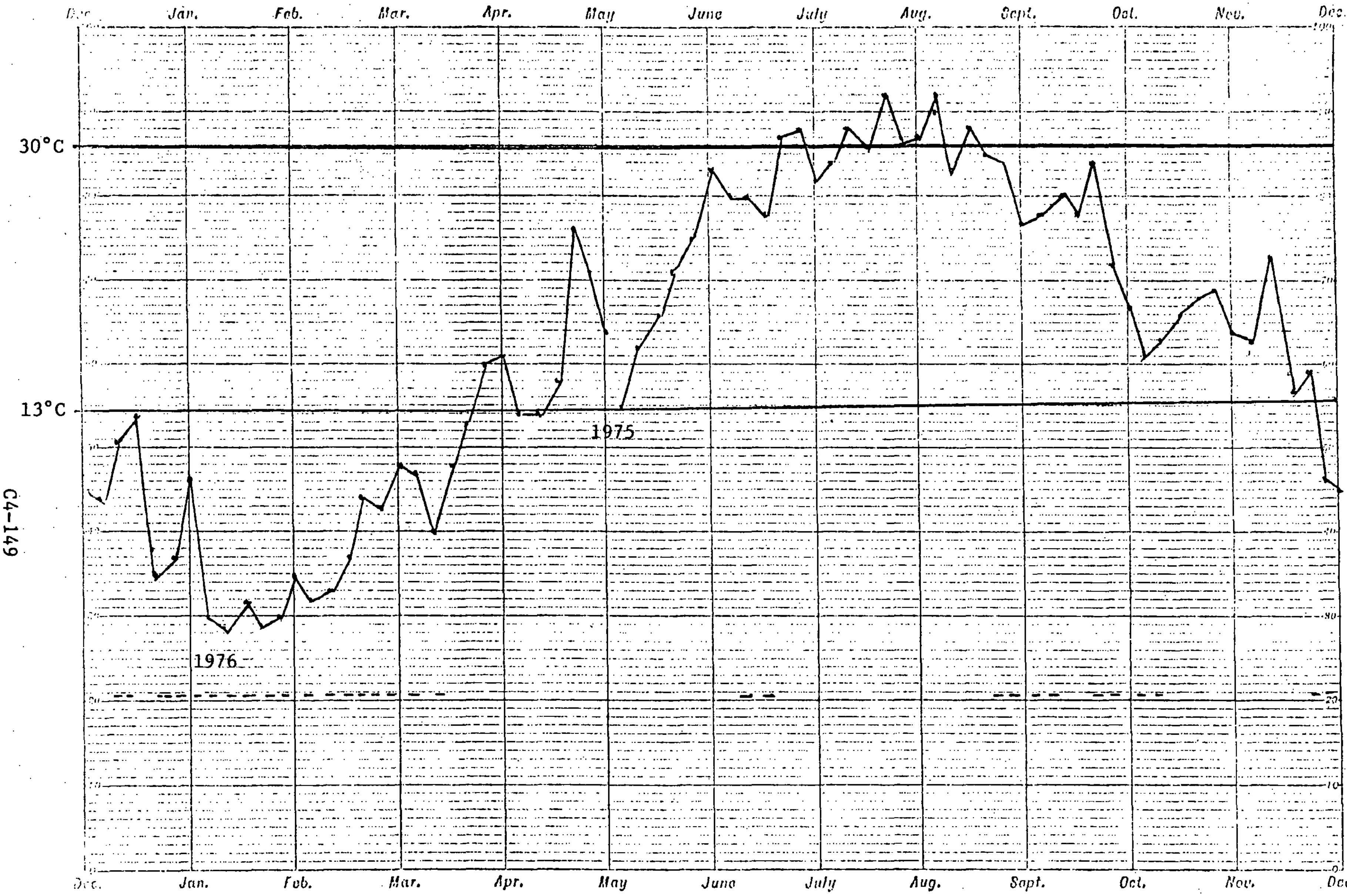
TABLE D-48. THE MEAN SALINITY AND MEAN TEMPERATURE AND THEIR RANGES AT EACH OF THE 17 EXPOSURE PANEL STATIONS*

Station	Salinity (o/oo) $\bar{X}$	Salinity (o/oo) Range	Temperature (C) $\bar{X}$	Temperature (C) Range
1	24.31	4.0 - 30.6	12.93	1.0 - 26.7
2	19.98	9.2 - 25.6	13.66	0.0 - 27.2
3	19.81	6.9 - 24.9	14.07	1.0 - 27.8
4	19.64	9.8 - 25.6	14.43	1.0 - 28.3
5	17.67	3.5 - 23.6	16.20	1.0 - 29.5
6	18.87	14.5 - 23.5	15.86	0.5 - 28.9
7	19.55	5.0 - 23.4	15.95	1.0 - 29.5
8	19.55	8.7 - 23.4	15.88	1.0 - 28.9
9	20.23	13.1 - 23.5	14.08	0.5 - 26.7
10	13.55	1 - 19.9	14.37	1.5 - 25.0
11	19.33	2.9 - 24.1	14.18	1.0 - 26.7
12	19.63	15.8 - 22.0	14.41	1.0 - 27.8
13	11.93	2.0 - 17.9	14.44	0.5 - 27.8
14	14.98	2.0 - 18.6	13.78	0.0 - 27.8
15	15.52	8.7 - 18.5	13.64	0.5 - 26.7
16	11.33	0.0 - 15.8	13.62	1.0 - 25.5
17	19.63	0.0 - 26.3	13.80	1.0 - 25.6

*The values presented were obtained from the salinities and temperatures obtained monthly from June, 1975, through May, 1976.

TABLE D-49. WATER TEMPERATURES °C FROM JUNE THROUGH NOVEMBER, 1975, AT EXPOSURE PANEL AND PLANKTON STATIONS

Station	Minimum	Maximum
1	14.0	26.7
2	14.0	27.2
3	13.5	27.8
4	14.0	28.3
5	17.5	29.5
6	15.5	28.9
7	17.5	29.5
8	18.0	28.9
9	13.5	26.7
10	14.0	25.0
11	14.5	26.7
12	14.5	27.8
13	14.0	27.8
14	14.0	27.8
15	13.5	26.7
16	14.5	25.5
17	17.0	25.6
A	17.5	29.5
B	13.5	27.0
C	14.0	27.0
D	13.5	27.0
E	13.5	28.0
F	15.0	27.0



30°C ——— Optimum range for borer breeding
13°C ———

---------- Plant down

FIGURE D-4. AVERAGE WATER TEMPERATURES °F AT OYSTER CREEK RAILROAD BRIDGE JUNE, 1975 THROUGH MAY, 1976

Based on the available salinity and seawater temperature data, it was not feasible to conduct correlations with these parameters in regard to the settling of larvae on the short-term panels or the destruction of the long-term panels.

However, the salinities recorded at each of the exposure panel and plankton stations were in the range to support breeding populations of *Bankia gouldi*, *Teredo navalis*, *Teredo bartschi*, *Teredo furcifera*, *Teredo* spp., and their larvae when they entered the plankton. The temperature tolerance range for *T. bartschi* and *T. furcifera* in Barnegat Bay is unknown. The summer water temperatures in Barnegat Bay were high enough to support subtropical species, however. The *Teredo* that were not identified to species were either too small or did not possess a sufficient number of essential taxonomic characters. Specific examples of the extent to which the above-mentioned species of teredinids were able to destroy long-term panels under various salinity conditions are presented later.

Table D-48 gives the mean salinity and temperature and their ranges at each of the exposure panel stations. The mean salinity, seawater temperature, and the mean percent destruction of the long-term panels at each exposure panel station is presented in Figure D-5. There was no pattern of destruction observed in relation to these parameters. The salinities recorded that were below the known limit to support teredinids were recorded only at exposure panel stations, and they occurred after the breeding season. The low salinities did not persist. The salinities recorded the month before and the month after the low readings were within the range to support teredinids. The seawater dilution occurred as a result of fresh water from precipitation and runoff and ice melting.

Most species of teredinids require normal marine conditions for spawning; however, adults may withstand long periods under a variety of extreme conditions by closing the burrow and becoming relatively inactive (Turner, 1966). Available salinity ranges for adult survival and reproduction for the four species of teredinids found in Barnegat Bay are presented in Table D-47.

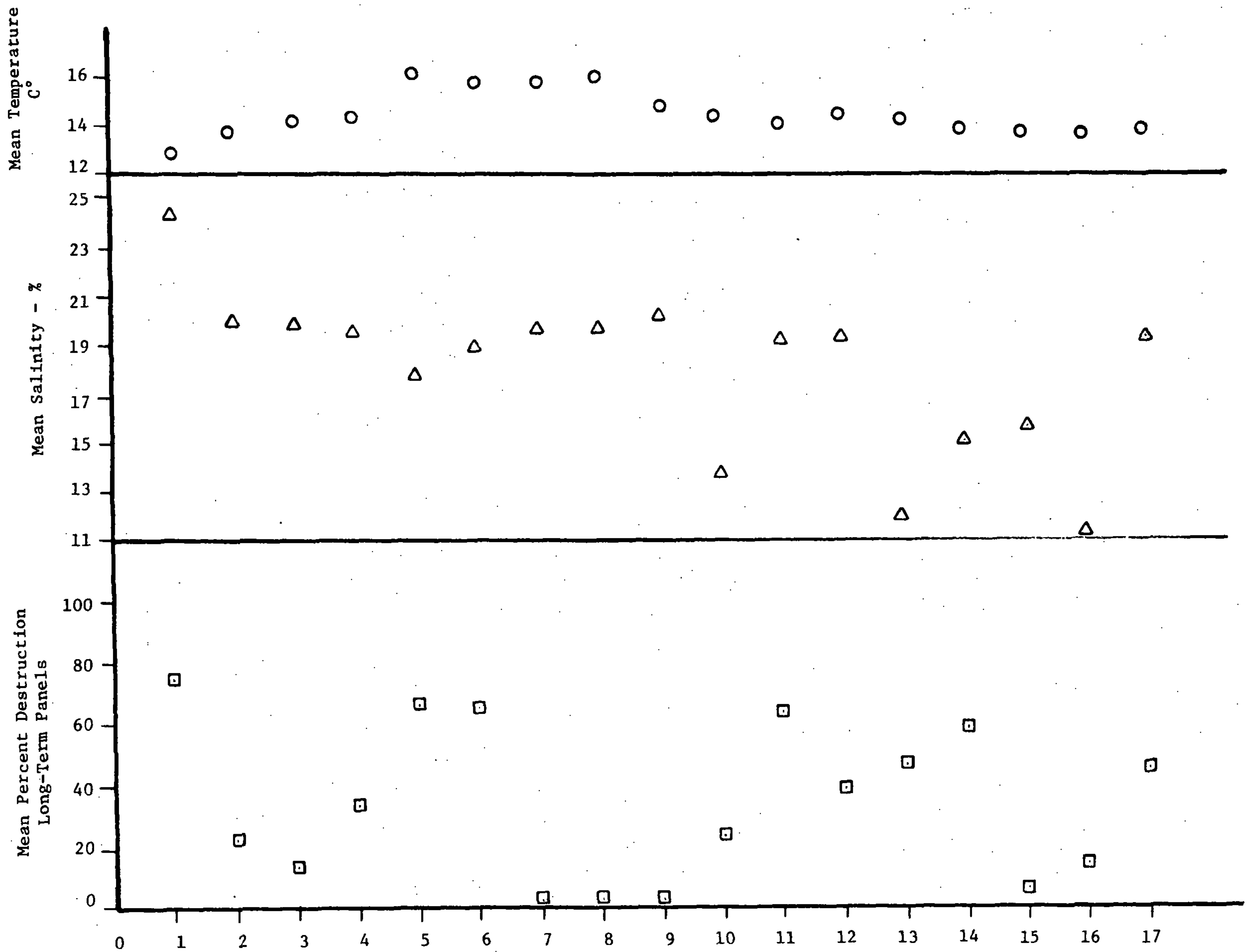


FIGURE D-5. MEAN PERCENT DESTRUCTION OF LONG-TERM PANELS, MEAN SALINITY, AND MEAN TEMPERATURE AT EACH OF THE 17 EXPOSURE PANEL STATIONS, BARNEGAT BAY

Bankia gouldi had the largest distribution of any teredinid identified to species. It was present at all stations and was the dominant teredinid at all stations except 1, 5, 6, 7, and 17. At Station 15 (east side of Barnegat Bay), *B. gouldi* was co-dominant with *Teredo navalis*. The stations where *B. gouldi* was the sole dominant were, except for Station 16, all located on the west side of the bay. Station 16 is on the east side of the bay.

B. gouldi occupied sites that were exposed to salinities from less than 1 o/oo to 30.6 o/oo and seawater temperatures from less than 1.0 C to 29.5 C.

The mean percent destruction of long-term panels at those stations dominated by *B. gouldi* was variable (Table A-13). The highest mean percent destruction of long-term panels occurred at Station 11. It was 63.3 percent and ranged from less than one to 100 percent. The mean salinity at this station was 19.3 o/oo and ranges from 1.0 o/oo to 26.0 o/oo. At Station 3, however, the mean salinity was 19.8 o/oo, with a range from 1.0 o/oo to 27.8 o/oo. The mean percent destruction of the long-term panels was only 15.4 percent, with a range from zero to 75 percent. The lowest mean destruction of long-term panels occurred at Station 16; it was 6.6 percent, with a range from zero to 40 percent (Table A-16). The mean salinity at this station was 11.33 o/oo and the range from less than one to 15.8 o/oo.

The mean percent destruction of the short-term panels at those stations that were dominated by *B. gouldi* was also variable. The heaviest attack occurred at Station 14, the mean was 9.3 percent and ranged from 0 to 45 percent. The mean salinity at this station was 14.98 o/oo and ranged from 2.0 to 18.6 o/oo. However, at Station 2, the percent destruction of the short-term panels was only 0.8 percent and ranged from 0 to 2 percent. The mean salinity was 19.98 o/oo and ranged from 9.2 to 25.6 o/oo.

The number of teredinids removed from the short-term panels at these stations also fluctuated. At Station 2, the mean was 2.83 and ranged from 0 to 6 organisms.

Teredo navalis was the dominant teredinid at Stations 1 and 17. It was co-dominant at Station 15 with *Bankia gouldi*. *T. navalis* was present at all stations except 5, 6, 7, 14, and 16.

Station 1 had the highest mean salinity, 21.0 o/oo, of any exposure panel station. The salinity ranged from 12.0 to 30.6 o/oo. At Station 17, however, the mean salinity was 18.0 o/oo, with a range from zero to 26.3 o/oo. The zero salinity reading apparently resulted from the presence of fresh water and occurred after the normal breeding season. Blum (1922) reported that *T. navalis* can survive for a month at 4.0 o/oo. At station 15 where *T. navalis* was co-dominant with *B. gouldi*, the mean salinity was 15.27 o/oo, with a range from 8.7 to 18.5 o/oo.

Teredo navalis is active and reproduces in salinities from normal seawater to as low as 9.0 o/oo (Miller, 1926). Thus, the salinities recorded at all stations where *T. navalis* was present were within the range to allow reproduction to occur.

The range of temperatures under which *T. navalis* was found varied from 1.0 to 26.7 C. Turner (1973) found *T. navalis* over a temperature range of 33 C, from 2 to 35 C.

The mean percent destruction of the long-term panels was highest at Station 1, 74.4 percent. The percent destruction ranged from 1 to 100 percent (Table A-16). At Station 17, the mean percent destruction of the long-term panels was 44.4 percent, and ranged from zero to 95 percent (Table A-16). The mean number of teredinids removed from the short-term panels was highest at Station 1, 1366.5, and ranged from 1 to 4250. The mean percent destruction of the short-term panels was 10.96 and ranged from <1 to 40 (Table A-15).

Teredo bartschi was only found at Stations 5 and 6 which are located in lagoons that open on to Oyster Creek. The mean salinity at Station 5 was 17.57 o/oo and ranged from 3.5 to 23.6 o/oo; at Station 6, the mean was 18.87 o/oo and ranged from 14.5 to 23.5 o/oo. The percent destruction of the long-term panels at three stations differed by less than five percent.

Teredo bartschi did not survive the decrease in water temperature that resulted after the power plant shut-down on December 26, 1975. By February, the *T. bartschi* in the long-term panels removed from Stations 5 and 6 were dead.

Teredo furcifera was not limited in its distribution by salinity. It was present at seven stations: 1, 2, 4, 10, 11, 15, and 16. The highest mean salinity was recorded at Station 1, the lowest at Station 16; they were 24.31 o/oo and 11.33 o/oo, respectively. The mean salinity and range for the remaining stations are given in Table D-48.

The teredinid plankton data (salinity, temperature, and number of teredinids per M^3) were subjected to analysis using the Kendall Correlation (Sokal and Rohlf, 1969). There was no correlation between salinity and temperature (Figure D-6), salinity and the number of teredinids per M^3 (Figure D-7), and temperature and the number of teredinids per M^3 (Figure D-8). The correlation coefficients were .0382, .0362, and .1548, respectively. The data set only included the first six sampling periods, June through December, since teredinids were not a component of the plankton community captured from December, 1975, to May, 1976.

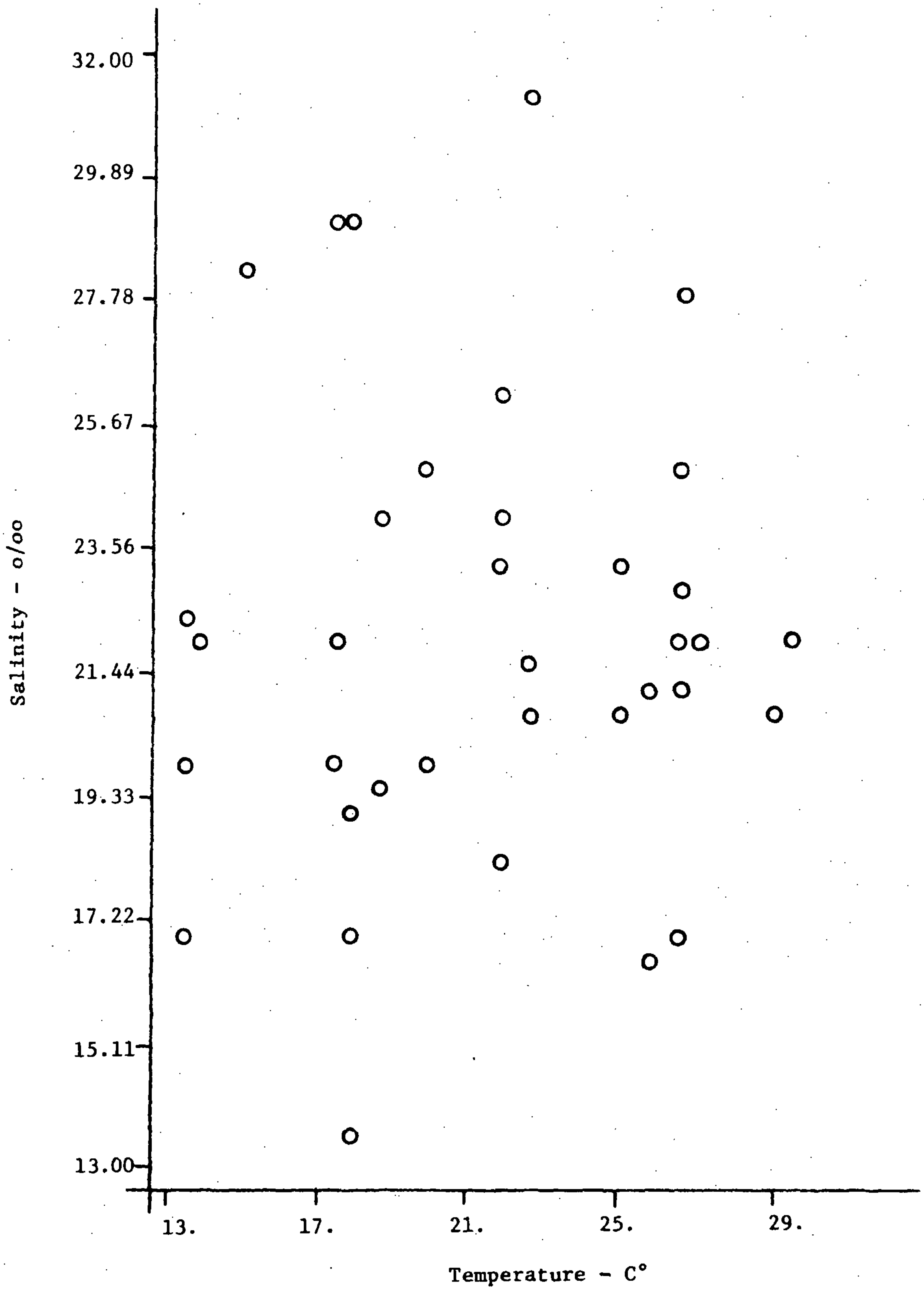


FIGURE D-6. CORRELATION OF TEMPERATURE AND SALINITY AT THE TEREDINID PLANKTON STATIONS

LITERATURE CITED

Allen, M.S. 1924. Toxicity of certain compounds on marine wood boring organisms together with some physiological considerations. In: W.G. Atwood, et al., Marine Structures, their deterioration and preservation. pp. 181-196. National Research Council, Wash., D.C.

Blum, H.F. 1922. On the effect of low salinity on Teredo navalis. University of California Publ. Zool., 22(4): 349-368.

Karande, A.A. & S.S. Pendsey. 1968. Field and Laboratory Observations on Teredo furcifera M., A Test Organism for the Bioassessment of Toxic Compounds. Proc. Md. Acad. Sci. B. Vol. LXX pp. 223-237.

Mawatari, S. 1950. Biological and industrial study of marine borer problem in Japan. Studies on the aquatic animals. Tokyo. 1(1): 45-124.

Miller, R.C. 1926. Ecological relations of marine wood-boring organisms in San Francisco Bay. Ecology 7(3): 247-254.

Roch, F. 1932. Einige Beobachtungen zur Ökologie und Physiologie von Teredo navalis L. Ark. för Zool., 24(A,2), paper No. 5, 18 p.

Scheltema, R.S. and R.V. Truitt. 1954. Ecological factors related to the distribution of Bankia gouldi Bartsch in Chesapeake Bay. Chesapeake Biol. Lab., Solomon Id., Maryland, Publ. 100.

Sokal, R.R. and F.J. Rohlf. 1969. Biometry: The principles and practice of statistics in biological research. W.H. Freeman and Company, San Francisco. 776 p.

Turner, R. 1966. A Survey and Illustrated Catalog of the Teredinidae (Mollusca:Bivalvia). Mus. Comp. Zool., Harvard University, Cambridge, Mass. 265 pp.

Turner, Ruth D. 1973. Report on Marine Borers (Teredinidae) in Oyster Creek, Waretown, N.J. Mus. Comp. Zool. Harvard Univ., Cambridge, Mass. First Report April 3, 1973. 30 pp.

APPENDIX C5

APPENDIX C5

ANNUAL REPORT

For the Period June 1, 1976 to November 30, 1977

on

WOODBORER STUDY ASSOCIATED WITH THE OYSTER CREEK GENERATING STATION

to

JERSEY CENTRAL POWER & LIGHT COMPANY

February 1, 1978

by

B. R. Richards, A. E. Rehm, C. I. Belmore, and R. E. Hillman

APPENDIX C5

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX C5

TABLE OF CONTENTS
(continued)

Page

LIST OF FIGURES

MANAGEMENT SUMMARY

Through Contract #EA-75-1, Jersey Central Power & Light Company requested Battelle's William F. Clapp Laboratories, Inc. to investigate whether the Oyster Creek Nuclear Generating Station thermal discharge significantly affects the marine borer population in the Barnegat Bay system. This report covers the portion of the study from June, 1976 to December, 1977, and makes pertinent comparisons with the data from June, 1975 to May, 1976.

The exposure panel data show that four species of teredinids were present in the Barnegat Bay system during the study period from 1975 through 1977. *Teredo navalis* dominated the east side of the bay and *Bankia gouldi* was dominant on the west side of the bay. The subtropical species, *Teredo bartschi* was found only in Oyster Creek. The presence of the subtropical *Teredo furcifera* became more restricted each year and was not found at any exposure panel station during the 1977 season, suggesting that this species is not truly established in Barnegat Bay.

The survival of *Teredo bartschi* in Oyster Creek suggested a positive thermal effect on the teredinid population in this body of water, but the absence of this species in other parts of the bay indicates that there is no apparent thermal effect on the dispersal of this species into the bay.

Based on the available thermal plume and hydrological data, the following nine areas are beyond the influence of the thermal discharge: Barnegat Inlet, Manahawkin, Conklin Island, Stouts Creek, Cedar Creek, Holly Park, Mantoloking, Seaside, and Island Beach State Park. Based upon the thermal plume study it would appear that the marine borer attack at these locations is not due to any power plant-caused effects.

Few shipworms settled in short-term panels in 1976 and 1977 at Station 4, Waretown, which is within an area affected by the thermal plume. The generating plant was not in operation in 1977 when teredinid settlement occurred at this location so no thermal effects were discerned.

The seawater drawn into Forked River comes from Barnegat Bay and the normal water flow in upper Barnegat Bay is from north to south. Based on thermal plume studies conducted by Woodward-Envicon, recirculation of the thermal plume occurs for approximately four percent of the year. The teredine larvae that enter the mouth of Forked River may originate in Oyster Creek, south and east of Oyster Creek, or north of Forked River. The latter seems more plausible considering the conditions necessary for recirculation of the Oyster Creek effluent.

From histological examinations of teredinid gonads there was an indication of a slightly earlier gonad development in teredinid specimens from Oyster Creek in 1976 but there was no evidence of any early release of larvae or gametes. No larvae were captured at any of the plankton stations through May of 1976 and no settlement occurred on any short-term panels at all exposure panel stations from January through June. This indicates that there was no early release of teredinid larvae or gametes although the water temperatures were high enough in May, 1977 for reproductive activity to take place. The power plant was not operating from May 1 to August 4, 1977, thus the power plant thermal discharge did not contribute to any early reproductive development during that period.

There has been a general decline in teredinid attack in the Barnegat Bay system from 1975 through 1977 in the exposure panels. This more than likely can be attributed to the severe winters of 1975-76 and 1976-77, and normal biological cycles. Also, the removal of the trash wood and the marinas from Oyster Creek substantially reduced the teredinid population in this body of water as well as the number of shipworm larvae that could have originated from this source.

The results of the teredinid plankton sampling program have shown that there was no significant difference in the mean number of teredinid larvae captured at any of the stations located on the west side of the bay. Thus, the Oyster Creek teredinid population did not contribute a greater number of larvae to the bay compared to the other areas. The results of statistical analysis showed that there was no correlation between water temperatures, salinity, and distribution of the teredinid larvae.

Temperature and salinity ranges for reproduction, or adult survival of *Teredo bartschi* have not yet been established. As a result of the exposure panel studies it appears that *Teredo bartschi* in Oyster Creek will settle and successfully penetrate wood at a water temperature of at least as low as 18.6 C.

A protozoan parasite, tentatively identified as a species of the sporozoan genus *Minchinia* has been found in all types of teredinid tissues thus far examined including gonads. Its wide distribution does not appear to be related to power station operations although infected shipworms in the warm effluent could conceivably be subjected to greater stress from the parasite.

Information received from personal communications indicates that some of the creosoted material in the Forked River area was not properly treated for placement in the marine environment. In addition, many of the existing creosoted structures have been in service for more than 20 years and may become vulnerable to teredinid attack.

There was no apparent thermal effect on the *Limnoria* population which was present only in the southern part of the bay and at the Inlet.

WOODBORER STUDY ASSOCIATED WITH THE
OYSTER CREEK GENERATING STATION

by

B.R. Richards, A.E. Rehm, C.I. Belmore, and R.E. Hillman

INTRODUCTION

It is well known that natural cycles in intensity of teredinid activity take place. Warm temperatures and lack of rainfall appear to have the greatest influence (Vrolik, 1860; Hoeven, 1861; Dons, 1949; Scheltema, 1954). A heavy infestation such as occurred in Barnegat Bay in 1975 would naturally be followed by fewer numbers of teredinids if cooler and wetter seasons should follow.

In the mid-nineteenth century Quatrefages (1849) hypothesized that most shipworms in the wood die during the winter, and the few surviving reproduce the following summer. Accepting this theory, dependent upon the availability of a suitable substrate and hydrographic conditions, particularly water temperature, only a few survivors are needed to repopulate or reinfest a given area. This appears to be the pattern in Oyster Creek. In 1975, shipworm attack was rampant and exposure panels submerged in June were 80 to 100 percent destroyed in three months (Richards et al., 1976). The winter of 1975-76 was severe and water temperatures were below lethal levels for adult survival most of January and February, 1976. Therefore it is probable that only a few survived until spring. During the spring of 1976 much of the trash wood was removed from Oyster Creek thereby eliminating some surviving teredinds as well as a large source of suitable substrata. That some teredinids survived is evidenced by the continued presence of teredinid attack.

Temperature is one of the most important water quality parameters for the maintenance of aquatic life (Odum, 1959; Reid, 1961) and its role in the life of any organism is so critical as to lead Gunter (1957) to suggest that it is a major factor controlling the distribution, reproduction, and growth rate of organisms inhabiting the marine environment. According to Hedgpeth and Gonor (1969) the environmental factor most important to synchronizing reproductive periodicity appears to be temperature. In many marine invertebrates, gamete production may take place during the early spring, but spawning will occur only when the water in which the organism lives reaches a critical temperature (Loosanoff and Nomejko, 1951; Bayne, 1965). Lossanoff and Davis (1963) report that the developing larvae of marine bivalves are relatively hardy and will tolerate sharp changes in temperatures but in some molluscan larvae the normal early cleavage stage of eggs are limited to a narrower temperature range than can be tolerated by more advanced stages of the eggs or larvae. Earlier, Clapp and Miller (1933) emphasized water temperature as the largest contributing factor for shipworm breeding.

Barnegat Bay is a large shallow bay with freshwater entering from numerous estuaries and with a tidal exchange primarily from Barnegat Inlet. The thermal effluent from the Oyster Creek Generating Plant is discharged into Oyster Creek. Because of this, marine organisms inhabiting Oyster Creek are, at times, exposed to temperatures that are higher than at other areas in the Barnegat Bay system.

As a result of this increase in water temperature, the Jersey Central Power & Light Company requested Battelle's William F. Clapp Laboratories to investigate the occurrence of marine borers in Barnegat Bay, New Jersey in order to determine whether the resident marine borer population in Oyster Creek is contributing significantly to the marine borer-caused damage in the Barnegat Bay system due to the thermal discharge and possible extended breeding seasons or by dispersal of viable larvae into the bay.

To accomplish this goal four integrated tasks have been conducted: (1) wooden exposure panels were installed at 17 locations (stations) in Barnegat Bay and adjacent areas to obtain information on woodborer distribution and activity, (2) plankton samples were obtained monthly from six stations in Barnegat Bay and adjacent waters to determine if Oyster Creek was serving as the primary source of teredinid larvae in Barnegat Bay, (3) the gonads of teredinids collected throughout Barnegat Bay and adjacent areas were studied to determine if the shipworms in the area of the thermal plume were experiencing an extended breeding season, and (4) water temperature, salinity, oxygen, and pH were recorded at all stations (Figure 1) monthly to determine if these parameters influenced the distribution, reproduction, and abundance of the shipworms. The most reliable results from a study program are obtained when that program operates over a number of successive years. This report presents data and results for the 18-month period June, 1976 to December, 1977 and includes in the discussion trends since the inception of the program in 1975.

The materials and methods and detailed results for the four portions of this study: woodborers, plankton, gonad analysis, and water quality are presented in Appendices A, B, C, and D, respectively.

RESULTS AND DISCUSSION

Exposure Panels

Four species of teredinids were found in the Barnegat Bay system during the 1976-1977 season. These same species were also reported in 1975.

As in previous seasons, the major, and historically endemic, species, *Bankia gouldi*, was present primarily on the west side of the bay with the heaviest attack occurring at stations north of Oyster Creek. This is consistent with our earlier findings and also with those of Hoagland and Turner (1977). The attack was very heavy at Stations 14, Holly Park, which is considerably north of the thermal plume (Woodward-Envicon, 1974).

The second endemic species, *Teredo navalis*, was dominant on the east side of the bay, particularly at the Inlet. Few *Teredo navalis* were present on the west side of the bay although no larger numbers such as reported by Nelson (1923) were found.

The presence of the two remaining species, *Teredo furcifera* and *Teredo bartschi*, in Barnegat Bay was first observed in 1974 (Firth et al., 1976). Considered (Turner, 1973) to be subtropical species, they were introduced into Barnegat Bay by unknown means (possibly by boats that previously had been in subtropical areas) and some have

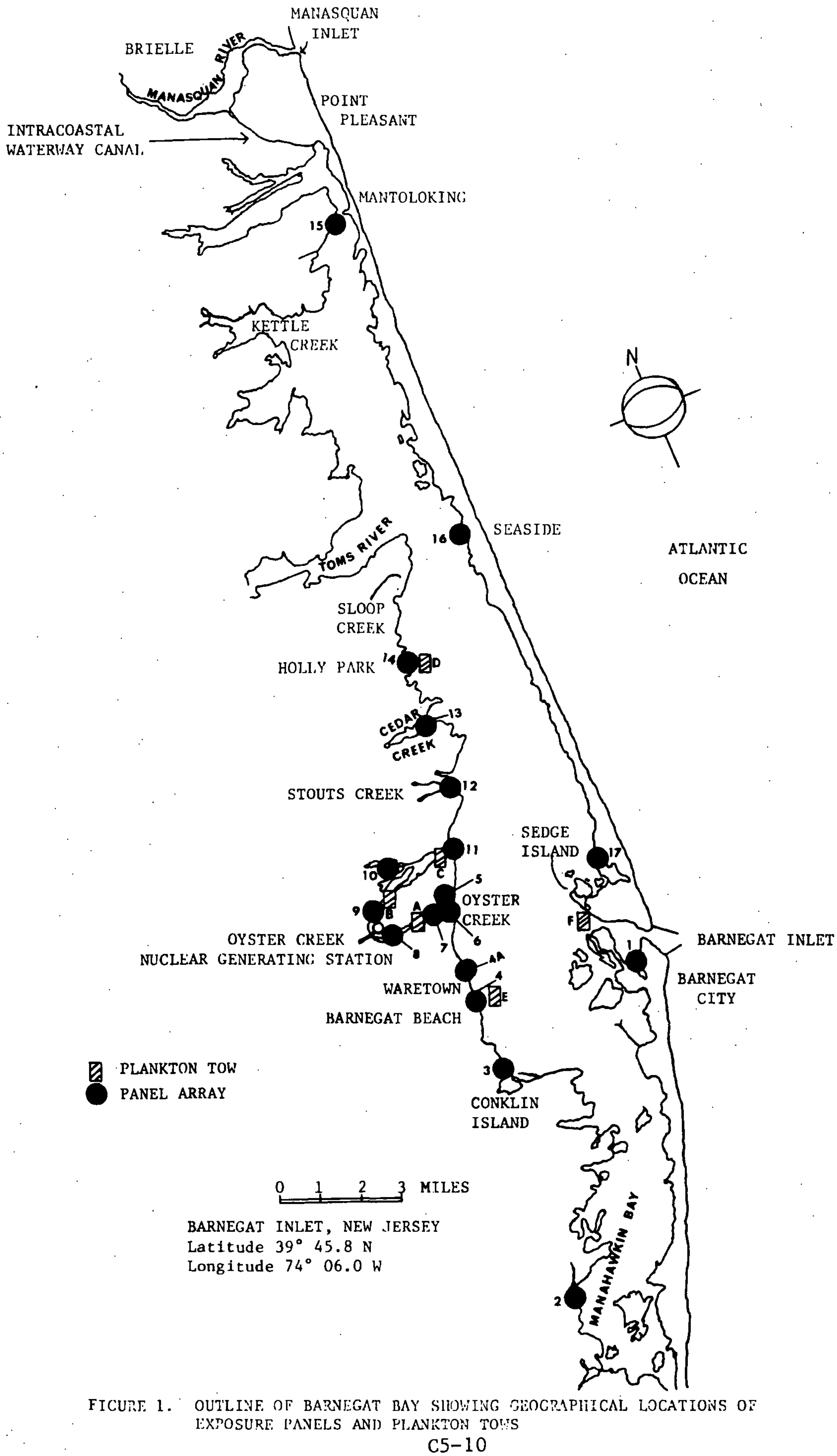


FIGURE 1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHICAL LOCATIONS OF EXPOSURE PANELS AND PLANKTON TOWS

survived. The presence of subtropical species as far north as Barnegat Bay is not singular, Turner (1966) found *T. furcifera* in a boat moored in Long Island Sound, but if it can become established it would indicate that the water temperatures and salinity, as well as other environmental parameters, are favorable. *Teredo furcifera* is becoming world-wide in its distribution (Turner, 1975). Karande (1968) called *T. furcifera* a gregarious species with wide temperature, 24-33 C, and salinity, 6-34 o/oo, ranges. During the breeding season, ambient water temperatures in Barnegat Bay may reach 24-30 C (Table D-77). During the 1976 season, *Teredo furcifera* were identified in panels from only four stations (2, 4, 7, and 11) in contrast to a total of seven stations in 1975 (1, 2, 4, 10, 11, 15, and 17). This suggests that the environmental parameters were not favorable for this species in 1976-77 at the other stations. However, the occurrence of *T. furcifera* specimens at any one station is insufficient to make this a positive assumption. No *Teredo furcifera* have yet been found in panels submerged during the 1977 season. Similar studies of 12-month exposure panels submerged during the 1976 season (Hoagland et al., 1977; and Hoagland and Turner, 1977) reported a few specimens of *T. furcifera* at ten locations throughout the bay.

The distribution and number of *Teredo furcifera* becomes more restricted each year suggesting that the species is not truly established in Barnegat Bay.

Teredo bartschi, which has been found only in Oyster Creek, was dominant in long-term panels removed in November and December, 1977 at Station 7. In October, 1977 *Teredo bartschi* was present but *Teredo* spp. was dominant at this location. Since no other *Teredo* species were found in subsequent panels removed at this location, we may assume that the October *Teredo* spp. were *T. bartschi* too small for identification (Tables A-19, A-20, A-21). *Teredo bartschi* containing umbonate larvae have been observed in long-term panels removed from Oyster Creek stations from August through February.

Teredo bartschi was present in 1975 at two locations at the mouth of Oyster Creek. The species was not present at these locations in 1976 although it was found at Station 7 which is west of Oyster Creek mouth, suggesting that the larvae are not dispersing eastward into the bay. This may be due to: a) temperature and salinity effects, b) proximity of suitable substrate, c) settlement behavior of *T. bartschi*, d) combinations of a through c. Since embryonic *T. bartschi* larvae are ready to settle soon after emergence [within 72 hours, (Lane et al., 1974)] any suitable, available wood is susceptible. There is no significant difference in salinities between the exposure panel stations in Oyster Creek and the stations in the bay. The minimum salinity range for *T. bartschi* is unknown, but salinity does not appear to affect its distribution. It is well known that temperature has definite effects on shipworm reproductive activities but it does not appear to effect the dispersal of *Teredo bartschi* in Oyster Creek. In August and September, 1977 settlement of *T. bartschi* occurred at Oyster Creek stations but not at stations near the mouth of Oyster Creek although there was no significant difference in water temperatures.

Teredo bartschi is found only in Oyster Creek. Where *T. bartschi* occurs it usually is found in association with *Bankia gouldi* (Clapp, 1923). Since *Bankia gouldi* occurs in large numbers outside of Oyster Creek it appears that the Oyster Creek Generating Station has no effect on the dispersal of *Teredo bartschi*.

Settlement in short-term panels indicates that teredinid larvae at the settlement stage were in the water and environmental parameters were conducive for their successful penetration into the wood. Thus, the short-term (one-month exposure) panels provide data concerning the season of the year that attack is initiated. Data from short-term panels exposed monthly since June, 1975 show that successful teredinid settlement does not take place in Barnegat Bay from December to June (Table A-23). Similar observations for 1976-77 were made by Hoagland and Turner (1977).

The number of successful penetrations per month in the short-term panels showed a significant decline ($\alpha = 0.10$) from 1975 to 1977. A sharp drop in settlement occurred at Station 1 in October and November, 1976 that probably was due to temperature change, when the water temperatures went from a high of 22 C in September to 5.5 C in November. An increase in attack occurred in September to November, 1977 at Station 7 which may be due to the presence of a localized infestation near the panel array which is located on an old pier in Oyster Creek. In 1977, penetrations were observed in October and November and the water temperatures at the Inlet remained at 14 C or above which is within the temperature limits for *Teredo navalis* settlement (Turner, 1973). Station 1 is well outside any plant influence so that settlement in October and November was not due to any thermal effects of the power plant.

Station 7 showed a settlement increase from September to November, 1977. All shipworms which settled in September and October at this location were specimens of *Teredo bartschi*. Temperature ranges for settlement are not known but the water temperatures were 25.6 C in September, 18.7 C in October, and 18.6 C in November. The greatest number of penetrations occurred in September (Tables A-23) diminishing approximately 50 percent in October and 96 percent in November (some of the decrease may be due to normal reproductive cycles). Thus it appears that *Teredo bartschi* in Oyster Creek will settle and successfully penetrate wood at a minimum water temperature of 18.6 C (Figure D-2).

Station 7 is in Oyster Creek and is affected by the thermal discharge as are Stations 5 and 6 at the mouth of the creek. The absence of *Teredo bartschi* at Stations 5 and 6 in 1976 and 1977 is a further indication that the thermal discharge does not encourage their dispersal into Barnegat Bay.

Few shipworms settled in short-term panels in 1976 and 1977 at Station 4, Waretown. Settlement in the panels occurred only in July, 1976 and in July and August, 1977 and was similar in both years (Table A-23). Although Station 4 is within an area affected by the thermal plume, the generating plant was not operating in July and August, 1977 so that there were no thermal effects during this period.

The seawater drawn in Forked River comes from Barnegat Bay. The teredine larvae that enter the mouth of Forked River may originate in Oyster Creek and/or other areas of Barnegat Bay. The latter seems more plausible considering that the hydrology in Barnegat Bay is such that few of the larvae in Oyster Creek would be drawn into Forked River (Woodward-Envicon, 1974).

At Station 10, north branch of Forked River, only the short-term panels removed in September, 1976 contained shipworms. No settlement occurred at Station 10 in 1977 in the short-term panels.

The August, 1977 short-term panel from Station 9, Forked River Railrod Bridge, was the only short-term panel from this location to contain settlement in 1976 or 1977. One *Bankia gouldi* was identified.

The rate of flow increases as water drawn into Forked River nears the generating plant, possibly creating an adverse settlement effect. Similarly, a lack of settlement occurs at Station 8 on the discharge side of the generating plant where there is also an increased flow.

Settlement was heavier in 1976 at Station 11, mouth of Forked River, than in 1977, but not as heavy as in 1975. The majority of the teredinids were *Bankia* sp. The largest number (56) was recorded in July, 1976. *Teredo* spp. were recorded in September, 1976 and July, 1977. The limited conditions required for recirculation of Oyster Creek water suggest that it is possible that locations north of Oyster Creek (Stations 12, 13, and 14) may be a source of teredinid infestation at Station 11. The fact that in 1977 the attack at Station 11, Forked River, was heavier than at Stations 12, 13, and 14 may be because teredinid larvae from these highly infested areas may be drawn into Forked River where there is wood available for settlement. Figures A-6 through A-8 show that there is no appreciable difference in water quality at these four stations.

Stations 12, 13, and 14 are north of Forked River and are not influenced by the thermal plume. Only *Bankia* sp. were identified in settlement on the short-term panels and occurred in July-September, 1976 and 1977. *Bankia gouldi* was the only species identified at Stations 12 and 13 and it was the dominant species at Station 14. The net water flow in upper Barnegat Bay is north to south (Carpenter, 1967). Since *Bankia* are oviperous and consequently have a longer planktonic life, up to 25 days, (Turner, 1973), it is possible that *Bankia* larvae released into the water from these locations may be drawn into Forked River.

The generating plant did not operate from May 1 to August 4, 1977. Therefore water temperatures were ambient throughout the Barnegat Bay system during the period when the greatest amount of teredinid (particularly *Bankia gouldi*) spawning, dispersal, and settlement takes place. Reference to Table A-23 shows that in July, 1976 a total of 73 successful settlements occurred in short-term panels from Stations 4-14 in contrast to 28 settlements in July, 1977. All but 7 settlements in 1976 and 5 in 1977 were recorded from stations outside of Oyster Creek. In August, 1976 the ratio was 20 settlements north of Oyster Creek to none in the Creek and in September, 1976 the ratio was 20 to 2. Of a total of 35 settlements in August, 1977, 28 were outside of Oyster Creek. This suggests that most *Bankia* settlement occurred in areas beyond influence of the plume. The large amount of successful settlement at Station 7 in September, 1977 was caused by *Teredo bartschi* which have not been found outside Oyster Creek and therefore this settlement was not included in the above assumption.

Table 1 shows that during periods in 1976 when the water in Oyster Creek was 6-7 C warmer than in other parts of the Barnegat system, more successful settlement occurred north of Oyster Creek. Greatest settlement occurred at Stations 11, 13, and 14. In 1977, when the generating plant was not operating and all the water temperatures were ambient, the same pattern of successful settlement occurred suggesting that the higher temperatures in Oyster Creek have no effect on teredinid settlement at these stations. (The large numbers of successfully settled shipworms in September and October, 1977 in panels from Station 7, Oyster Creek, were *Teredo bartschi* which were not found beyond Oyster Creek and therefore were not included in this assumption). Since *Bankia gouldi* constitutes the major contributor to shipworm attack on the west side of the bay, it would appear that a large source of teredinids, especially *Bankia* is from the northwestern part of the bay.

At the remaining five stations (2, 3, 15, 16, and 17), teredinid settlement was only present in July and August, 1976 at Station 2, and in

TABLE 1. NUMBERS OF TEREDINID SETTLEMENT IN SHORT-TERM PANELS VS WATER TEMPERATURE AT OYSTER CREEK STATIONS 5-8 AND BARNEGAT BAY STATIONS 11-14

	Stations 5-8		Stations 11-14	
	Teredinids	Temperature	Temperature	Teredinids
1976				
June	0	27.5-28.5	21.5-22.5	0
July	7	26.5-27.0	21.5-24.0	64
Aug.	0	27.5-30.0	26.0-28.0	20
Sep.	2	22.0-28.0	22.0-24.5	18
Oct.	0	18.0-21.0	14.0-17.0	0
1977				
June	0	19.5-20.0*	18.3-19.0	0
July	5	24.5-25.1*	25.0-26.0	22
Aug.	7	29.5-32.0	27.5-30.0	25
Sep.	147	25.3-25.6	21.0-22.0	3
Oct.	84	18.7-19.1	14.5-16.5	0

* = Ambient temperatures, generating plant not operating

July and August, 1977 at Station 17. These locations are beyond the influence of the thermal plume and the decline in settlement may be attributed to natural occurrences.

It may be seen from Table A-23 that settlement patterns in Barnegat Bay differ for the various species. *Teredo navalis* successfully settles from July to November, and *Bankia gouldi* from July to September with the greatest number settling in July and August. *Teredo bartschi* which usually is found in association with *Bankia gouldi* appears to show a preferential settling pattern and settles mostly in September and October. No *Teredo furcifera* were identified in short-term panels, thus no settlement pattern was discerned.

The amount of destruction to the long-term panels was variable and appeared to be independent of salinity, oxygen, and pH effects (Figure D-3) but was affected by temperature. Reference to Tables A-25 and A-26 shows a definite decrease in the 1976 attack at all stations. The winter of 1975-76 was severe, and the generating plant was not operating from December 26, 1975 to March 11, 1976 so that the water temperatures in Oyster Creek as well as all of Barnegat Bay were below recognized lethal levels for survival of adult teredinids (Table D-78). Unpublished data from Clapp Laboratories shows a similar decrease in attack in other areas along the Atlantic coast.

Panels removed through December, 1977 showed that the attack continued to decrease at most of the stations during the 1977 season. Unpublished data from Normandeau Associates (personal communication, 1977) and Clapp Laboratories show a similar decrease in areas in Long Island Sound and on the Atlantic Coast. The increase at Station 7, Oyster Creek, was due primarily to a successful settlement of *Teredo bartschi*. The increase in *Bankia* attack at Stations 10 and 11 may be due, as mentioned earlier, to nearby resident population and/or from larvae drawn into Forked River from the bay. The heavy *Bankia* attack at Stations 13 and 14, which are north of influence of the thermal plume, does not appear to be due to any power plant-caused effects.

Station 11 is located in the Forked River Beach area. Many of the wooden pilings at these locations were given a 12-pound creosote treatment, and were installed from the late 1950's through 1965 by Mr. Charles Pearl (personal communication, Mr. James Vouglitois, Jersey Central Power & Light Company, 1978). In order to ensure that a wooden piling placed in a marine environment will remain free of teredinid attack for any length of time it must be given a minimum creosote treatment of 20 pounds (AWPA Specification C3, 1976). The destruction of the wooden pilings at the two beach areas given above may be attributed to the piling having not been subjected to the proper creosote treatment before they were installed. Even if it is assumed that the pilings installed in the late 1950's were treated with 20 pounds of creosote, their life expectancy in the marine environment would be approaching their limit. It is probable that the destruction of wooden structures in the vicinity of Station 11 can be attributed to improper creosote treatment and not to power plant related effects.

The amount of destruction was significantly greater at Station 1 than at any other exposure panel station (Figure A-5). This station is beyond the influence of the thermal plume and is dominated by *Teredo navalis*, which historically has caused destruction at this location. The panels from Stations 11, 13, and 14 had less destruction than Station 1 but significantly more than panels from the other locations. Stations 4, 5, 7, 10, 12, 15, and 17 were not significantly different in terms of attack.

Using the mean percent attack for the 1975-76 seasons and the first six months of the 1977 season (Table A-28) the stations were ranked in descending order (Table A-29). Station 1 ranked number 1 for all three seasons. Two Oyster Creek Stations, 5 and 6, ranked in the upper third in 1975 but dropped to the middle third in the following seasons. This may be attributed to the removal of trash wood from Oyster Creek. The same six stations (1, 11, 7, 13, 14, and 12) were ranked in the top third in 1976 and 1977. Of these stations, all but Stations 7 and 11 are beyond the influence of the plume, and all but Station 7, which is located on an old pier in Oyster Creek, are north of Oyster Creek or at the Inlet.

Reference to Figures A-6 through A-8 shows that station groupings as a result of principal component analysis (using rates of borer attack and water quality parameters) are similar for 1976 and 1977. In both years, the stations north of Oyster Creek group tightly while Stations 1, 2, 3, and 4 appear to be different. The similar groupings in the two years indicate no radical changes in the relationships in the water parameters or attack rates at any one station.

Plankton

As a result of the thermal plume flowing through Oyster Creek prior to entering Barnegat Bay it was assumed that the shipworm populations occupying Oyster Creek may have had an extended breeding season, and thus contribute significantly greater numbers of larvae to the bay compared to other areas. However, this assumption can not be supported based on the results of the statistical analysis of the available teredinid larvae, salinity, and water quality data.

The results of the teredinid plankton sampling program conducted from June, 1975 through November, 1977, have shown that there was no significant difference (alpha 0.10) in the mean number of teredinid larvae captured at any of the stations located on the west side of the bay. There was a significantly greater number of teredinid larvae captured at Station F, Barnegat Inlet, which can be attributed to the large numbers of teredinid larvae captured per cubic meter during the November, 1977 sampling effort (Figure B-2; Table B-3).

The Kendall and Spearman Correlation Coefficients were utilized to determine if there was a relationship between the mean number of teredinid larvae captured per cubic meter of seawater filtered and seawater temperature. The results of the analysis showed that there was no significant correlation between the number of larvae captured and seawater temperature at any station or all stations combined at an alpha of 0.05.

The winters of 1975-1976 and especially 1976-1977 were unusually severe. The reduction in water temperatures during these periods may have caused a "natural kill" of adult teredinids throughout Barnegat Bay. If a "natural kill" did occur and the adult shipworm population was significantly reduced it would account for the low numbers of teredinid larvae captured in the plankton.

Borer Development

Phases of gonad development studied in the four species of teredine borers over the length of the program indicate some interesting differences between predominant species in Barnegat Bay, *Bankia gouldi*, and the species of *Teredo*.

As expected, the gonads of *B. gouldi* were generally in the late active through spent phases in the summer and early fall of each year. Based on the most advanced stages of gonad development at each station, it appears as if spawning began slightly earlier at Stations 7 and 8 in 1976 than at the other stations, since these two stations were the only stations having shipworms with gonads in the partially spent stage by August, 1976, when shipworms were first recovered after the start of the spawning season. With the onset of colder water temperatures, only early to late active phases were found, with most specimens being in the early active phase. One exception to that observation was the occurrence of a partially spent male at Station 9 in February, 1976.

Spring gonadal activity commences at a time when we do not ordinarily recover shipworms from the regular panels because of the six-month exposure cycle. Additional panels were installed at each station in August, 1976 for the purpose of monitoring the early spring stages. They were removed in May and June, 1977 but all specimens were dead, and no results could be obtained. There is no evidence from shipworms recovered from any station in March of 1976 or 1977 which would indicate that any significant gonadal development had occurred by that time.

Developmental patterns in *Teredo navalis* were a little surprising in that ripe gonads were found in the late active through spawning phases late into the winter. Ripe gonads were found at Stations 2, 9, and 15 as late as February, 1976. At Station 1, gonads were ripe throughout the winter of 1976/1977. Ripe gonads were also found as late as December, 1976 at Stations 15 and 17, and in November at Station 11.

Far fewer specimens of *T. navalis* than *B. gouldi* were found at the sites directly affected by the thermal discharge, and there was, again, no evidence to indicate that the discharge has had any influence of breeding cycles of *T. navalis* since it occurrs generally throughout Barnegat Bay.

Specimens of *T. furcifera* with late active and partially spent gonads were found at Stations 2 and 11 as late as January, 1976. Throughout the rest of the 1976 season specimens of *T. furcifera* for gonad studies were recovered only at Stations 4, 7, and 11, and then only rarely. Only one specimen was found with ripe gonads, and that was at Station 7 in September, 1976.

Very few specimens of *T. bartschi* were recovered for gonad development analysis. From August, 1975, through January, 1976 they occurred only at Station 6 and were ripe and spawning in August and September, as expected. One specimen was recovered from Station 6 in January, 1976 but no gonadal tissue was discernable in the sections.

Five specimens were recovered in November, 1976 from Station 7. One had ripe gonads, one was in the partially spent phase, and three showed no signs of gonadal activity. Three more specimens were recovered from Station 7 in August, 1977, all of which showed gonads in the late active phase.

A protozoan parasite discovered in specimens of the various species of *Teredo* (Hillman, 1978) may be complicating the breeding patterns, and possibly the abundance, of shipworms of that group. The parasite, tentatively identified as a species of the sporozoan genus *Minchinia* has been found in all types of tissues thus far examined, including the gonads. In heavy infections, tissue destruction is considerable. The distribution of the parasite does not appear to be related to power station operations although infected shipworms in the warm effluent could conceivably be subjected to greater stress from the parasite.

Water Quality

The extent to which marine organisms are able to become established in a particular geographic region is in part dependent on their ability to cope with changes in their physical environment, such as temperature, salinity, dissolved oxygen concentration, and pH, on a daily and seasonal basis. These water quality parameters were monitored monthly at the 17 exposure panel stations established at various locations around Barnegat Bay (Figure 1) from July, 1975 through December, 1977. The same water quality parameters were monitored monthly at the six teredinid plankton stations from June, 1975, through June, 1976; from July, 1976, through November, 1977, water quality was monitored bimonthly, coincident with the additional plankton sampling.

The water quality parameters measured monthly at all stations from June, 1975, through May, 1976 are presented in the first annual report

(Richards et al., 1976). Water quality parameters measured from June, 1976, through December, 1977 are presented by month in Tables D-1 through D-51, and by stations in Tables D-52 through D-76.

The dissolved oxygen concentrations, salinity, and pH values recorded each month were within the range to support teredinids throughout the Barnegat Bay system. The known, published, water quality ranges for teredinids found in Barnegat Bay are presented in Table D-78.

On occasion salinity values were recorded at several exposure panel stations that were below the known limit for teredinid survival, but their duration was not long enough to cause teredinid mortality. The salinity reductions were caused by precipitation, freshwater run-off, and ice melting.

Of the water quality parameters monitoried, temperature is considered the most important single factor governing the occurrence and behavior of life (Gunter, 1957). Because of the release of a thermal effluent by the Oyster Creek electric generating station and the resulting increase in water temperature it was assumed that there may have been an extension of the teredinid breeding season and the number of teredinid larvae produced (Figure D-2).

The extent to which the thermal effluent released by the Oyster Creek nuclear power generating station can extend the breeding season of teredinids around Barnegat Bay is dependent on the dimensions of the thermal plume, its ΔT, and its direction of flow. The area covered by the thermal plume as calculated by Woodward-Envicon (1974) was from a line not more than 1.5 miles to the north of the mouth of Oyster Creek, south for a distance not exceeding 3.0 miles, and to the east for about 1.0 to 1.5 miles, depending on wind conditions. Recirculation of the thermal plume into Forked River has been estimated to occur for approximately four percent of the year (14.6 days). However, before recirculation can occur the wind must be from the south or southeast, blowing at 12 knots or greater, and the tide must be in the flood stage. The thermal plume flows essentially to the south. This can be attributed to the predominantly southward flow of the water currents in Barnegat Bay (Carpenter, 1967).

Based on the above information, the following nine stations were beyond the influence of the thermal plume: Station 1, Coast Guard

Station; Station 2, Ashton's Marina, Manahawkin; Station 3, Iggies Marina, Conklin Island; Station 12, Stouts Creek; Station 13, Rocknak's Yacht Basin, Cedar Creek; Station 14, Dick's Landing, Holly Park; Station 15, Winter Yacht Basin, Mantoloking; Station 16, Berkely Yacht Basin, Seaside; and Station 17, Island Beach State Park, near Sedge Island (Figure 1).

Optimum water temperatures for molluscan borer spawning range from 13 to 30 C (Table D-78; Figure D-2). When the exposure panel arrays were initially installed in June, 1975, the seawater temperatures at the 17 stations were already high enough for *Teredo navalis* to release larvae and for *Bankia gouldi* to spawn. The seawater temperatures recorded in June at all stations except Station 1 ranged from 21 to 25 C. At Station 1, the seawater temperature was 17.0 C.

Seawater temperatures recorded monthly from June, 1975, through November 4-6, 1975, remained high enough for *Teredo navalis* to release larvae. Temperatures high enough for *B. gouldi* to spawn occurred through October at all stations. By November, only Oyster Creek had seawater temperatures high enough for *B. gouldi* to spawn. The seawater temperatures recorded from December, 1975, through March 9-11, 1976 were too low for any of the teredinid species occupying Barnegat Bay and adjacent areas to remain or become sexually active. By April 6-7, 1976, seawater temperatures were above the known minimum for *Teredo navalis* to release larvae only in Oyster Creek. By May 5-6, 1976, water temperatures were high enough at all stations except 1 and 17 for *T. navalis* to release larvae. By June seawater temperatures were high enough for *T. navalis* to release larvae at all stations, and remained so until October.

At the time of the May, 1976 sampling, temperatures high enough for *B. gouldi* to be sexually active were recorded at 10 stations which included the four Oyster Creek stations (Table D-78).

By June, 1976, water temperatures were high enough at all stations for *Teredo navalis* to release larvae and for *Bankia gouldi* to spawn; and the water temperatures may have been high enough at all stations, except Station 1 for *Teredo furcifera* and *Teredo bartschi* to be sexually active if they were present. Water temperatures in Oyster Creek, however, were high enough for the last two mentioned species to be sexually active (Figure D-2). During July and August, 1976, water temperatures were high enough to be classified as subtropical throughout Barnegat Bay. In September, 1976, water temperatures recorded in Oyster Creek at Stations 5, 7, and 8 were high enough for *T. furcifera* and *T. bartschi* to release larvae, and may have been high enough at the remaining 15 stations, since the lowest water temperature, 21.5 C, was recorded at Station 2. However, by October only Stations 6, 7, and 8 may have had water temperatures high enough for *T. furcifera* and *T. bartschi* to be sexually active. From November, 1976, through May, 1977, water temperatures were too low for these two species to be sexually active. However, by June water temperatures may have been high enough for *T. furcifera* and *T. bartschi* to be sexually active at Stations 5, 6, 7, and 10. In July and August, 1977, water temperatures were high enough for these subtropical species to be sexually active at all stations if they were present; however, by September only Stations 5 through 9 had water temperatures high enough for sexual activity. From October through December water temperatures were below the known survival limits for *T. furcifera* and *T. bartschi*.

Water temperatures throughout the bay remained high enough for *T. navalis* and *B. gouldi* to be sexually active through October, 1976. Water temperatures recorded at all stations in November were below the known limits for any of the teredinids found in Barnegat Bay to be sexually active.

The water temperatures recorded on November 9, 1976, at Stations 2, 3, 13, 14, 15, 16, and 17 were below the known survival limit for *Bankia gouldi*, which has been reported as 5 C (Turner, 1973). In December temperatures below 5 C were recorded at all stations except 6, 7, 8, and 17.

Water temperatures recorded in November were still above the minimum survival temperature for *Teredo navalis*, which has been at 2 C (Turner, 1973). However, by December water temperatures below 2 C were recorded at Stations 2 and 14. The January, 1977, water temperatures recorded at Stations 8 and 11 was 0.0 C, at Stations 5 and 7 it was 3 C.

Due to the freezing over of Barnegat Bay and most of its tributaries in January and February, 1977, it was not possible to record water temperatures at most of the exposure panel stations. Water temperatures were recorded in January at Stations 5, 7, 8, and 11, and were below the known survival limit for *B. gouldi*.

From March through December, 1977, water temperatures were above the known survival limits for *Bankia gouldi* and *Teredo navalis*. Except for the water temperatures recorded at Stations 5 through 8, all other stations had water temperatures too low for *T. navalis* to be sexually active in April, 1977. Only Station 1, in April, had water temperatures high enough for *B. gouldi* to be sexually active.

By May, 1977, water temperatures were high enough for *T. navalis* to release larvae and remained so through November; the December water temperature was too low. From May through September water temperatures remained high enough for *B. gouldi* to spawn. However, by October the only stations which had water temperatures high enough for *B. gouldi* to spawn were 1, 5 though 8, 10, 12, and 13. In November only Stations 5 through 11 and 13 had water temperatures high enough for *B. gouldi* to spawn. Water temperatures recorded at all stations in December were too low for *B. gouldi* to spawn.

The Oyster Creek power plant was not releasing a thermal effluent into Oyster Creek during the following period: December 26, 1975 to March 11, 1976; July 28 through July 30, 1976; and from May 1 through August 4, 1977. Thus, for the first time period the organisms inhabiting this body of water were subjected to normal winter-spring temperatures for the area. During the second and third periods organisms were subjected to ambient spring-summer water temperatures.

Since the first down-time of the plant took place in 1976 before the teredinid reproductive season is apparent in Barnegat Bay and the remaining down-time occurred when ambient water temperatures in the bay would support teredinids, it is not possible at this time to determine if any real differences in patterns of reproductive cycles, settling, and attack due to station caused effects exist.

Limnoria

Limnoria were present in panels from the four stations at the southern end of Barnegat Bay, Stations 2, 3, 4, and 4A, and at the Inlet Station 1. *Limnoria tripunctata* was the only species identified and the overall attack was slight to moderate. The heaviest attack occurred at Station 4A, Holiday Harbor, Waretown, which is the station nearest the mouth of Oyster Creek and is in the thermal influence of the power plant. There is no evidence of *Limnoria* at stations north of this location although salinity levels are within limits of supporting this species. *Limnoria* were not found in any of the creosoted panels or adjacent creosoted structures.

CONCLUSIONS

- Data from exposure panels show that four species of teredinids were present in the Barnegat Bay system during the study period of 1975 through 1977. *Teredo navalis* was predominant on the east side of the bay and *Bankia gouldi* was predominant on the west side of the bay. The subtropical *Teredo bartschi* was found only in Oyster Creek. The subtropical species *Teredo furcifera* was not found at any exposure panel station during the 1977 season, and this species does not appear to be established in Barnegat Bay.
- Studies to date indicate that the survival of *Teredo bartschi* in Oyster Creek suggests a positive thermal effect on the teredinid populations in this body of water.
- It appears that *Teredo bartschi* in Oyster Creek will settle and successfully penetrate wood at a water temperature of at least as low as 18.6 C.

- Absence of settlement on short-term panels removed at all stations from January through June, 1976 and 1977 suggested that there was no early release of teredinid larvae or gametes by the adult shipworm populations inhabiting Oyster Creek.
- The fact that larvae were not captured during any of the plankton studies and the absence of settlement on the short-term panels at any of the exposure panel stations outside of Oyster Creek removed from January through June, 1976 and 1977, indicates that teredinids did not become sexually mature in advance of the normal breeding season.
- There was an indication of a slightly earlier gonad development in teredinid specimens from Oyster Creek in 1976 but there was no evidence of any early release of larvae or gametes.
- A protozoan parasite, tentatively identified as a species of the sporozoan genus *Minchinia* has been found in all types of teredinid tissues thus far examined including gonads. Its wide distribution does not appear to be related to power station operations although infected shipworms in the warm effluent could conceivably be subjected to greater stress from the parasite.
- There has been a general decline in teredinid attack in Barnegat Bay from 1975 through 1977 in the exposure panels which more than likely can be attributed to the severe winter of 1975-76 and especially to the winter of 1976-77.
- In May, 1977 water temperatures were high enough at all exposure panel stations for *Teredo navalis* to release larvae and for *Bankia gouldi* to spawn. The power

plant was not operating from May to August 4, 1977, thus power plant operations did not contribute to any early reproductive development.

- Based on the available plankton data and results of statistical analyses, there was no correlation between water temperatures, salinity, and distribution of larvae during those periods when teredinid larvae were a component of the plankton community at one or more stations.
- Since the net water flow in Barnegat Bay is to the south, teredinid larvae released from the highly infested areas of Holly Park, Cedar Creek, and Stouts Creek could possibly be drawn into Forked River where there is wood available for settlement, and where the teredinid attack is heavy.
- There is a good indication that some of the creosoted material in the Forked River area was not properly treated for placement in the marine environment. In addition, many of the existing creosoted structures have been in service for more than 20 years and may become vulnerable to teredinid attack.
- Based on the thermal plume studies conducted by Woodward-Envicon, recirculation of the thermal plume occurs for approximately four percent of the year. It is doubtful that such a brief residence time would account for the intensity of the teredinid activity at the mouth of Forked River.
- The removal of the trash wood and the marinas from Oyster Creek substantially reduced the teredinid population in this body of water and the number of shipworm larvae that could have originated from this source.

- The amount of untreated wood remaining in Oyster Creek is probably no greater than what can be found in other areas of the bay, e.g., Cedar Creek. Subsequent removal of the remaining wood with teredinids probably would not result in a reduction in the intensity of shipworm attacks in other parts of Barnegat Bay.
- There was no apparent thermal effect on the *Limnoria* population which was present only in the southern part of the bay and at the Inlet.

LITERATURE CITED

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

Clapp, W.F. 1923. A new species of *Teredo* from Florida. Proc. Boston Soc. Nat. Hist., 37:31-38.

Clapp, W.F. and R. Kenk. 1963. Marine Borers, An annotated bibliography. ACR-74, Office of Naval Research, Dept. of the Navy, Wash., D.C. 1136 pp.

Clapp, W.F. and J. Miller 1934. Notes on the life history of *Teredo navalis*. New England Comm, on Marine Piling Invest. Prog. Rept., 1:19-25.

Dons, C. 1949. *Teredo* reproduction and the temperature of the sea. Norske Vidensk. Selsk. Forh., 21(42):186-190. In Clapp and Kenk, 1963.

Firth, R.W. Jr., et al. 1976. Woodward-Clyde Consultants, Final Report of 1974-1975 Field and Laboratory Studies for Jersey Central Power and Light Company.

Hillman, R.E. 1977. Occurrence of *Minchinia* sp. in Species of the Molluscan Borer *Teredo*. Int. Symp. on Haplospondian and Haplospondian-Like Diseases of Shellfish, VIMS, Gloucester Point, Va. August 17-19, 1977.

Hoagland, K.E., M. Rochester, and L. Crockett. 1977. Analysis of Populations of Boring and Fouling Organisms in the Vicinity of the Oyster Creek Nuclear Generating Station with Discussion of Relevant Physical Parameters over the Period June 1 - August 31, 1977. Wetlands Institute, Lehigh Univ., Stone Harbor, N.J.

Hoagland, K.E. and R.D. Turner. 1977. The Effects of Nuclear Power Plant Operations on Populations of Boring and Fouling Invertebrates. Tech. Prog. Rept. (AT(49-24)-0347). Second Quarterly Report to USNRC. Lehigh Univ., Stone Harbor, N.J.

Hoeven, J. van der. 1861. Observations on *Teredo navalis* and the mischief caused by it in Holland. Rep. Brit. Assoc. Adv. Sci. Meeting, 30 (1860), In Clapp and Kenk, 1963.

Karande, A.A. and S.S. Pendsey. 1968. Field and Laboratory Observations on *Teredo furcifera* M., A Test Organism for the Bioassessment of Toxic Compounds. Proc. Md. Acad. Sci. B., Vol. LXX, pp. 223-237.

Lane, C.E., Tierney, J.Q, and R.E. Hennacy. 1954. The respiration of normal larvae of *Teredo bartschi* Clapp. Biol. Bull. Mar. Biol. Lab. Woods Hole, 106:323-327.

Loosanoff, V.L. 1942. Seasonal gonadal changes in adult oysters, *Ostrea virginica*, of Long Island Sound. Biol. Bull. 82:195-20.6

Nelson, T.C. 1923. Annual Report New Jersey State Agricult. Exper. Station, 43 (for 1922):321-343.

Quatrefage, A. de. 1849. Memior on the genus *Teredo* Linni. Ann. des Sci. Nat. Zool. (3) 11 (Jan.):19-64, (Feb.):65-73. In Clapp and Kenk.

Richards, B.R. and C.I. Belmore. 1975. Evaluation of the Extent and Effect of the Marine Woodborer Population in Oyster Creek Upon the Overall Barnegat Bay Marine Woodborer Population. Report No. 14609 to Jersey Central Power & Light Company, 39 pp.

Richards, B.R., A.E. Rehm, C.I. Belmore, and R.E. Hillman. 1976. Woodborer Study Associated with the Oyster Creek Generating Station. Ann. Rept. for the period June 1, 1973 to May 31, 1976. Report No. 14729 to Jersey Central Power & Light Company.

Shafto, S.S. 1972. The boring and fouling communities of Barnegat Bay, New Jersey. Masters Thesis, Rutgers University, New Brunswick, N.J.

Scheltema, R.A. and R.V. Truitt. 1954. Ecological factors related to the distribution of *Bankia gouldi* Bartsch in Chesapeake Bay. Ches. Biol. Lab. (Sol. Is., Md.), Publ. 100. In Clapp and Kenk.

Turner, R. 1966. A Survey and Illustrated Catalog of the Teredinidae (Mollusca: Bivalvia). Mus. Comp. Zool., Harvard Univ., Cambridge, Mass. 265 pp.

Turner, R.D. 1973. Report on Marine Borers (Teredinidae) in Oyster Creek, Waretown, New Jersey. Mus. Comp. Zool., Harvard University, Cambridge, Mass. First Report April 3, 1973.

Turner, R.D. 1975. Bivalve Life History, Larval Behavior, Dispersal and Identification. (Unpublished). Seminar, W.F. Clapp Labs., Duxbury, Mass. December, 1975.

Woodward-Envicon. 1974. The physical behavior of the thermal plume discharge from the Oyster Creek Nuclear Generating Station - Results of the 1974 thermal plume measurements.

Vrolik, W. et al. 1860. Report on the shipworm. Amsterdam: Natuurkundige Afdeeling der Koninklijke Akademie van Wetenschappen, 1860. In Clapp and Kenk.

APPENDIX A

APPENDIX A

EXPOSURE PANELS

Introduction

Continuous operation of exposure panels maintained on a perpetuating exposure cycle provide invaluable data on marine borers and fouling organisms, particularly in the assessment of environmental changes. The use of long-term and short-term panels provides data on the incidence and distribution of individual species, their survival and extent of growth, the breeding seasons and amount of destruction to the substrate as well as seasonal variations. The data thus obtained increase in value the longer continuous monitoring takes place.

The Jersey Central Power & Light Company requested Battelle's William F. Clapp Laboratories to investigate the occurrence of marine borers in Barnegat Bay, New Jersey, in order to determine whether the resident marine borer population in Oyster Creek is contributing significantly to the marine borer-caused damage in the Barnegat Bay system.

This phase of the study addresses the results obtained for the 18-month period June, 1976 to December, 1977 from wood panels maintained on continuous long-term (6-month) and short-term (1-month) exposure cycles.

Materials and Methods

Procedures

Exposure panel arrays are maintained in the Barnegat Bay system at eighteen exposure sites (Figure A-1 and Table A-1). The sites (stations) were selected to include locations that were representative of geographical differences in Barnegat Bay, and included areas within and beyond the influence of the Oyster Creek thermal plume (Woodward-Envicon, 1974). The panel arrays were placed near existing structures, i.e., docks and bulkheads, to permit assessment of potential borer damage. All panel stations are accessible by land.

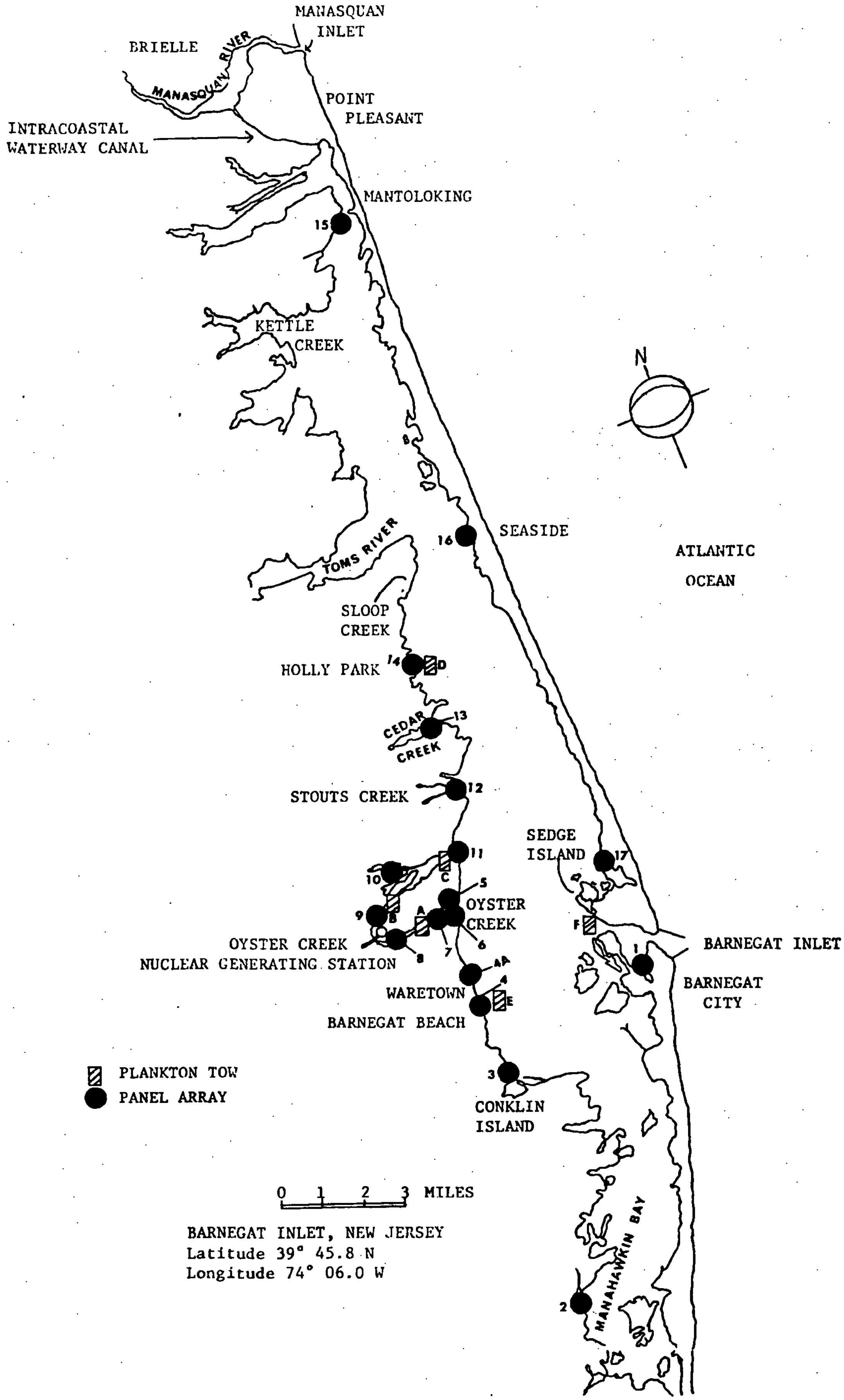


FIGURE A-1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHICAL LOCATIONS OF EXPOSURE PANELS AND PLANKTON TOWS

TABLE A-1. GEOGRAPHICAL LOCATIONS OF WILLIAM F. CLAPP LABORATORIES' EXPOSURE PANEL ARRAYS SUBMERGED JUNE, 1975, BARNEGAT BAY, NEW JERSEY

Site No.	Site	Structure to be used for suspension of rack	Nearest previous data stations	Approximate latitude and longitude
1.	Barnegat Coast Guard Station Barnegat Inlet	Finger Pier	WC 1 WFCL 1948-1967	Lat. 39° 45.8'N Long. 74° 06.5'W
2.	Ashton Marina 1450 Bay Ave. Manahawkin, N.J.	Bulkhead	WC 13,14	Lat. 39° 40'N Long. 74° 13'W
3.	Iggie's Marina East Bay Ave. Barnegat, N.J. (Conklin Island)	Bulkhead	WC 16,17,18,19	Lat. 39° 45'N Long. 74° 12.5'W
4.	Liberty Harbor Marina Washington Ave. Waretown, N.J.	Bulkhead	WC 21 R. Turner Rutgers U.	Lat. 39° 47'N Long. 74° 11'W
5.	Mouth of Oyster Creek, Lot 4, Compass Road Offshore End	Dock	WC 29,30 Rutgers U.	Lat. 39° 48.5'N Long. 74° 10.3'W
6.	Oyster Creek #1 Lagoon, Inshore End 37 Capstan Drive	Dock		Lat. 39° 48.5'N Long.74° 10.35'W
7.	Private Dock Dock Ave. Oyster Creek Sands Pt. Harbor Waretown, N.J.	End of Dock	WC 27,28 R. Turner Rutgers U.	Lat. 39° 48.5'N Long. 74° 11.1'W

TABLE A-1. (continued)

Site No.	Site	Structure to be used for suspension of rack	Nearest previous data stations	Approximate latitude and longitude
8.	Oyster Creek-R.R. Bridge Discharge Canal	Cross Member Bridge	WC 26 Rutgers U.	Lat. 39° 48.7'N Long. 74° 12'W
9.	Forked River South Branch Intake Canal	Cross Member R.R. Bridge	WC 31 Rutgers U.	Lat. 39° 49.2'N Long. 74° 12.2'W
10.	Teds Marina Bay Ave. Forked River	Pier	WC 33,34	Lat. 39° 50.1'N Long. 74° 11.6'W
11.	Forked River (near mouth) 1413 River View Drive	Bulkhead	WC 35 Rutgers U.	Lat. 39° 49.7'N Long. 74° 10'W
12.	Stouts Creek 1273 Capstan Drive	Bulkhead	WC 38,40,41 R. Turner Wurtz Rutgers U.	Lat. 39° 50.5'N Long. 74° 08.8'W
13.	Rocknak's Yacht Basin Seaview Ave. Lanoka Harbor Cedar Creek, N.J.	End of Pier	WC 46	Lat. 39° 52'N Long. 74° 09'W
14.	Dicks Landing Island Drive Bayville, N.J. (Holly Park)	Pier	WC 49 R. Turner Nelson	Lat. 39° 54'W Long. 74° 08.1'W

TABLE A-1. (continued)

Site No.	Site	Structure to be used for suspension of rack	Nearest previous data stations	Approximate latitude and longitude
15.	Winter Yacht Basin Inc. Rt. 528 Mantoloking Bridge W. Mantoloking, N.J.	Pier	WC 57	Lat. 40° 02.5'N Long. 74° 03.5'W
16.	Berkely Yacht Basin J. Street, Seaside	Pier	WC 60,61	Lat. 39° 55.9'N Long. 74° 04.9'W
17.	Island Beach State Park (Sedge Island)	Pier	WC 68	Lat. 39° 47.1'N Long. 74° 05.9'W
4-A*	Holiday Harbor Marina Lighthouse Drive Waretown, New Jersey	Bulkhead	WC 21 R. Turner Rutgers U.	Lat. 39° 48'N Long. 74° 11'N

All exposure panel racks suspended in a minimum water depth at mean low water of at least three feet. Racks hung with nylon line from existing structures so the bottom panels are close to, but not touching the bottom. Racks at Forked River railroad bridge and Oyster Creek railroad bridge suspended with wire rope.

WC = Woodward-Clyde
WFCL = William F. Clapp Laboratories

* Site 4-A installed April, 1977

The panels are mounted on an iron frame (Figure A-2) which is submerged vertically near the bottom. Each array consists of seven 10-inch by 3.5-inch by 0.75-inch untreated soft pine panels, and two soft pine panels containing a 20-pound treatment of marine grade creosote. The long-term paenls are labelled 1 through 6 and the short-term panels are labelled C.

Each month a long-term and a short-term panel are removed from exposure and replaced with new untreated soft pine panels that have been seasoned for two weeks in seawater passed through a Steroline Aquafine Electronic Liquid Sterilizer (Model PVC 6). The sequence of panel exchange provides six-months exposure for each long-term and one-month exposure for each short-term panel. The creosoted panels are not removed, but are inspected in situ for evidences of *Limnoria tripunctata* attack.

Each month, the panels removed from exposure are immediately wrapped in newspaper dampened with seawater and returned to the laboratory in refrigerator containers.

In the laboratory, the panels are examined macro-and micro-scopically for the presence of marine borers. Size, number, and extent of panel damage are determined. Species identification and notations of sexual conditions are made when possible. The short-term panels also provide data concerning seasonality of larval settlement and extent of growth within a one-month period. The primary reference sources used for species identification are Turner, 1966, 1971; Purushotham, et al., 1971; Clapp, 1923; and Menzies, 1951, 1959.

The ratings used for evaluating the prevalence and destructiveness of marine borers are shown in Table A-2 and Figures A-3 and A-4.

Modifications to Panel Exposures

Vandalism, severe weather conditions, and/or heavy borer attack can cause individual panel loss which, thereby, affects length of exposure periods. The severe 1976-1977 winter ice conditions

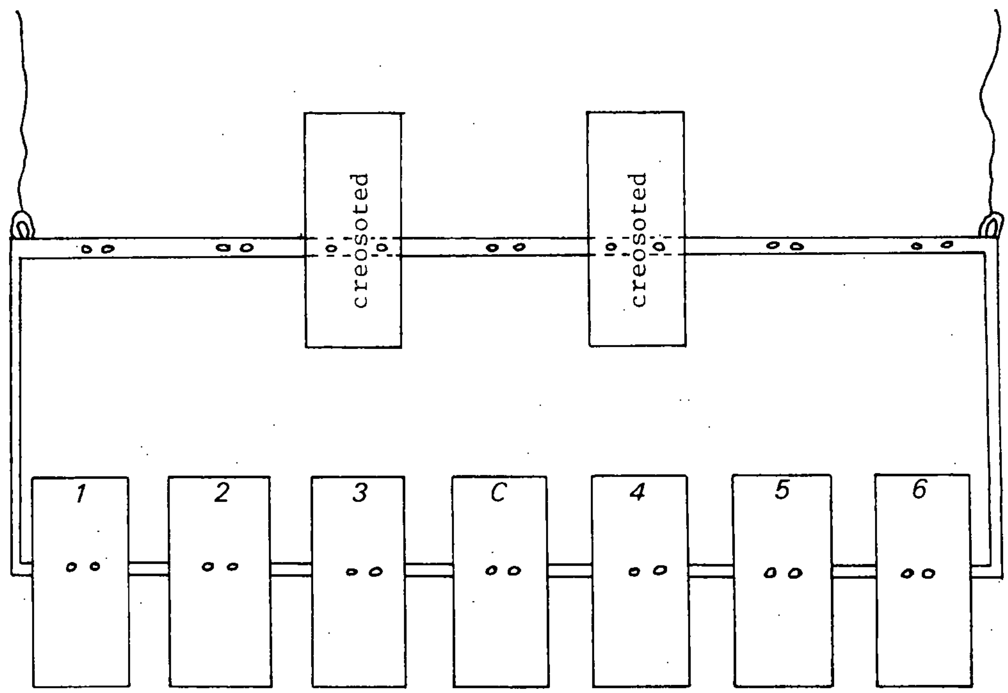


FIGURE A-2. EXPOSURE PANEL ARRAY

TABLE A-2. RATING SCALE FOR TEREDINID AND *Limnoria* ATTACK

Teredinidae

No. of tubes per panels	Percent filled*	Attack Rating
1-5	<5	Trace
6-25	5-10	Slight
26-100	11-25	Moderate
101-250	26-50	Medium heavy
251-400	51-75	Heavy
>400+**	76-100	Very heavy

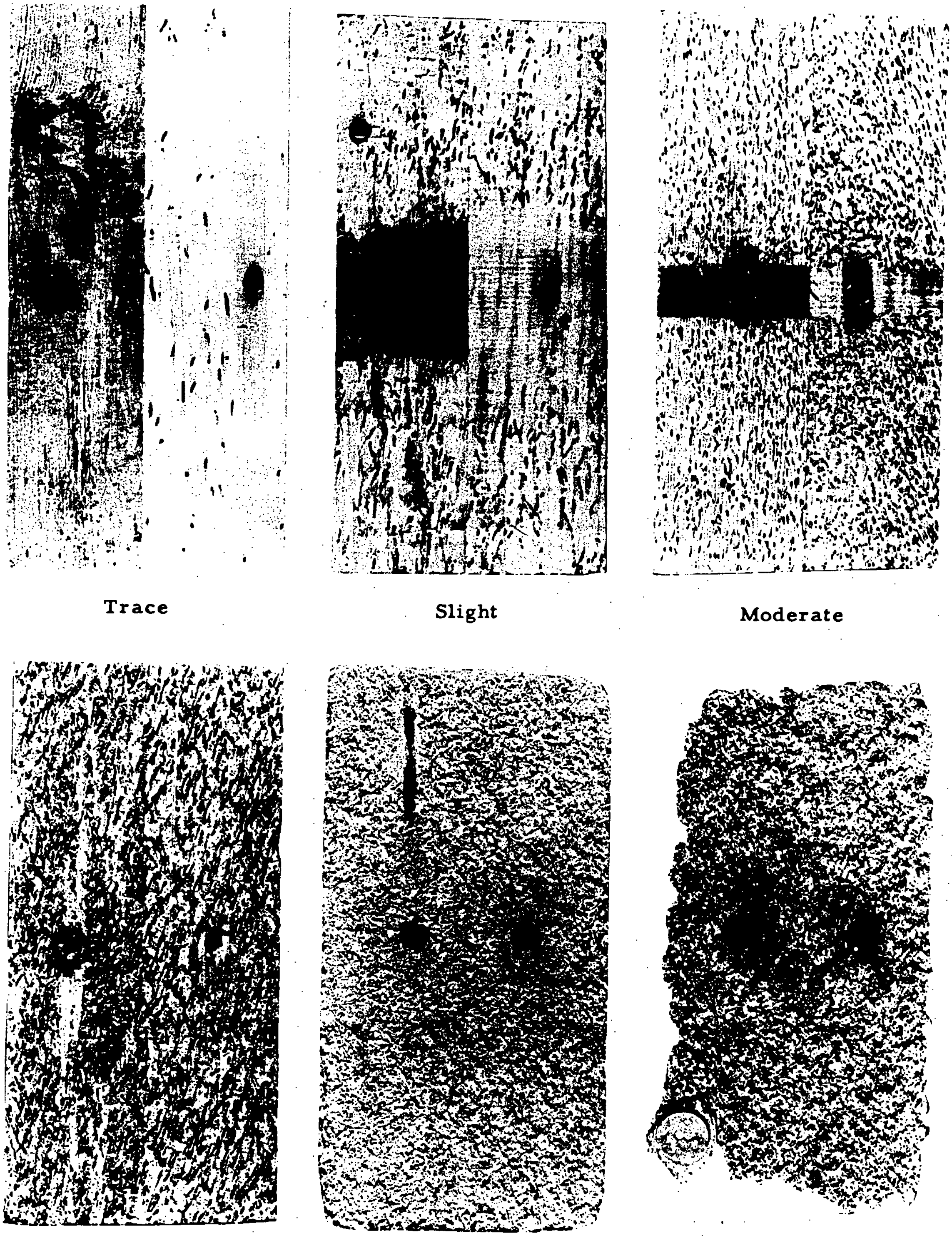
* Percent filled depends upon size of specimens present in panels
** Arbitrary number assigned to panels 76-100 percent filled.

Limnoria

No. of tunnels per sq. inch	Total no. of tunnels	Attack Rating
1	1-85	Trace
10	86-850	Slight
25	851-2125	Moderate
50	2126-4250	Medium heavy
75	4251-6375	Heavy
100*	6375-8500	Very heavy

* Ratings of approximately 100 per square inches indicate the maximum density beyond which it is impossible to count

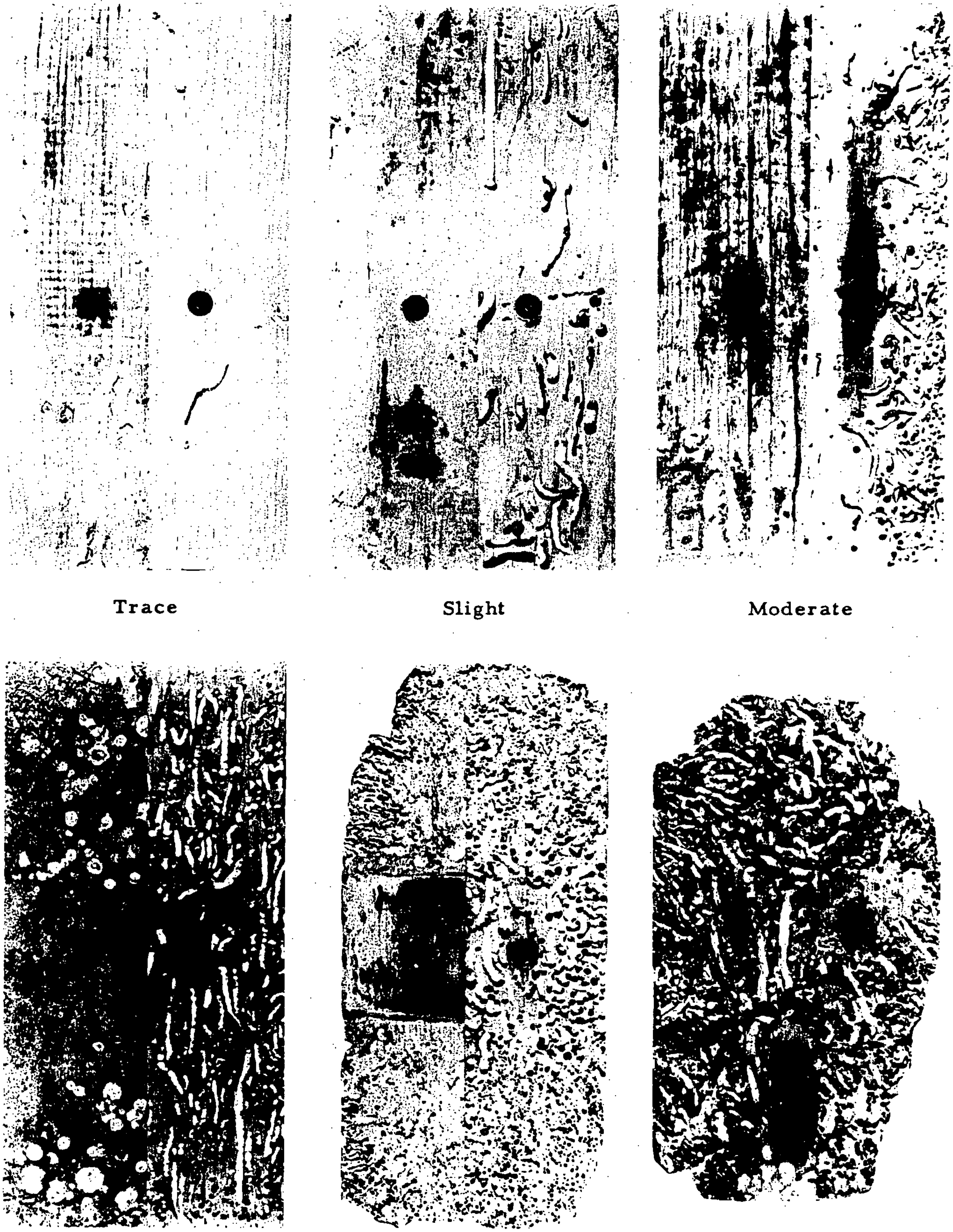
LIMNORIDAE



Trace — Slight — Moderate

Moderately Heavy — Heavy — Very Heavy

FIGURE A-4. RATING OF LIMNORID ATTACK



Trace | Slight | Moderate

Moderately Heavy | Heavy | Very Heavy

FIGURE A-3. RATING OF TEREDINID ATTACK

in Barnegat Bay, for example, resulted in many piers being damaged or destroyed.

In January, 1977 the entire dock at Island Beach (Station 17) was destroyed by ice. The exposure array was retrieved with no loss of panels and resubmerged at an adjacent dock. The array at Station 14 became detached from the dock, but also was retrieved with no loss of panels.

Ice conditions were so severe in January and February, 1977 that retrieval and replacement of panels could not be accomplished at all stations.

On January 18, 1977, panels were obtained and replaced only from exposure sites 5, 7, and 8.

Exposure panels from sites 5, 7, 8, 9, 11, and 13 were obtained on February 8, 1977. Two long-term panels and one short-term panel were retrieved and replaced at sites 9, 11, and 13 in order to maintain the proper monhtly-panel-removal sequence.

During the March removal period, January panels from sites 1 through 4, 6, and 9 through 17, and February panels from sites 1 through 4, 6, 10, 12, and 14 through 17 were also removed and replaced in order to maintain the proper monthly-panel-removal sequence. Notations were entered in all data records concerning changes in length of exposure periods.

No exposure panels were lost from the severe winter ice conditions in the bay, and fortunately no vandalism occurred.

An additional exposure panel array, 4A, was submerged April 8, 1977 at Holiday Harbor Marina, Waretown, New Jersey which is operated in the same sequence as the other locations. This site was selected for its proximity to the mouth of Oyster Creek, and because the pilings at the marina show severe damage from *Limnoria* attack.

In October, 1977 the long-term panel in the first position on the rack at Station 1 was removed 3 months early due to severe

Teredo navalis attack. A replacement panel is scheduled to go in at the regular (January, 1978) removal period thus maintaining the six-month cycle.

A total of eight creosoted panels were lost due to ice or mechanical failure and replaced as follows:

Station 3	-	one panel, May 4, 1977
Station 4	-	one panel, April 5, 1977
Station 6	-	one panel, April 5, 1977
Station 13	-	one panel, April 7, 1977
Station 14	-	two panels, May 5, 1977
Station 14	-	one panel, September 14, 1977
Station 8	-	one panel, September 13, 1977

Statistical Analysis

Wherever applicable the use of statistical analysis was employed using the following methods:

Tukey Statistic. The Tukey statistic is used to compare means of treatment levels once an analysis of variance test has been completed and indicates significant differences. The Tukey procedure is appropriate when multiple pairwise comparisons between treatment means are requested. The procedure uses the studentized range distribution to calculate significant differences. To test whether the difference between the means of two levels of factor A, we use

$$D = \bar{X}_{i.} - \bar{X}_{i.}$$

$$s^2(D) - \frac{2MSE}{bn} = \text{variance of } D$$

and

$$T = \frac{1}{\sqrt{2}}\, q\ (1 - \alpha;\ a,(n-1)ab) = \text{Tukey statistic}$$

where

MSE is the mean square error from the analysis of variance

b is the number of levels of factor B

a is the number of levels of factor A

n is the number of replicates at combination of levels of factors A and B, and

α is the significance level for the test.

This leads to the confidence intervals

$$D-Ts(D) \leq \mu_{i.} - \mu_{i.} \leq D + Ts\ (D)$$

with and overall probability of 1α that all statements in the family are correct. The results are non-significant if the confidence interval includes zero.

Spearman Rank Correlation Coefficient. Spearman's coefficient is a distribution-free test statistic which corresponds to the classical sample correlation coefficient applied to the rankings of the (X,Y) observations within their respective samples. The statistic is given

by $$< = \frac{12 \sum_{i=1}^{n} [R_i - (n+1)/2][S_i - (n+1)/2]}{n\ (n^2 - 1)}$$

where R_i is the rank of X_i in the joint ranking of $X_1,\ldots,X_n$
S_i is the rank of Y_i in the joint rankings of $Y_1,\ldots,Y_n$
n is the number of pairs.

The significance of any r coefficient can be determined by comprising the quantity

$$r\left(\frac{n-2}{1-r^2}\right)1/2$$

with the Student's t distribution with n-2 degrees of freedom.

Kendall Rank Correlation Coefficient. Kendall's coefficient is similar to the Spearmen coefficient except in the application. If the data to be analyzed has a large number of ties in the ranks, the Kendall coefficient is more appropriate. The statistic is given by

$$T = \frac{2 \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \xi(X_i,\ X_j,\ Y_i,\ Y_j)}{n\ (n-1)}$$

where

$$n = \text{number of pairs } (X_i, Y_i)$$

$$\xi(X_i, X_j, Y_i, Y_j) = \begin{cases} 1 \text{ if } & (X_i - X_j)(Y_i - Y_j) > 0 \\ -1 \text{ if } & \quad " \qquad\quad " \quad < 0. \end{cases}$$

The significance of tau is determined by comparison with a normal distribution with a standard deviation of $[(4n+10)/(9n^2-9n)]^{1/2}$.

Factor Analysis

Factor analysis is used as a technique to reduce a large number of factors to a more manageable set. For our data, the principal component method was used with the correlations between stations. Data to be reduced consisted of rates of borer attack for short- and long-term panels and the water quality parameters collected from the beginning of the program by year. The results reduced the data to terms of two factors and provide graphs of the factor values for each station in each year. From the graphs obtained, one can see which stations are most similar in that they are near one another in the plot. Biological explanations can then be used for defining the meanings of the factors and the clusters of stations.

Results

Summary data for the 19-month period, June, 1976, through December, 1977 are presented in Tables A-3 through A-21.

Teredinid Distribution and Dominance

Four species of teredinids were present in wood panels exposed at 17 locations during 1976 and 18 locations in 1977, with the establishment of Station 4A in April, 1977.

Bankia gouldi continued to have the most extensive distribution of the borers found in the Barnegat Bay system. It was present at all locations except Stations 2, 16, and 17. It was the dominant species at all other locations except at Station 1 where *Teredo navalis* was dominant (Table A-22). At Station 7, *B. gouldi* was present from October through December, 1977; for this same time period *Teredo bartschi* was dominant.

TABLE A-3. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED JUNE, 1976

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
1	p	12/2/75	6/8/76	6	0					12	0		
	c	5/6/76	6/8/76	1	0					0			
2	p	12/3/75	6/9/76	6	0					21	29	*L. tripunctata*	4 gravid females
	c	5/4/76	6/9/76	1	0					28	20	17 *L. tripunctata*	3 unidentified
3	p	12/3/75	6/9/76	6	0					9	4	*L. tripunctata*	
	c	5/4/76	6/9/76	1	0					4	7	*L. tripunctata*	3 gravid females
4	p	12/3/75	6/9/76	6	0					16	11	*L. tripunctata*	
	c	5/4/76	6/9/76	1	0					3	0		
5	p	12/3/75	6/9/76	6	0					0	0		
	c	5/4/76	6/9/76	1	0					0	0		
6	p	12/3/75	6/9/76	6	0					0	0		
	c	5/4/76	6/9/76	1	0					0	0		
7	p	12/3/75	6/9/76	6	0					0	0		
	c	5/4/76	6/9/76	1	0					0	0		
8	p	11/3/75	6/9/76	6	0					0	0		
	c	5/5/76	6/9/76	1	0					0	0		
9	p	12/3/75	6/9/76	6	0					0	0		
	c	5/5/76	6/9/76	1	0					0	0		
10	p	12/3/75	6/9/76	6	0					0	0		
	c	5/4/76	6/9/76	1	0					0	0		
11	p	12/3/75	6/9/76	6	0					0	0		
	c	5/4/76	6/9/76	1	0					0	0		

TABLE A-3. (continued)

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
12	p	12/3/75	6/10/75	6	0					0	0		
	c	5/4/76	6/10/76	1	0					0	0		
13	p	12/3/75	6/10/76	6	0					0	0		
	c	5/4/76	6/10/76	1	0					0	0		
14	p	12/3/75	6/10/76	6	0					0	0		
	c	5/4/76	6/10/76	1	0					0	0		
15	p	12/4/75	6/10/76	6	0					0	0		
	c	5/6/76	6/10/76	1	0					0	0		
16	p	12/4/75	6/10/76	6	0					0	0		
	c	5/5/76	6/10/76	1	0					0	0		
17	p	12/4/75	6/10/76	6	0					0	0		
	c	5/5/76	6/10/76	1	0					0	0		

p = long-term panel
c = short-term panel

TABLE A-4. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED JULY, 1976

				Teredinidae						*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
1	p	1/7/76	7/14/76	6	5	<1	1-3			2	4	*L. tripunctata*	**Two** gravid females.
	c	6/8/76	7/14/76	1	33	1	<1-4	*Teredo* spp.*		1	2	*L. tripunctata*	**One** gravid female.
2	p	1/7/76	7/13/76	6	0					550±	350±	61 *L. tripunctata*	
	c	6/9/76	7/13/76	1	1	<1	<1			13	9	2 *L. tripunctata*	
3	p	1/7/76	7/13/76	6	2	<1	<1			410±	362	47 *L. tripunctata*	
	c	6/9/76	7/13/76	1	0					9	10	2 *L. tripunctata*	
4	p	1/7/76	7/13/76	6	1	<1	<1			27	34	13 *L. tripunctata*	
	c	6/9/76	7/13/76	1	2	<1	<1			0	0		
5	p	1/7/76	7/13/76	6	2	<1	<1-5	*B. gouldi*		0	0		
	c	6/9/76	7/13/76	1	2	<1	<1			0	0		
6	p	1/7/76	7/13/76	6	0					0	0		
	c	6/9/76	7/13/76	1	0					0	0		
7	p	2/10/76	7/13/76	5	7	<1	1-7	*B. gouldi*		0	0		
	c	6/9/76	7/13/76	1	1	<1	5	*Bankia* spp.*		0	0		
8	p	1/7/76	7/13/76	6	2	<1	4-6	*Bankia* spp.*		0	0		
	c	6/9/76	7/13/76	1	4	<1	2-5	*Bankia* spp.*		0	0		
9	p	1/7/76	7/13/76	6	0					0	0		
	c	6/9/76	7/13/76	1	0					0	0		
10	p	1/7/76	7/13/76	6	0					0	0		
	c	6/9/76	7/13/76	1	0					0	0		
11	p	1/7/76	7/15/76	6	47	2	1-9	*B. gouldi*		0	0		
	c	6/9/76	7/15/76	1	56	2	1-8	*B. gouldi*		0	0		
12	p	1/7/76	7/13/76	6	0					0	0		
	c	6/10/76	7/13/76	1	0					0	0		

TABLE A-4. Continued

				Teredinidae						*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
13	p	1/7/76	7/13/76	6	3	<1	2-5			0	0		
	c	6/10/76	7/13/76	1	7	<1	1-3			0	0		
14	p	1/7/76	7/13/76	6	6	<1	2-6	*B. gouldi*		0	0		
	c	6/10/76	7/13/76	1	1	<1	3			0	0		
15	p	1/8/76	7/15/76	6	0					0	0		
	c	6/10/76	7/15/76	1	0					0	0		
16	p	1/8/76	7/13/76	6	0					0	0		
	c	6/10/76	7/13/76	1	0					0	0		
17	p	1/8/76	7/13/76	6	0					0	0		
	c	6/10/76	7/13/76	1	0					0	0		

* = *Teredo/Bankia* not identified to species due to size of condition of pallets
p = Long-term panel
c = Short-term panel

TABLE A-5. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED AUGUST, 1976

					Tereinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
1	p	2/10/76	8/12/76	6	151	15	<1-43	*T. navalis*		28	21	*L. tripunctata*	Several gravid females, juveniles.
	c	7/14/76	8/12/76	1	494	5	<1-10	*Teredo* spp.*	majority < 2 mm.	2	2	*L. tripunctata*	
2	p	2/10/76	8/11/76	6	1	<1	17	*T. furcifera*?		1075±	>100	*L. tripunctata*	Several gravid feamles, numerous juveniles.
	c	7/1/376	8/11/76	1	1	<1	9	*Teredo* spp.*		105	117	*L. tripunctata*	Some with two specimens per tunnel. Few gravid females.
3	p	2/10/76	8/11/76	6	0					530±	500±	*L. tripunctata*	Several gravid females, several juveniles.
	c	7/13/76	8/11/76	1	0					0	0		
4	p	2/10/76	8/11/76	6	2	1	12-24	*B. gouldi*		14	11	*L. tripunctata*	Two gravid females, several juveniles.
	c	7/13/76	8/11/76	1	0					2	3		One gravid female.
5	p	2/10/76	8/11/76	6	2	3	35-60	*B. gouldi*	ripening gonads	0	0		
	c	7/13/76	8/11/76	1	0					0	0		
6	p	2/10/76	8/11/76	6	0					0	0		
	c	7/13/76	8/11/76	1	0					0	0		
7	p	2/10/76	8/11/76	6	4	6	6-115	*B. gouldi*, *Teredo* spp.*	ripening gonads	0	0		
	c	7/13/76	8/11/76	1	0					0	0		
8	p	2/10/76	8/11/76	6	2	7	90-140	*B. gouldi*		0	0		
	c	7/13/76	8/11/76	1	0					0	0		
9	p	2/10/76	8/11/76	6	1	1	35	*B. gouldi*		0	0		
	c	7/13/76	8/11/76	1	0					0	0		
10	p	2/10/76	8/11/76	6	0					0	0		
	c	7/13/76	8/11/76	1	0					0	0		
11	p	2/10/76	8/11/76	6	28	7	<1-20	*B. gouldi*	Larger specimens dead	0	0		
	c	7/15/76	8/11/76	1	0					0	0		
12	p	2/10/76	8/11/76	6	2	2	37-43	*B. gouldi*		0	0		
	c	7/13/76	8/11/76	1	0					0	0		

TABLE A-5. Continued

				Teredinidae						*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
13	p	2/10/76	8/11/76	6	29	25	4-120	*B. gouldi*	ripening gonads	0	0		
	c	7/13/76	8/11/76	1	1	<1	8	*B. gouldi*		0	0		
14	p	2/10/76	8/11/76	6	7	8	10-80	*B. gouldi*		0	0		
	c	7/13/76	8/11/76	1	19	2	1-15	*B. gouldi*		0	0		
15	p	2/13/76	8/12/76	6	3	4	40-65	*B. gouldi*		0	0		
	c	7/15/76	8/12/76	1	0					0	0		
16	p	2/10/76	8/11/76	6	0					0	0		
	c	7/13/76	8/11/76	1	0					0	0		
17	p	2/10/76	8/11/76	6	0					0	0		
	c	7/13/76	8/11/76	1	0					0	0		

* = Teredo not identified to species due to size or condition of pallets
p = Long-term panel
c = Short-term panel

TABLE A-6. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED SEPTEMBER, 1976

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
1	p	3/9/76	9/15/76	6	450	95	8-90	*T. navalis*	Ripe gonads, larvae pres.	80	32	*L. tripunctata*	
	c	8/12/76	9/15/76	1	560	10	<1-19	*T. navalis*		5	2	*L. tripunctata*	
2	p	3/9/76	9/14/76	6	0					600	100±	*L. tripunctata*	Sev. juvs.
	c	8/11/76	9/14/76	1	0					27	10	*L. tripunctata*	
3	p	3/9/76	9/14/76	6	0					670	60±	*L. tripunctata*	Sev. juvs.
	c	8/11/76	9/14/76	1	0					4	0		
4	p	3/9/76	9/14/76	6	3	8	80-92	*B. gouldi*		17	8	*L. tripunctata*	
	c	8/11/76	9/14/76	1	0					0	0		
5	p	3/9/76	9/14/76	6	1	6	220	*B. gouldi*		0	0		
	c	8/11/76	9/14/76	1	0					0	0		
6	p	3/9/76	9/14/76	6	2	7	120-142	*B. gouldi*		0	0		
	c	8/11/76	9/14/76	1	0					0	0		
7	p	3/9/76	9/14/76	6	3	15	110-230	2 *B. gouldi*, 1 *T. furcifera*		0	0		
	c	8/11/76	9/14/76	1	2	<1	9-10	*T.* spp.*		0	0		
8	p	3/10/76	9/14/76	6	4	15	70-150	3 *B. gouldi*, 1 *T. navalis*		0	0		
	c	8/11/76	9/14/76	1	0					0	0		
9	p	3/10/76	9/14/76	6	0					0	0		
	c	8/11/76	9/14/76	1	0					0	0		
10	p	3/9/76	9/14/76	6	1	3	120	*B. gouldi*		0	0		
	c	8/11/76	9/14/76	1	2	<1	1-2			0	0		
11	p	3/9/76	9/14/76	6	111	50	<1-200	*B. gouldi, T. navalis*		0	0		
	c	8/11/76	9/14/76	1	15	3	<1-37	*B. gouldi, T. navalis*		0	0		

TABLE A-6. (continued)

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.+	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
12	p	3/9/76	9/14/76	6	5	20	90–195	*B. gouldi*		0	0		
	c	8/11/76	9/14/76	1	1	<1	1			0	0		
13	p	3/9/76	9/14/76	6	31	75	60–185	*B. gouldi*		0	0		
	c	8/11/76	9/14/76	1	2	<1	<1			0	0		
14	p	3/9/76	9/14/76	6	11	50	85–235	*B. gouldi*		0	0		
	c	8/11/76	9/14/76	1	0					0	0		
15	p	3/12/76	9/17/76	6	8	18	40–160	7 *B. gouldi*, 1 *T. navalis*		0	0		
	c	8/12/76	9/17/76	1	0					0	0		
16	p	3/9/76	9/14/76	6	0					0	0		
	c	8/11/76	9/14/76	1	0					0	0		
17	p	3/9/76	9/14/76	6	1	<1	6	*T.* spp.* (pallets broken)		0	0		
	c	8/11/76	9/14/76	1	0					0	0		

**Teredo/Bankia* not identified to species due to size or condition of pallets.
p = Long-term panels.
c = Short-term panels.
sev. juvs. = several juveniles.

TABLE A-7. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED OCTOBER, 1976

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
1	p	4/6/76	10/12/76	6	480	99	20-105	*T. navalis*		110	51	*L. tripunctata*	Sev. juvs.
	c	9/15/76	10/12/76	1	2	<1	1			4	3	*L. tripunctata*	
2	p	4/6/76	10/13/76	6	0					780	520	*L. tripunctata*	Few gravid females, numerous juvs.
	c	9/14/76	10/13/76	1	0					1	0		
3	p	4/6/76	10/13/76	6	0					530	135	*L. tripunctata*	Sev. juvs.
	c	9/14/76	10/13/76	1	0					0	0		
4	p	4/6/76	10/13/76	6	3	4	3-110	*B. gouldi*, *B.* spp.*, *T. navalis*		41	18	*L. tripunctata*	Sev. juvs.
	c	9/14/76	10/13/76	1	0					0	0		
5	p	4/6/76	10/12/76	6	3	30	150-380	*B. gouldi*		0	0		
	c	9/14/76	10/12/76	1	0					0	0		
6	p	4/6/76	10/12/76	6	1	10	330	*B. gouldi*		0	0		
	c	9/14/76	10/12/76	1	0					0	0		
7	p	4/7/76	10/12/76	6	9	50	14-300	*B. gouldi*, *T. navalis*, ? *T.* spp.	Pallets broken, *T.* spp.*	0	0		
	c	9/14/76	10/12/76	1	0					0	0		
8	p	4/7/76	10/13/76	6	1	8	280	*B. gouldi*		0	0		
	c	9/14/76	10/13/76	1	0					0	0		
9	p	4/7/76	10/13/76	6	2	10	60-275	1 *B. gouldi*, 1 *T.* spp.	Pallets broken, *T.* spp.*	0	0		
	c	9/14/76	10/13/76	1	0					0	0		
10	p	4/6/76	10/13/76	6	1	4	140	*B. gouldi*		0	0		
	c	9/14/76	10/13/76	1	0					0	0		
11	p	4/6/76	10/13/76	6	45	25	6-130	*B. gouldi*, *T. navalis*		0	0		
	c	9/14/76	10/13/76	1	0					0	0		

TABLE A-7. (continued)

					Teredinidae					Limnoria			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
12	p	4/6/76	10/13/76	6	8	50	110-230	*B. gouldi*		0	0		
	c	9/14/76	10/13/76	1	0					0	0		
13	p	4/6/76	10/12/76	6	26	90	65-210	*B. gouldi*		0	0		
	c	9/14/76	10/12/76	1	0					0	0		
14	p	4/6/76	10/13/76	6	19	85	85-230	*B. gouldi*		0	0		
	c	9/14/76	10/13/76	1	0					0	0		
15	p	4/8/76	10/13/76	6	1	4	140	*B. gouldi*		0	0		
	c	9/17/76	10/13/76	1	0					0	0		
16	p	4/7/76	10/13/76	6	0					0	0		
	c	9/14/76	10/13/76	1	0					0	0		
17	p	4/7/76	10/13/76	6	8	10	15-80	*T. navalis*		0	0		
	c	9/14/76	10/13/76	1	0					0	0		

**Bankia/Teredo* not identified to species due to size or condition of pallets.
p = Long-term panel.
c = Short-term panel.
sev. juvs. = several juveniles.

TABLE A-8. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED NOVEMBER, 1976

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
1	p	5/6/76	11/12/76	6	400	100	27-88	*T. navalis*, 1 *B. gouldi*		66	41	*L. tripunctata*	Few juvs.
	c	10/12/76	11/12/76	1	1	<1	<1			0	0		
2	p	5/4/76	11/9/76	6	0					290	210	*L. tripunctata*	Sev. juvs., 2 grav. females
	c	10/13/76	11/9/76	1	0					0	0		
3	p	5/4/76	11/9/76	6	0					195	160	*L. tripunctata*	Sev. juvs.
	c	10/13/76	11/9/76	1	0					0	0		
4	p	5/4/76	11/9/76	6	6	20	5-170	*B. gouldi*, 1 *B.* spp.*		158	94	*L. tripunctata*	1 grav. female, numerous juvs.
	c	10/13/76	11/9/76	1	0					0	0		
5	p	5/4/76	11/9/76	6	4	30	110-300	*B. gouldi*		0	0		
	c	10/12/76	11/9/76	1	0					0	0		
6	p	5/4/76	11/9/76	6	0					0	0		
	c	10/12/76	11/9/76	1	0					0	0		
7	p	5/4/76	11/9/76	6	20	75	10-240	*B. gouldi*, *T. navalis*, *T. bartschi*	Larvae present in 4 *T. bartschi*	0	0		
	c	10/12/76	11/9/76	1	0					0	0		
8	p	5/4/76	11/9/76	6	1	8	250	*B. gouldi*		0	0		
	c	10/13/76	11/9/76	1	0					0	0		
9	p	5/4/76	11/9/76	6	0					0	0		
	c	10/13/76	11/9/76	1	0					0	0		
10	p	5/4/76	11/9/76	6	0					0	0		
	c	10/13/76	11/9/76	1	0					0	0		

TABLE A-8. (continued)

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
11	p	5/4/76	11/9/76	6	65	65	15-165	*B. gouldi, T. navalis, T./B.* spp.		0	0		
	c	10/13/76	11/9/76	1	0					0	0		
12	p	5/4/76	11/9/76	6	10	50	5-210	*B. gouldi, B.* spp.		0	0		
	c	10/13/76	11/9/76	1	0					0	0		
13	p	5/4/76	11/9/76	6	20	85	80-220	*B. gouldi*		0	0		
	c	10/12/76	11/9/76	1	0					0	0		
14	p	5/4/76	11/9/76	6	17	85	100-260	*B. gouldi*		0	0		
	c	10/13/76	11/9/76	1	0					0	0		
15	p	5/6/76	11/9/76	6	2	10	140-200	*B. gouldi*		0	0		
	c	10/13/76	11/9/76	1	0					0	0		
16	p	5/5/76	11/9/76	6	0					0	0		
	c	10/13/76	11/9/76	1	0					0	0		
17	p	5/5/76	11/9/76	6	17	25	30-110	*T. navalis*		0	0		
	c	10/13/76	11/9/76	1	0					0	0		

**Teredo/Bankia* not identified to species due to size or condition of pallets.
p = Long-term panel.
c = Short-term panel.
sev. juvs. = several juveniles.

TABLE A-9. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED DECEMBER, 1976

					Teredinidae					*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	% Filled	Sz. Range in mm.	Species Identification	Remarks	No. of Tunnels	No. of Specimens	Species Identification	Remarks
1	p	6/8/76	12/10/76	6	>400	100	35-95	*T. navalis*		19	7	*L. tripunctata*	
	c	11/12/76	12/10/76	1	0					0	0		
2	p	6/9/76	12/7/76	6	1	<1	24	*T. navalis*	Dead	160	115	*L. tripunctata*	1 gravid; sev. juvs.
	c	11/9/76	12/7/76	1	0					0	0		
3	p	6/9/76	12/7/76	6	0					0	0		
	c	11/9/76	12/7/76	1	0					0	0		
4	p	6/9/76	12/7/76	6	6	15	5-135	*B. gouldi*		0	0		
	c	11/9/76	12/7/76	1	0					0	0		
5	p	6/9/76	12/7/76	6	0					0	0		
	c	11/9/76	12/7/76	1	0					0	0		
6	p	6/9/76	12/7/76	6	1	6	190	*B. gouldi*	Dead	0	0		
	c	11/9/76	12/7/76	1	0					0	0		
7	p	6/9/76	12/7/76	6	4	25	170-280	*B. gouldi* (3) *T. navalis* (1)	1 Dead	0	0		
	c	11/9/76	12/7/76	1	0					0	0		
8	p	6/9/76	12/8/76	6	5	35	145-280	*B. gouldi*		0	0		
	c	11/9/76	12/8/76	1	0					0	0		
9	p	6/9/76	12/8/76	6	0					0	0		
	c	11/9/76	12/8/76	1	0					0	0		
10	p	6/9/76	12/7/76	6	2	10	150-165	*B. gouldi*		0	0		
	c	11/9/76	12/7/76	1	0					0	0		
11	p	6/9/76	12/7/76	6	47	35	8-120	*T. navalis* (11) *B. gouldi* (36)	5 Dead	0	0		
	c	11/9/76	12/7/76	1	0					0	0		

TABLE A-9. (continued)

Site	Panel	Submerged	Removed	Months Exposed	Teredinidae No. of Specs.±	Teredinidae % Filled	Teredinidae Sz. Range in mm.	Teredinidae Species Identification	Teredinidae Remarks	*Limnoria* No. of Tunnels	*Limnoria* No. of Specimens	*Limnoria* Species Identification	*Limnoria* Remarks
12	p	6/10/76	12/7/76	6	7	25	9-230	*B. gouldi*		0	0		
	c	11/9/76	12/7/76	1	0					0	0		
13	p	6/10/76	12/7/76	6	21	85	100-190	*B. gouldi*		0	0		
	c	11/9/76	12/7/76	1	0					0	0		
14	p	6/10/76	12/8/76	6	10	85	120-270	*B. gouldi*		0	0		
	c	11/9/76	12/8/76	1	0					0	0		
15	p	6/10/76	12/7/76	6	4	15	80-180	*T. navalis*(1) *B. gouldi*(4)		0	0		
	c	11/9/76	12/7/76	1	0					0	0		
16	p	6/10/76	12/7/76	6	0					0	0		
	c	11/9/76	12/7/76	1	0					0	0		
17	p	6/10/76	12/7/76	6	22	40	16-150	*T. navalis*		0	0		
	c	11/9/76	12/7/76	1	0					0	0		

p = Long-term panels.
c = Short-term panels
sev. juvs. = several juveniles.

TABLE A-10. SUMMARY DATA FOR INCIDENCE OF TEREDINIDAE IN PANELS REMOVED JANUARY, 1977

Site*	Panel	Submerged	Removed	Months Exposed	No. of Specs. ±	% Filled	Size Range in mm.	Species Identification
5	p	7/13/76	1/18/77	6	0			
	c	12/7/76	1/18/77	1	0			
7	p	7/13/76	1/18/77	6	3	4	<1-100	*B. gouldi*, Teredinidae
	c	12/7/76	1/18/77	1	0			
8	p	7/13/76	1/18/77	6	0			
	c	12/8/76	1/18/77	1	0			

* Sites 1-4, 6, and 9-17 were iced in, panels not removed.
No *Limnoria* were present.

TABLE A-11. SUMMARY DATA FOR INCIDENCE OF TEREDINIDAE IN PANELS REMOVED FEBRUARY, 1977

Site*	Panel	Submerged	Removed	Months Exposed	No. of Specs. ±	% Filled	Size Range in mm.	Species Identification	Remarks
5	p	8/11/76	2/8/77	6	1	2	82	*B. gouldi*	
	c	1/18/77	2/8/77	1	0				
7	p	8/11/76	2/8/77	6	8	5	3-120	*B. gouldi*, *T.* spp. *T. bartschi*	2 Dead
	c	1/18/77	2/8/77	1	0				
8	p	8/11/76	2/8/77	6	0				
	c	1/18/77	2/8/77	1	0				
9	p	7/13/76	2/8/77	7	0				
	p	8/11/76	2/8/77	6	0				
	c	12/8/76	2/8/77	2	0				
11	p	7/15/76	2/8/77	7	60	35	5-120	*B. gouldi*, *T. navalis*, *T. furcifera*	1 Dead
	p	8/11/76	2/8/77	6	43	25	9-120	*B. gouldi*, *T. navalis*, *T. furcifera*	4 Dead
	c	12/7/76	2/8/77	2	0				
13	p	7/13/76	2/8/77	7	5	18	20-240	*B. gouldi*	
	p	8/11/76	2/8/77	6	2	2	13-70	*B. gouldi*	
	c	12/7/76	2/8/77	2	0				

* Sites 1-4, 6, 10, 12, and 14-17 were iced in, panels not removed.
No *Limnoria* were present.

TABLE A-12. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED MARCH, 1977

					Teredinidae				*Limnoria*		
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	Percent Filled	Sz. Range in mm.	Species Identification	No. of Tunnels	No. of Specs.	Species Identification
1	p	7/14/76	3/10/77	8	>400	100	18-70	*T. navalis*	0	0	
	p	8/12/76	3/10/77	7	>400	100	<1-50	*T. navalis*	26	31	*L. tripunctata*
	p	9/15/76	3/10/77	6	7	<1	<1-7	*T. navalis*, *T.* spp.	5	1	*L. tripunctata*
	c	12/10/76	3/10/77	3	0				0	0	
2	p	7/13/76	3/8/77	8	5	2	3-29	*T. navalis*, *T. furcifera*	285	300±	*L. tripunctata*
	p	8/11/76	3/8/77	7	0				53	37	*L. tripunctata*
	p	9/14/76	3/8/77	6	0				1	1	*L. tripunctata*
	c	12/7/76	3/8/77	3	0				0	0	
3	p	7/13/76	3/8/77	8	0				0	0	
	p	8/11/76	3/8/77	7	0				1	0	
	p	9/14/76	3/8/77	6	0				0	0	
	c	12/7/76	3/8/77	3	0				0	0	
4	p	7/13/76	3/8/77	8	0				1	1	*L. tripunctata*
	p	8/11/76	3/8/77	7	3	2	7-70	*B. gouldi*, *T. furcifera*	0	0	
	p	9/14/76	3/8/77	6	0				0	0	
	c	12/7/76	3/8/77	3	0				0	0	
5	p	9/14/76	3/8/77	6	0				0	0	
	c	2/8/77	3/8/77	1	0				0	0	
6	p	7/13/76	3/8/77	8	1	4	130	*B. gouldi* (dead)	0	0	
	p	8/11/76	3/8/77	7	1	4	125	*B. gouldi*	0	0	
	p	9/14/76	3/8/77	6	0				0	0	
	c	12/7/76	3/8/77	3	0				0	0	
7	p	9/14/76	3/8/77	6	0				0	0	
	c	2/8/76	3/8/77	1	0				0	0	
8	p	9/14/76	3/8/77	6	0				0	0	
	c	2/8/77	3/8/77	1	0				0	0	

TABLE A-12. (continued)

					Teredinidae				*Limnoria*		
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.+	Percent Filled	Sz. Range in mm.	Species Identification	No. of Tunnels	No. of Specs.	Species Identification
9	p	9/14/76	3/8/77	6	0				0	0	
	c	2/2/77	3/8/77	1	0				0	0	
10	p	7/13/76	3/10/77	8	0				0	0	
	p	8/11/76	3/10/77	7	0				0	0	
	p	9/14/76	3/10/77	6	0				0	0	
	c	12/7/76	3/10/77	3	0				0	0	
11	p	9/11/76	3/9/77	6	1	<1	2		0	0	
	c	2/10/77	3/9/77	1	0				0	0	
12	p	7/13/76	3/8/77	8	6	8	10-95	*B. gouldi*	0	0	
	p	8/11/76	3/8/77	7	2	2	18-45	*B. gouldi*	0	0	
	p	9/14/76	3/8/77	6	0				0	0	
	c	12/7/76	3/8/77	3	0				0	0	
13	p	9/14/76	3/8/77	6	1	<1	1		0	0	
	c	2/8/77	3/8/77	1	0				0	0	
14	p	7/13/76	3/8/77	8	2	10	165-180	*B. gouldi*	0	0	
	p	8/11/76	3/8/77	7	0				0	0	
	p	9/14/76	3/8/77	6	0				0	0	
	c	12/8/76	3/8/77	3	0				0	0	
15	p	7/15/76	3/10/77	8	0				0	0	
	p	8/12/76	3/10/77	7	0				0	0	
	p	9/17/76	3/10/77	6	0				0	0	
	c	12/7/76	3/10/77	3	0				0	0	
16	p	7/13/76	3/8/77	8	0				0	0	
	p	8/11/76	3/8/77	7	0				0	0	
	p	9/14/76	3/8/77	6	0				0	0	
	c	12/7/76	3/8/77	3	0				0	0	

TABLE A-12. (continued)

Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	Percent Filled	Sz. Range in mm.	Species Identification	No. of Tunnels	No. of Specs.	Species Identification
17	p	7/13/76	3/8/77	8	4	6	22-95	*T. navalis*	0	0	
	p	8/11/76	3/8/77	7	2	3	21-75	*T. navalis*	0	0	
	p	9/14/76	3/8/77	6	0				0	0	
	c	12/7/76	3/8/77	3	0				0	0	

p = Long-term panels
c = Short-term panels

TABLE A-13. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED APRIL, 1977

Site	Panel	Submerged	Removed	Months Exposed	Teredinidae No. of Specs.±	Teredinidae Percent Filled	Teredinidae Sz. Range in mm.
1	p	10/12/76	4/7/77	6	0		
	c	3/10/77	4/7/77	1	0		
2	p	10/13/76	4/5/77	6	0		
	c	3/8/77	4/5/77	1	0		
3	p	10/13/76	4/5/77	6	0		
	c	3/8/77	4/5/77	1	0		
4	p	10/13/76	4/5/77	6	0		
	c	3/8/77	4/5/77	1	0		
5	p	10/12/76	4/5/77	6	0		
	c	3/8/77	4/5/77	1	0		
6	p	10/12/76	4/5/77	6	0		
	c	3/8/77	4/5/77	1	0		
7	p	10/12/76	4/5/77	6	0		
	c	3/8/77	4/5/77	1	0		
8	p	10/13/76	4/5/77	6	0		
	c	3/8/77	4/5/77	1	0		
9	p	10/13/76	4/5/77	6	0		
	c	3/8/77	4/5/77	1	0		
10		Panels not removed - dock under repair.					

TABLE A-13. (continued)

Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	Percent Filled	Sz. Range in mm.
11	p	10/8/76	4/6/77	6	1	< 1	2
	c	3/9/77	4/6/77	1	0		
12	p	10/13/76	4/6/77	6	0		
	c	3/8/77	4/6/77	1	0		
13	p	10/12/76	4/5/77	6	0		
	c	3/8/77	4/5/77	1	0		
14	p	10/13/76	4/7/77	6	0		
	c	3/8/77	4/7/77	1	0		
15	p	10/13/76	4/5/77	6	0		
	c	3/10/77	4/5/77	1	0		
16	p	10/13/76	4/5/77	6	0		
	c	3/8/77	4/5/77	1	0		
17	p	10/13/76	4/5/77	6	0		
	c	3/8/77	4/5/77	1	0		

p = Long-term panel
c = Short-term panel
No *Limnoria* present

TABLE A-14. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED MAY, 1977

Site	Panel	Submerged	Removed	Months Exposed	*Limnoria* Number of Tunnels	*Limnoria* No. of Specs.	*Limnoria* Species Identification
1	p	11/12/76	5/4/77	6	0	0	
	c	4/7/77	5/4/77	1	0	0	
2	p	11/9/76	5/4/77	6	0	0	
	c	4/5/77	5/4/77	1	0	0	
3	p	11/9/76	5/4/77	6	0	0	
	c	4/5/77	5/4/77	1	0	0	
4	p	11/9/76	5/4/77	6	0	0	
	c	4/5/77	5/4/77	1	0	0	
4A	p	4/8/77	5/4/77	1	1	1	*L. tripunctata*
	c	4/8/77	5/4/77	1	0	0	
5	p	11/9/76	5/4/77	6	0	0	
	c	4/5/77	5/4/77	1	0	0	
6	p	11/9/76	5/4/77	6	0	0	
	c	4/5/77	5/4/77	1	0	0	
7	p	11/9/76	5/4/77	6	0	0	
	c	4/5/77	5/4/77	1	0	0	
8	p	11/9/76	5/5/77	6	0	0	
	c	4/5/77	5/5/77	1	0	0	
9	p	11/9/76	5/5/77	6	0	0	
	c	4/5/77	5/5/77	1	0	0	
10	p	10/13/76	5/5/77	7	0	0	
	p	11/9/76	5/5/77	6	0	0	
	c	3/10/76	5/5/77	2	0	0	

TABLE A-14. (continued)

Site	Panel	Submerged	Removed	Months Exposed	*Limnoria* Number of Tunnels	*Limnoria* No. of Specs.	*Limnoria* Species Identification
11	p	11/5/76	5/4/77	6	0	0	
	c	4/6/77	5/4/77	1	0	0	
12	p	11/9/76	5/3/77	6	0	0	
	c	4/6/77	5/3/77	1	0	0	
13	p	11/9/76	5/5/77	6	0	0	
	c	4/5/77	5/5/77	1	0	0	
14	p	11/9/76	5/5/77	6	0	0	
	c	4/7/77	5/5/77	1	0	0	
15	p	11/9/76	5/5/77	6	0	0	
	c	4/5/77	5/5/77	1	0	0	
16	p	11/9/76	5/5/77	6	0	0	
	c	4/5/77	5/5/77	1	0	0	
17	p	11/9/76	5/5/77	6	0	0	
	c	4/5/77	5/5/77	1	0	0	

p = Long-term panel
c = Short-term panel
No teredinids were present

TABLE A-15. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED JUNE, 1977

Site	Panel	Submerged	Removed	Months Exposed	*Limnoria* Number of Tunnels	*Limnoria* No. of Specs.	*Limnoria* Species Identification
1	p	12/10/76	6/7/77	6	1	0	
	c	5/4/77	6/7/77	1	1	0	
2	p	12/7/76	6/6/77	6	13	17	*L. tripunctata*
	c	5/4/77	6/6/77	1	0	0	
3	p	12/7/76	6/6/77	6	0	0	
	c	5/4/77	6/6/77	1	0	0	
4	p	12/7/76	6/6/77	6	28	35	*L. tripunctata*
	c	5/4/77	6/6/77	1	19	24	*L. tripunctata*
4A	p	4/8/77	6/6/77	2	9	7	*L. tripunctata*
	c	5/4/77	6/6/77	1	0	0	
5	p	12/7/76	6/6/77	6	0	0	
	c	5/4/77	6/6/77	1	0	0	
6	p	12/7/76	6/6/77	6	0	0	
	c	5/4/77	6/6/77	1	0	0	
7	p	12/7/76	6/6/77	6	0	0	
	c	5/4/77	6/6/77	1	0	0	
8	p	12/8/76	6/6/77	6	0	0	
	c	5/5/77	6/6/77	1	0	0	
9	p	12/8/76	6/6/77	6	0	0	
	c	5/5/77	6/6/77	1	0	0	
10	p	12/7/76	6/6/77	6	0	0	
	c	5/5/77	6/6/77	1	0	0	

TABLE A-15. (continued)

Site	Panel	Submerged	Removed	Months Exposed	*Limnoria* Number of Tunnels	*Limnoria* No. of Specs.	*Limnoria* Species Identification
11	p	12/7/76	6/6/77	6	0	0	
	c	5/5/77	6/6/77	1	0	0	
12	p	12/7/76	6/7/77	6	0	0	
	c	5/3/77	6/7/77	1	0	0	
13	p	12/7/76	6/6/77	6	0	0	
	c	5/5/77	6/6/77	1	0	0	
14	p	12/8/76	6/7/77	6	0	0	
	c	5/5/77	6/7/77	1	0	0	
15	p	12/7/76	6/6/77	6	0	0	
	c	5/5/77	6/6/77	1	0	0	
16	p	12/7/76	6/6/77	6	0	0	
	c	5/5/77	6/6/77	1	0	0	
17	p	12/7/76	6/6/77	6	0	0	
	c	5/5/77	6/6/77	1	0	0	

p = Long-term panel
c = Short-term panel
No teredinids were present

TABLE A-16. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED JULY, 1977

					Teredinidae				*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	Percent Filled	Sz. Range in mm.	Species Identification	No. of Tunnels	No. of Specs.	Species Identification	Remarks
1	p	3/10/77	7/13/77	4	0				28	21	*L. tripunctata*	Few gravid, juveniles.
	c	6/7/77	7/13/77	1	0				4	6	*L. tripunctata*	2 gravid.
2	p	3/8/77	7/12/77	4	0				85	98	*L. tripunctata*	Several gravid, juveniles.
	c	6/6/77	7/12/77	1	0				0	0		
3	p	3/8/77	7/12/77	4	0				0	0		
	c	6/6/77	7/12/77	1	0				0	0		
4	p	3/8/77	7/12/77	4	0				530±	500±	*L. tripunctata*	Numerous gravid, juveniles.
	c	6/6/77	7/12/77	1	1	<1	2 mm.	*Bankia* spp.	4	5	*L. tripunctata*	
4A	p	4/8/77	7/12/77	3	0				118	132	*L. tripunctata*	Several gravid, juveniles.
	c	6/6/77	7/12/77	1	0				13	11	*L. tripunctata*	Juveniles.
5	p	1/8/77	7/12/77	6	0				0	0		
	c	6/6/77	7/12/77	1	0				0	0		
6	p	3/8/77	7/12/77	4	0				0	0		
	c	6/6/77	7/12/77	1	0				0	0		
7	p	1/18/77	7/12/77	6	6	<1	<1-13	1 *Teredo* spp.	0	0		
	c	6/6/77	7/12/77	1	5	<1	<1		0	0		
8	p	1/18/77	7/12/77	6	0				0	0		
	c	6/6/77	7/12/77	1	0				0	0		
9	p	2/8/77	7/12/77	5	0				0	0		
	c	6/6/77	7/12/77	1	0				0	0		
10	p	3/10/77	7/12/77	4	0				0	0		
	c	6/6/77	7/12/77	1	0				0	0		
11	p	2/8/77	7/12/77	5	3	<1	<1		0	0		
	c	6/6/77	7/12/77	1	9	<1	<1-2	2 *Teredo* spp.	0	0		

TABLE A-16. (continued)

Site	Panel	Submerged	Removed	Months Exposed	Teredinidae: No. of Specs.±	Teredinidae: Percent Filled	Teredinidae: Sz. Range in mm.	Teredinidae: Species Identification	*Limnoria*: No. of Tunnels	*Limnoria*: No. of Specs.	*Limnoria*: Species Identification
12	p	3/8/77	7/13/77	4	1	<1	<1		0	0	
	c	6/7/77	7/13/77	1	4	<1	<1		0	0	
13	p	2/8/77	7/13/77	5	12	<1	<1-2	*Teredo* spp.	0	0	
	c	6/6/77	7/13/77	1	7	<1	<1-2		0	0	
14	p	3/8/77	7/13/77	4	1	<1	12	pallets broken-*Teredo* spp.	0	0	
	c	6/7/77	7/13/77	1	2	<1	<1		0	0	
15	p	3/10/77	7/12/77	4	0				0	0	
	c	6/6/77	7/12/77	1	0				0	0	
16	p	3/8/77	7/12/77	4	0				0	0	
	c	6/6/77	7/12/77	1	0				0	0	
17	p	3/8/77	7/12/77	4	0				0	0	
	c	6/6/77	7/12/77	1	2	<1	<1		0	0	

p = Long-term panel
c = Short-term panel

TABLE A-17. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED AUGUST, 1977

					Teredinidae				*Limnoria*			
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	Percent Filled	Sz. Range in mm.	Species Identification	No. of Tunnels	No. of Specs.	Species Identification	Remarks
1	p	3/10/77	8/10/77	5	107	1	<1-2		67	98	*L. tripunctata*	Several gravid and juveniles.
	c	7/13/77	8/10/77	1	265	2	<1-3	*Teredo* spp.	21	32	*L. tripunctata*	Several gravid.
2	p	3/8/77	8/9/77	5	0				115	70±	*L. tripunctata*	Several gravid and juveniles.
	c	7/12/77	8/9/77	1	0				6	7	*L. tripunctata*	Several gravid and juveniles.
3	p	3/8/77	8/9/77	5	0				127	153	*L. tripunctata*	Several gravid and juveniles.
	c	7/12/77	8/9/77	1	0				0	0		
4	p	3/8/77	8/9/77	5	1	<1	18	*Bankia gouldi*	1900	2150	*L. tripunctata*	Many gravid and juveniles.
	c	7/12/77	8/9/77	1	2	<1	1-2		11	7	*L. tripunctata*	
4A	p	4/8/77	8/9/77	4	0				480	550	*L. tripunctata*	
	c	7/12/77	8/9/77	1	0				11	9	*L. tripunctata*	
5	p	2/8/77	8/9/77	6	4	<1	<1-9	1 *Bankia gouldi*	0	0		
	c	7/12/77	8/9/77	1	3	<1	1-5	2 *Bankia gouldi*	0	0		
6	p	3/8/77	8/9/77	5	0				0	0		
	c	7/12/77	8/9/77	1	0				0	0		
7	p	2/8/77	8/9/77	6	16	3	<1-43	*Bankia gouldi*	0	0		
	c	7/12/77	8/9/77	1	4	<1	<1-6	*Bankia gouldi*				
8	p	2/8/77	8/9/77	6	0				0	0		
	c	7/12/77	8/9/77	1	0				0	0		
9	p	2/8/77	8/9/77	6	0				0	0		
	c	7/12/77	8/9/77	1	1	<1	4	*Bankia gouldi*	0	0		
10	p	3/10/77	8/9/77	5	1	<1	3	*Bankia gouldi*	0	0		
	c	7/12/77	8/9/77	1	0				0	0		
11	p	2/8/77	8/9/77	6	29	15	<1-65	*B. gouldi*, *Teredo* spp.	0	0		
	c	7/12/77	8/9/77	1	19	1	<1-10	*Bankia gouldi*	0	0		

TABLE A-17. (continued)

Site	Panel	Submerged	Removed	Months Exposed	Teredinidae No. of Specs.±	Teredinidae Percent Filled	Teredinidae Sz. Range in mm.	Teredinidae Species Identification	*Limnoria* No. of Tunnels	*Limnoria* No. of Specs.	*Limnoria* Species Identification
12	p	3/8/77	8/9/77	5	1	<1	23	*Bankia gouldi*	0	0	
	c	7/13/77	8/9/77	1	1	<1	<1		0	0	
13	p	2/8/77	8/9/77	6	5	3	5-44	*Bankia gouldi*	0	0	
	c	7/13/77	8/9/77	1	2	<1	2-3	*B. gouldi, Bankia* spp.	0	0	
14	p	3/8/77	8/9/77	5	1	<1	30	*Bankia gouldi*	0	0	
	c	7/13/77	8/9/77	1	3	<1	1-12		0	0	
15	p	3/10/77	8/11/77	5	1	<1	4		0	0	
	c	7/12/77	8/11/77	1	0				0	0	
16	p	3/8/77	8/9/77	5	0				0	0	
	c	7/12/77	8/9/77		0				0	0	
17	p	3/8/77	8/9/77	5	0				0	0	
	c	7/12/77	8/9/77	1	1	<1	<1		0	0	

p = Long-term panel
c = Short-term panel

TABLE A-18. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED SEPTEMBER, 1977

					Teredinidae				*Limnoria*		
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	Percent Filled	Sz. Range in mm.	Species Identification	No. of Tunnels	No. of Specs.	Species Identification
1	p	3/10/77	9/14/77	6	320	75%	<1-83	*T. navalis**	230	200	*L. tripunctata*
	c	8/10/77	9/14/77	1	0				0	0	
2	p	3/8/77	9/13/77	6	0				45	31	*L. tripunctata*
	c	8/9/77	9/13/77	1	0				1	0	
3	p	3/8/77	9/13/77	6	0				95	34	*L. tripunctata****
	c	8/9/77	9/13/77	1	0				0	0	
4	p	3/8/77	9/13/77	6	2	4%	55-60	*B. gouldi*	130	85	*L. tripunctata****
	c	8/9/77	9/13/77	1	0				1	1	*L. tripunctata*
4-A	p	4/8/77	9/13/77	6	1	4%	120	*B. gouldi*	875	650	*L. tripunctata*****
	c	8/9/77	9/13/77	1	0				47	44	*L. tripunctata*
5	p	3/8/77	9/13/77	6	6	10%	30-98		0	0	
	c	8/9/77	9/13/77	1	0				0	0	
6	p	3/8/77	9/13/77	6	0				0	0	
	c	8/9/77	9/13/77	1	0				0	0	
7	p	3/8/77	9/13/77	6	10	10%	<1-200	*B. gouldi; T. bartschi***	0	0	
	c	8/9/77	9/13/77	1	147	10%	<1-40	*T. bartschi*	0	0	
8	p	3/8/77	9/13/77	6	1	3%	100		0	0	
	c	8/9/77	9/13/77	1	0				0	0	
9	p	3/8/77	9/13/77	6	0				0	0	
	c	8/9/77	9/13/77	1	0				0	0	
10	p	3/10/77	9/13/77	6	1	<1%	17		0	0	
	c	8/9/77	9/13/77	1	0				0	0	

TABLE A-18. (continued)

Site	Panel	Submerged	Removed	Months Exposed	Teredinidae: No. of Specs.+	Teredinidae: Percent Filled	Teredinidae: Sz. Range in mm.	Teredinidae: Species Identification	*Limnoria*: No. of Tunnels	*Limnoria*: No. of Specs.	*Limnoria*: Species Identification
11	p	3/8/77	9/13/77	6	89	75%	15-155	*B. gouldi*	0	0	
	c	8/9/77	9/13/77	1	0				0	0	
12	p	3/8/77	9/14/77	6	3	7%	23-95	*B. gouldi*	0	0	
	c	8/9/77	9/14/77	1	0				0	0	
13	p	3/8/77	9/13/77	6	13	35%	8-150	*B. gouldi*	0	0	
	c	8/9/77	9/13/77	1	0				0	0	
14	p	3/8/77	9/14/77	6	7	18%	<1-145	*B. gouldi; T. navalis*	0	0	
	c	8/9/77	9/14/77	1	3	2%	5-38	*B. gouldi*	0	0	
15	p	3/10/77	9/13/77	6	1	1%	43	*T. navalis*	0	0	
	c	8/11/77	9/13/77	1	0				0	0	
16	p	3/10/77	9/13/77	6	0				0	0	
	c	8/9/77	9/13/77	1	0				0	0	
17	p	3/8/77	9/13/77	6	1	<1%	1		0	0	
	c	8/9/77	9/13/77	1	0				0	0	

* Straight hinge larvae
** Umbonate larvae
*** Several juveniles
**** Numerous juveniles

TABLE A-19. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED OCTOBER, 1977

					Teredinidae				*Limnoria*		
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	Percent Filled	Sz. Range in mm.	Species Identification	No. of Tunnels	No. of Specs.	Species Identification
1	p	4/7/77	10/12/77	6	340	90%	<1-130	*T. navalis*	210	140	*L. tripunctata***
	c	9/14/77	10/12/77	1	108	1%	<1-2		1	1	*L. tripunctata*
2	p	4/5/77	10/11/77	6	1	<1%	23	*T. navalis*	128	105	*L. tripunctata***
	c	9/13/77	10/11/77	1	0				0	0	
3	p	4/5/77	10/11/77	6	1	2%	70		2	0	
	c	9/13/77	10/11/77	1	0				0	0	
4	p	4/5/77	10/11/77	6	1	<1%	<1		65	58	*L. tripunctata****
	c	9/13/77	10/11/77	1	0				0	0	
4-A	p	4/8/77	10/11/77	6	3	15%	155-170	*B. gouldi*	1400	900	*L. tripunctata****
	c	9/13/77	10/11/77	1	0				0	0	
5	p	4/5/77	10/11/77	6	4	15%	<1-185		0	0	
	c	9/13/77	10/11/77	1	1	<1%	<1		0	0	
6	p	4/5/77	10/11/77	6	0				0	0	
	c	9/13/77	10/11/77	1	1	<1%	1		0	0	
7	p	4/5/77	10/11/77	6	95	40%	<1-230	*B. gouldi; T. bartschi**	0	0	
	c	9/13/77	10/11/77	1	82	3%	<1-9	*T. bartschi*	0	0	
8	p	4/5/77	10/11/77	6	0				0	0	
	c	9/13/77	10/11/77	1	0				0	0	
9	p	4/5/77	10/11/77	6	0				0	0	
	c	9/13/77	10/11/77	1	0				0	0	
10	p	5/5/77	10/11/77	5	2	9%	100-225		0	0	
	c	9/13/77	10/11/77	1	0				0	0	

TABLE A-19. (continued)

Site	Panel	Submerged	Removed	Months Exposed	Teredinidae: No. of Specs.±	Teredinidae: Percent Filled	Teredinidae: Sz. Range in mm.	Teredinidae: Species Identification	*Limnoria*: No. of Tunnels	*Limnoria*: No. of Specs.	*Limnoria*: Species Identification
11	p	4/6/77	10/11/77	6	60	85%	45-210		0	0	
	c	9/13/77	10/11/77	1	0				0	0	
12	p	4/6/77	10/12/77	6	7	20%	30-150	*B. gouldi*	0	0	
	c	9/14/77	10/12/77	1	0				0	0	
13	p	4/5/77	10/11/77	6	10	50%	75-220	*B. gouldi*	0	0	
	c	9/13/77	10/11/77	1	0				0	0	
14	p	4/7/77	10/12/77	6	13	50%	<1-245	*B. gouldi; T. navalis*	0	0	
	c	9/14/77	10/12/77	1	0				0	0	
15	p	4/5/77	10/11/77	6	0				0	0	
	c	9/13/77	10/11/77	1	0				0	0	
16	p	4/5/77	10/11/77	6	0				0	0	
	c	9/9/77	10/11/77	1	0				0	0	
17	p	4/5/77	10/11/77	6	0				0	0	
	c	9/13/77	10/11/77	1	0				0	0	

* Umbonate larvae
** Several juveniles
*** Several gravid; juveniles

TABLE A-20. SUMMARY DATA FOR INCIDENCE OF MARINE WOODBORER ATTACK FOR PANELS REMOVED NOVEMBER, 1977

					Teredinidae				*Limnoria*		
Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	Percent Filled	Sz. Range in mm.	Species Identification	No. of Tunnels	No. of Specs.	Species Identification
1	p	5/4/77	11/9/77	6	390	99%	15-115	*T. navalis*	140	95	*L. tripunctata***
	c	10/12/77	11/9/77	1	184	1%	<1		0	0	
2	p	5/4/77	11/8/77	6	0				27	0	
	c	10/11/77	11/8/77	1	0				0	0	
3	p	5/4/77	11/8/77	6	0				14	5	*L. tripunctata*
	c	10/11/77	11/8/77	1	0				0	0	
4	p	5/4/77	11/8/77	6	1	5%	165		110	7	*L. tripunctata****
	c	10/11/77	11/8/77	1	0				0	0	
4-A	p	5/4/77	11/8/77	6	0				1300	650	*L. tripunctata*****
	c	10/11/77	11/8/77	1	0				0	0	
5	p	5/4/77	11/8/77	6	8	30%	<1-220		0	0	
	c	10/11/77	11/8/77	1	0				0	0	
6	p	5/4/77	11/8/77	6	0				0	0	
	c	10/11/77	11/8/77	1	0				0	0	
7	p	5/4/77	11/8/77	6	212	90%	<1-210	*B. gouldi; T. bartschi**	0	0	
	c	10/11/77	11/8/77	1	3	<1%	<1		0	0	
8	p	5/4/77	11/9/77	6	0				0	0	
	c	10/11/77	11/9/77	1	0				0	0	
9	p	5/4/77	11/9/77	6	0				0	0	
	c	10/11/77	11/9/77	1	0				0	0	
10	p	5/4/77	11/9/77	6	1	5%	175	*B. gouldi*	0	0	
	c	10/11/77	11/9/77	1	1	0			0	0	

TABLE A-20. (continued)

Site	Panel	Submerged	Removed	Months Exposed	Teredinidae: No. of Specs.+	Teredinidae: Percent Filled	Teredinidae: Sz. Range in mm.	Teredinidae: Species Identification	*Limnoria*: No. of Tunnels	*Limnoria*: No. of Specs.	*Limnoria*: Species Identification
11	p	5/5/77	11/8/77	6	47	98%	17-145	*B. gouldi; T. navalis*	0	0	
	c	10/11/77	11/8/77	1	0	0%			0	0	
12	p	5/3/77	11/9/77	6	7	30%	90-195	*B. gouldi*	0	0	
	c	10/12/77	11/9/77	1					0	0	
13	p	5/5/77	11/8/77	6	8	50%	80-210	*B. gouldi*	0	0	
	c	10/11/77	11/8/77	1	0				0	0	
14	p	5/5/77	11/8/77	6	5	35%	135-280	*B. gouldi*	0	0	
	c	10/12/77	11/8/77	1	0				0	0	
15	p	5/5/77	11/8/77	6	1	3%	120	*T. navalis*	0	0	
	c	10/11/77	11/8/77	1	0				0	0	
16	p	5/5/77	11/8/77	6	0				0	0	
	c	10/11/77	11/8/77	1	0				0	0	
17	p	5/5/77	11/8/77	6	0				0	0	
	c	10/11/77		1	0				0	0	

* Umbonate larvae
** Few gravid, juveniles
*** Several juveniles
**** Many juveniles

TABLE A-21. SUMMARY DATA FOR INCIDENCE OF TEREDINIDAE IN PANELS REMOVED DECEMBER, 1977

Site	Panel	Submerged	Removed	Months Exposed	No. of Specs.±	Percent Filled	Size Range in mm.	Species Identification
1	p	6/7/77	12/6/77	6	380	98	40-140	*T. navalis*
	c	11/9/77	12/6/77	1	0			
2	p	6/6/77	12/6/77	6	0			
	c	11/8/77	12/6/77	1	0			
3	p	6/6/77	12/6/77	6	1	<1	1	
	c	11/8/77	12/6/77	1	0			
4	p	6/6/77	12/6/77	6	0			
	c	11/8/77	12/6/77	1	0			
4A	p	6/6/77	12/6/77	6	1	8	260	*B. gouldi*
	c	11/8/77	12/6/77	1	0			
5	p	6/6/77	12/6/77	6	4	35	105-430	*B. gouldi*
	c	11/8/77	12/6/77	1	0			
6	p	6/6/77	12/6/77	6	1	7	230	*B. gouldi*
	c	11/8/77	12/6/77	1	0			
7	p	6/6/77	12/6/77	6	207	95	4-280	*B. gouldi, T. bartschi*
	c	11/8/77	12/6/77	1	0			
8	p	6/6/77	12/6/77	6	1	8	270	*B. gouldi*
	c	11/9/77	12/6/77	1	0			
9	p	6/6/77	12/6/77	6	1	2	95	*T. navalis*
	c	11/9/77	12/6/77	1	0			
10	p	6/6/77	12/6/77	6	2	15	240-250	*B. gouldi*
	c	11/9/77	12/6/77	1	0			
11	p	6/6/77	12/6/77	6	26	80	75-195	*B. gouldi, T. navalis*
	c	11/8/77	12/6/77	1	0			
12	p	6/7/77	12/6/77	6	7	40	140-230	*B. gouldi*
	c	11/9/77	12/6/77	1	0			
13	p	6/6/77	12/6/77	6	18	90	120-260	*B. gouldi*
	c	11/8/77	12/6/77	1	0			
14	p	6/7/77	12/6/77	6	11	60	2-300	*B. gouldi*
	c	11/8/77	12/6/77	1	0			
15	p	6/6/77	12/7/77	6	0			
	c	11/8/77	12/7/77	1	0			
16	p	6/6/77	12/6/77	6	0			
	c	11/8/77	12/6/77	1	0			
17	p	6/6/77	12/6/77	6	0			
	c	11/8/77	12/6/77	1	0			

p = long-term panel
c = short-term panel

TABLE A-22. DOMINANCE OF SPECIES OF TEREDINIDAE IN LONG-TERM PANELS JULY, 1975, THROUGH DECEMBER, 1977

Location	*Bankia gouldi*	*Teredo navalis*	*Teredo bartschi*	*Teredo furcifera*	*Teredo* spp.*
1	√	√ dominant		√	x√
2	o√ dominant	+√		x√	x√
3	x√ dominant	o√			o√
4	+√ dominant	x√		x√	o√
4A	+√				o
5	+√		o√ dominant		o√
6	+√		o√ dominant		o√
7	+√	x	+ **	x	x√ dominant
8	+√ dominant	x√			o√
9	+√ dominant	x√			x
10	+√ dominant	o√		o√	o√
11	+√ dominant	x√		x√	x√
12	+√ dominant	o√			o√
13	+√ dominant	o√			x√
14	+√ dominant	x			x√
15	+√ dominant	x√ dominant		o√	o√
16	o√ dominant				
17	o√	x√ dominant		o√	x√

* = Specimens too small or too poor condition for speciating
√ = Species present 1975-1976 study period
Dominant = species present 1975-1976 study period
o = Teredinidae not present 1976-1977 study
x = Teredinidae present 1976-1977 study
\+ = Teredinid species dominant 1976-1977 study
** = Present October, dominant November and December, 1977

Teredo navalis was identified at ten locations but was dominant at only Stations 1, 2, and 17. It was not found at Stations 3, 4A, 5, 6, 10, 12, 13, and 16.

A 1976 set of *Teredo furcifera* occurred at Stations 2, 4, 7, and 11 but the species was never dominant. No *T. furcifera* were found in 1977.

Teredo bartschi was found only at Station 7, Oyster Creek, and was the dominant species in November and December, 1977. Previously this species had occurred at Stations 5 and 6 (also in Oyster Creek) in 1975.

Teredo spp. includes those specimens whose taxonomic characters were partially lacking or too small for positive species identification. *Teredo* spp. were found in panels removed from eight stations (Table A-22). *Teredo* spp. was dominant at Station 7 in October, 1977.

Teredinid Reproduction

Ripe gonads in adult *Bankia* were first observed in August, 1976. This agrees with our finding in 1975 (Richards et al., 1976). Reproductively active *Bankia* were present in panels from Stations 5 and 7 in Oyster Creek, and Station 13 in Cedar Creek.

In September, 1976 several *Teredo navalis* with ripe gonads and a few containing larvae were present at Station 1, Barnegat Light.

Specimens of *Teredo bartschi* containing umbonate larvae were present at Station 7 in Oyster Creek in November, 1976. No teredinids containing larvae were present at any other location during the 1976 season.

During the 1977 season (through December) teredinids containing larvae were found only in panels from Stations 1 and 7. *Teredo navalis* with ripe gonads or larvae were present in September at Station 1; and *Teredo bartschi* with umbonate larvae were present from September through November at Station 7.

Additional detailed data on teredinid gonad development is presented in Appendix C.

Settlement on Short-term Panels

Successful settlement of teredinid larvae occurred in short-term panels removed from July through November in 1976 and 1977. No settlement took place during December through June in either year (Table A-23). This same pattern was observed in 1975. Similar observations for 1976-77 were made by Hoagland and Turner, (June, 1977).

Settlement was greater in the July, 1976 short-term panels than in 1977. The largest settlement of *Bankia* sp. (56) was in the panel from the mouth of Forked River, Station 11. *Bankia* sp. also was successful at Stations 7 and 8 (1 and 4 entrances). Station 1 had the largest settlement of specimens of *Teredo* (33). Panels from Stations 2, 4, 5, 13, and 14 had from 1 to 17 teredinid entrances but the individuals were not developed enough for generic identification.

A significant increase in settlement was observed in short-term panels removed in August and September, 1976 from Station 1. The majority were large enough for identification and were *Teredo* spp. The short-term panel removed in August, 1976 from Station 14 had 19 *Bankia* sp. successfully settle. One *Bankia* sp was present in the short-term panel from Station 13 and one *Teredo* spp. from Station 2.

One to 15 successful penetrations occurred in the short-term panels removed in September from Stations 7, 10, 11, 12, and 13. *Teredo* spp. were identified at Stations 7 and 11, and *Bankia* sp. at Station 11.

In October and November, 1976 settlement occurred on short-term panels only at Station 1. There was no settlement in short-term panels removed from December, 1976, through June, 1977.

Of the eighteen short-term panels removed in July, 1977, only seven had teredinid entrances, the number of entrances recorded ranging from 1 to 9. *Teredo* spp. was identified at Station 11. Teredinid specimens were also found at Stations 4, 7, 12, 13, 14, and 17.

TABLE A-23. NUMBERS OF TEREDINIDS IN SHORT-TERM PANELS EXPOSED DURING 1976-1977*

		1976						1977									
Site	Submerged Removed	May Jun	Jun Jul	Jul Aug	Aug Sep	Sep Oct	Oct Nov	Jun Jul	Jul Aug	Aug Sep	Sep Oct	Oct Nov	Nov Dec	Total #	% Total	x̄	σ
1		0	33T	494T	560T	2	1	0	265T	97	108	184	0	1744	80.59	174.40	205.41
2		0	1	1T	0	0	0	0	0	0	0	0	0	2	0.09	0.20	0.42
3		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4		0	2	0	0	0	0	1	2	0	0	0	0	5	0.23	0.50	0.85
4A**		–	–	–	–	–	–	0	0	0	0	0	0	0	0	0	0
5		0	2	0	0	0	0	0	3B	0	1	0	0	6	0.28	0.60	1.07
6		0	0	0	0	0	0	0	0	0	1	0	0	1	0.05	0.10	0.32
7		0	1B	0	2T	0	0	5	4B	147Tb	82Tb	3	0	244	11.28	24.40	49.93
8		0	4B	0	0	0	0	0	0	0	0	0	0	4	0.18	0.40	1.26
9		0	0	0	0	0	0	0	1B	0	0	0	0	1	0.05	0.10	0.32
10		0	0	0	2	0	0	0	0	0	0	0	0	2	0.09	0.20	0.63
11		0	56B	0	15T,B	0	0	9T	19B	0	0	0	0	99	4.57	9.90	17.71
12		0	0	0	1	0	0	4	1	0	0	0	0	6	0.28	0.60	1.26
13		0	7	1B	2	0	0	7	2B	0	0	0	0	19	0.88	1.90	2.81
14		0	1	19B	0	0	0	2	3	3B	0	0	0	28	1.29	2.80	5.83
15		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17		0	0	0	0	0	0	2	1	0	0	0	0	3	0.12	0.30	0.67

* = Short-term panels removed from December, 1976, through June, 1977 were free of teredinids
** = Station 4A was not established until April, 1977
T = *Teredo* spp.
B = *Bankia* sp.
Tb = *Teredo bartschi*

The largest settlement on short-term panels removed in August was at Station 1 where 265 *Teredo* spp. were found. One to four *Bankia* sp. were observed in short-term panels from Stations 5, 7, 9, and 13. Nineteen *Bankia* sp. were present at Station 11. Stations 4, 12, 14, and 17 had 1 to 3 teredinid entrances.

In September, 1977 marine borer entrances were recorded at three locations. Station 1 had 97 teredinid entraces, Station 14 had three *Bankia* sp., and the panel from Station 7 had 147 *Teredo bartschi*.

The numbers of teredinids was higher in the panel removed in October, 1977 from Station 1. The number of *Teredo bartschi* at Station 7 dropped to 82. One borer (unidentified) entrance each was found in panels from Stations 5 and 6.

Short-term panels removed in November had teredinid settlement at Stations 1 and 17, while all other stations were free of borer attack.

No settlement in short-term panels occurred in December, 1977.

Destruction to Short-term Panels

The amount of destruction to the short-term panels removed from June, 1976, through December, 1977 is shown in Table A-24.

Only one fourth of all the short-term panels that contained a 1976 teredinid attack had greater than 1 percent destruction. The largest amount of destruction was to panels removed from Station 1 in August and September (5 and 10 percent, respectively). The short-term panel removed from Station 11 in September had sustained 3 percent destruction. Two percent destruction occurred in the July panel from Station 11 and the August panel from Station 14.

Except for a less than one percent destruction to short-term panels removed from Station 1 in October and November, no attack was present in short-term panels at any station from September, 1976, through June, 1977.

TABLE A-24. PERCENT OF SHORT-TERM PANELS FILLED WITH TEREDINIDAE SUBMERGED MAY, 1976 THROUGH OCTOBER, 1977 AND REMOVED SEQUENTIALLY FROM JUNE, 1976 THROUGH DECEMBER, 1977*

Site	Submerged Removed	1976 May Jun	1976 Jun Jul	1976 Jul Aug	1976 Aug Sep	1976 Sep Oct	1976 Oct Nov	1977 Jun Jul	1977 Jul Aug	1977 Aug Sep	1977 Sep Oct	1977 Oct Nov	1977 Nov Dec	$\bar{x}$	σ
1		0	1	5	10	<1	<1	0	2	10	1	1	0	3.2	3.82
2		0	<1	<1	0	0	0	0	0	0	0	0	0	0.2	0.42
3		0	0	0	0	0	0	0	0	0	0	0	0	0	0
4		0	<1	0	0	0	0	<1	<1	0	0	0	0	0.3	0.48
4A**		-	-	-	-	-	-	0	0	0	0	0	0	0	0
5		0	<1	0	0	0	0	0	<1	0	<1	0	0	0.3	0.48
6		0	0	0	0	0	0	0	0	0	<1	0	0	0.1	0.32
7		0	<1	0	<1	0	0	<1	<1	10	3	<1	0	1.8	3.01
8		0	<1	0	0	0	0	0	0	0	0	0	0	0.1	0.32
9		0	0	0	0	0	0	0	<1	0	0	0	0	0.1	0.32
10		0	0	0	<1	0	0	0	0	0	0	0	0	0.1	0.32
11		0	2	0	3	0	0	<1	1	0	0	0	0	0.7	1.06
12		0	0	0	<1	0	0	<1	<1	0	0	0	0	0.3	0.48
13		0	<1	<1	<1	0	0	<1	<1	0	0	0	0	0.5	0.53
14		0	<1	2	0	0	0	<1	<1	2	0	0	0	0.7	0.82
15		0	0	0	0	0	0	0	0	0	0	0	0	0	0
16		0	0	0	0	0	0	0	0	0	0	0	0	0	0
17		0	0	0	0	0	0	<1	<1	0	0	0	0	0.2	0.42

* = Teredinids were not present in short-term panels removed from December, 1976 through June, 1977
** = Station 4A was not established utnil April, 1977

The destruction caused to short-term panels by the 1977 teredinid set was less than one percent in two-thirds of the short-term panels attacked. Seven of 18 short-term panels removed in July had initial teredinid attack but destruction was less than one percent.

Short-term panels removed in August from Station 1 sustained 2 percent destruction and 1 percent destruction at Station 11. Destruction was from 0 to less than 1 percent at all other stations.

The greatest amount of destruction in 1977 to any short-term panel took place in the panels removed in September from Stations 1 and 7. Both panels were 10 percent destroyed. Two percent destruction occurred in the panel removed from Station 14.

Short-term panels removed in October, 1977 showed less than 1 to 1 percent destruction at Stations 1, 5, and 6; and 3 percent destruction at Station 7.

Slight destruction, less than 1 to 1 percent, took place in short-term panels removed in November from Stations 1 and 17. All other stations were free of attack.

Destruction to Long-term Panels

All attack in long-term panels removed from July, 1976, through March, 1977 had to have been caused by the 1976 set of marine borers since there was no settlement on long- or short-term panels submerged after October, 1976 and removed before July, 1977.

Similar conditions prevailed in 1977, so that the data obtained from long-term panels removed July, 1977, through December, 1977 relates to the 1977 marine borer generation.

Table A-25 presents the percent of long-term panels filled with Teredinidae (destruction to panel) in 1976 and 1977. The numbers of teredinids present for these periods are presented in Table A-26.

All long-term panels were exposed for six-months except for the first five removals at the new location at Station 4A, and those panels iced-in in January and February, 1977.

TABLE A-25. PERCENT OF LONG-TERM PANELS FILLED WITH TEREDINIDAE, SUBMERGED DECEMBER, 1975 TO JUNE, 1977 AND REMOVED SEQUENTIALLY JUNE, 1976, THROUGH DECEMBER, 1977*

		1976						1977										
	Submerged	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Jan	Feb	Mar	Apr	May	Jun		
Site	Removed	Jul	Aug	Sep	Oct	Nov	Dec	Jan**	Feb**	Mar	Jul	Aug	Sep	Oct	Nov	Dec	$\bar{x}$	σ
1		<1	15	95	99	100	100	100	100	<1	$0^{(4)}$	$1^{(5)}$	75	90	99	98	64.93	45.47
2		0	<1	0	0	0	<1	2	0	0	$0^{(4)}$	$0^{(5)}$	0	<1	0	0	.33	.62
3		<1	0	0	0	0	0	0	0	0	$0^{(4)}$	$0^{(5)}$	0	2	0	1	.27	.59
4		<1	1	8	4	20	15	0	2	0	$<1^{(4)}$	$<1^{(5)}$	4	<1	5	0	4.20	5.92
4A***		-	-	-	-	-	-	-	-	-	$0^{(3)}$	$0^{(4)}$	4	15	0	8	4.50	6.06
5		<1	3	6	30	30	0	0	2	0	$0^{(6)}$	$<1^{(6)}$	10	15	30	35	10.87	13.44
6		0	0	7	10	0	6	4	4	0	$0^{(4)}$	$0^{(5)}$	0	0	0	7	2.53	3.48
7		<1	6	15	50	75	25	4	5	0	$<1^{(6)}$	$3^{(6)}$	10	40	90	95	28.00	33.94
8		<1	7	15	8	8	35	0	0	0	$0^{(6)}$	$0^{(6)}$	3	0	0	8	5.67	9.33
9		0	1	0	10	0	0	0	0	0	$0^{(5)}$	$0^{(6)}$	0	0	0	2	.87	2.59
10		0	0	3	4	0	10	0	0	0	$0^{(4)}$	$<1^{(5)}$	<1	9	5	15	3.20	4.66
11		2	7	50	25	65	35	35****	25	<1	$<1^{(5)}$	$15^{(6)}$	75	85	98	80	39.93	33.42
12		0	2	20	50	50	25	8	2	0	$<1^{(4)}$	$<1^{(5)}$	7	20	30	40	17.07	18.28
13		<1	25	75	90	85	85	18****	2	<1	$<1^{(5)}$	$3^{(6)}$	35	50	50	90	40.73	36.43
14		<1	8	50	85	85	85	10	0	0	$<1^{(4)}$	$<1^{(5)}$	18	50	35	60	32.60	33.86
15		0	4	18	4	10	15	0	0	0	$0^{(4)}$	$<1^{(5)}$	1	0	3	0	3.73	5.87
16		0	0	0	0	0	0	0	0	0	$0^{(4)}$	$0^{(5)}$	0	0	0	0	0	0
17		0	0	<1	10	25	40	6	3	0	$0^{(4)}$	$0^{(5)}$	<1	0	0	0	5.73	11.58

* = From April through June, 1977 there were no teredinids found in the long-term panels at any station
** = Panels removed in March, 1977 because of ice
*** = Station 4A was established in April, 1977
**** = Panels removed in February, 1977
() = The numbers in parenthesis is the number of months the long-term panels were submerged at each of the 18 exposure panel stations

TABLE A-26. NUMBERS OF TEREDINIDS IN LONG-TERM PANELS EXPOSED DURING 1976-1977*

Site	Submerged Removed	Dec Jun	1976 Jan Jul	Feb Aug	Mar Sep	Apr Oct	May Nov	Jun Dec	Jul** Jan	Aug** Feb	Sep Mar	1977 Jan Jul	Feb Aug	Mar Sep	Apr Oct	May Nov	Jun Dec	Total #	% Total	x̄	σ
1		0	5	151	450	480	>400	>400	>400	>400	7	0	107	320	340	390	380	4230	69.17	282.00	175.02
2		0	0	1	0	0	0	1	5	0	0	0	0	0	1	0	0	8	0.13	0.53	1.30
3		0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	1	4	0.07	0.27	0.59
4		0	1	2	3	3	6	6	0	3	0	0	1	2	1	1	0	29	0.47	1.93	1.98
4A***		0										0	0	1	3	0	1	5	0.08	0.83	1.17
5		0	2	2	1	3	4	0	0	1	0	0	4	6	4	8	4	39	0.64	2.60	2.41
6		0	0	0	2	1	0	1	1	1	0	0	0	0	0	0	1	7	0.11	0.47	0.64
7		0	7	4	3	9	20	4	3	8	0	6	16	10	95	212	207	604	9.88	40.27	72.47
8		0	2	2	4	1	1	5	0	0	0	0	0	1	0	0	1	17	0.28	1.13	1.55
9		0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	1	4	0.07	0.27	0.59
10		0	0	0	1	1	0	2	0	0	0	0	1	1	2	1	2	11	0.18	0.73	0.80
11		0	47	28	111	45	65	47	60****	43	1	3	29	89	60	47	26	701	11.46	46.73	28.93
12		0	0	2	5	8	10	7	6	2	0	1	1	3	7	7	7	66	1.08	4.40	3.27
13		0	3	29	31	26	20	21	5****	2	1	12	5	13	10	8	18	204	3.34	13.60	10.03
14		0	6	7	11	19	17	10	2	0	0	1	1	7	13	5	11	110	1.80	7.33	6.09
15		0	0	3	8	1	2	4	0	0	0	0	1	1	0	1	0	21	0.34	1.40	2.20
16		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17		0	0	0	1	8	17	22	4	2	0	0	0	1	0	0	0	55	0.90	3.67	6.85

* = There were no teredinids in the long-term panels removed in April, May, and June, 1977
** = Panels removed in March, 1977 because of ice
*** = Station 4A was established in April, 1977
**** = Panels removed in February, 1977
Stations 1, 5, 7, and 8 removed on regular schedule in 1977
>400 = Estimated count, panel 75-100 percent riddled

The data for the incidence of teredinids and amount of destruction for those panels with a longer submergence were treated as six-month data, since no new borer activity occurred after October, 1976.

The greatest amount of destruction took place at Station 1 where panels were 95 percent destroyed three months after first settlement of the 1976 teredinid set (Table A-25). Panels from Stations 13 showed 75 percent destruction, and Stations 11 and 14 had 50 percent destruction. The panels from the remaining stations were 0 to 20 percent destroyed.

In October, 1976 long-term panels removed from Stations 1, 13, and 14 were 85 to 99 percent filled with teredinids. The panels from Stations 7 and 12 were 50 percent filled and those removed from Stations 5 and 11 were 30 and 25 percent filled, respectively. Panels from Stations 4, 6, 8, 9, 10, 15, and 17 were 4 to 10 percent filled. No teredinids were present in panels taken from Stations 2, 3, and 16.

By November, 1976 panels from six locations (1, 7, 11, 12, 12, and 14) had 50 to 100 percent teredinids present and five locations (4, 5, 8, 15, and 17) had 8 to 30 percent. The panels from the remaining locations were free of teredinids.

The long-term panels removed December, 1976 from Stations 1, 13, and 14 continued to be 85 to 100 percent filled. There was a slight increase in attack at Stations 2, 6, 8, 10, 15, and 17. Panels from Stations 4, 7, 11, and 12 were 15 to 35 percent filled and no teredinids were present in panels from Stations 3, 5, 9, and 16.

In January, 1977 only Stations 5, 7, and 8 could be serviced. The panels from the other locations were removed at a later date but since no new teredinid attack took place after October, 1976 they were considered January panels. Except at Station 1, the January panels were installed after the heaviest teredinid settlement occurred, as evidenced by the drop in the percent of the panels filled. The panels from Stations 11 and 13 were 35 to 18 percent filled, respectively. Panels from all other locations were 0 to 10 percent filled.

The long-term panels removed in February continued to show a decrease in the amount of destruction and by the March, 1977 removal, teredinids were present at only three locations (Stations 1, 11, and 13) and the panels were less than 1 percent filled.

All long-term panels removed from April through June, 1977 were free of teredinid attack.

The long-term panels removed from July to December, 1977 contained only teredinids of the 1977 set.

By July, 1977 less than 1 percent destruction had occurred and then at only five locations (Stations 7, 11, 12, 13, and 14) (Table A-25).

The panel removed in August, 1977 from Station 11 had the greatest attack and was 15 percent filled with borers. The attack was light (from less than 1 to 3 percent filled) at nine stations, and the remainder were completely free of attack.

By September, attack was present at 13 locations and destruction had increased to 75 percent at Stations 1 and 11, to 35 percent at Station 13, and to 18 percent at Station 14. Panels from nine locations were from less than 1 to 4 percent filled. Five locations were without attack. That month was the first time attack was recorded from Station 4A, which was added in April, 1977.

In October long-term panels from Stations 1 and 11 were 85 to 90 percent filled and those from Stations 7, 13, and 14 were 40 to 50 percent filled. Fifteen to 20 percent destruction occurred at Stations 4A, 5, and 12. From less than one to 9 percent destruction took place at Stations 2, 3, 4, and 10. There was no attack in panels from the remaining stations.

The November long-term panels from Stations 1, 7, and 11 were 90 to 99 percent filled with teredinids. The panels removed from Stations 5, 12, 13, and 14 were 30 to 35 percent filled. Panels from three locations, Stations 4, 10, and 15, were 3 to 5 percent filled. All others were without attack.

At the December removal period, panels from all but five stations contained teredinids. Panels from Stations 1, 7, 11, and 13 were 80 to 98 percent filled and panels from Stations 5, 12, and 14 were 35 to 60 percent filled. The panels from the remaining stations with attack were 1 to 15 percent filled.

No teredinids from either the 1976 or 1977 season entered the panels at Station 16.

Tukey's statistic was used for a two-factor analysis of variance to ascertain if the percent destruction by teredinids to the panels was significantly different at any of the exposure panel stations since the program was initiated in 1975. The months April through July were not included in the analysis due to absence of, or, insufficient attack (Table A-27).

The amount of destruction to the panels was significantly greater at Station 1 than at any of the other exposure panel stations (Figure A-5). The panels from Stations 11, 13, and 14 had less destruction than Station 1 but significantly more than panels from the other locations. There was no significant difference (α=.05) in the destruction to panels from Stations 4, 5, 7, 10, 12, 15, and 17.

Data from Stations 2, 3, 4A, 6, 8, 9, and 16 were not included in the analysis due to insufficient numbers of organisms or lack of borer attack.

The annual mean percent attack for the 1975-76 seasons, and for the first six months of the 1977 season is presented in Table A-28. These results were used to rank the stations in descending order (Table A-29).

Station 1, Barnegat Inlet which historically had had heavy *Teredo navalis* attack ranks number 1 for all three years.

Two Oyster Creek Stations, 5 and 6, ranked in the upper third in 1975, dropped to the middle third in the following seasons. Much of this decrease can be attributed to the removal of the trash wood from Oyster Creek. The heavy attack in October and November, 1977 at Station 7 may possibly be due to the presence of some infested wood close to the panel array which is located on an old pier in Oyster Creek.

TABLE A-27. TWO-FACTOR ANALYSIS OF VARIANCE OF THE PERCENT DESTRUCTION OF LONG-TERM PANELS BY MONTHS* AND STATIONS** FOR THE PERIOD AUGUST, 1975, THROUGH NOVEMBER, 1977

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	113297.128	16	7081.071	10.415	<0.001
Station Effects	36828.359	6	6138.060	9.028	<0.001
Month Effects	76920.398	10	7692.040	11.314	<0.001
Month/Station Interaction	37620.740	60	627.012	0.922	0.625***
Residual	50990.000	75	679.867		
Total	201907.868	151			

* = Panels removed April through July omitted due to lack of significant data
** = Stations 1,4,5,7,10,11,12,13,14,15,17
*** = Not significant

Stations 2, 3,6,8,9, and 16 omitted due to insignificant attack

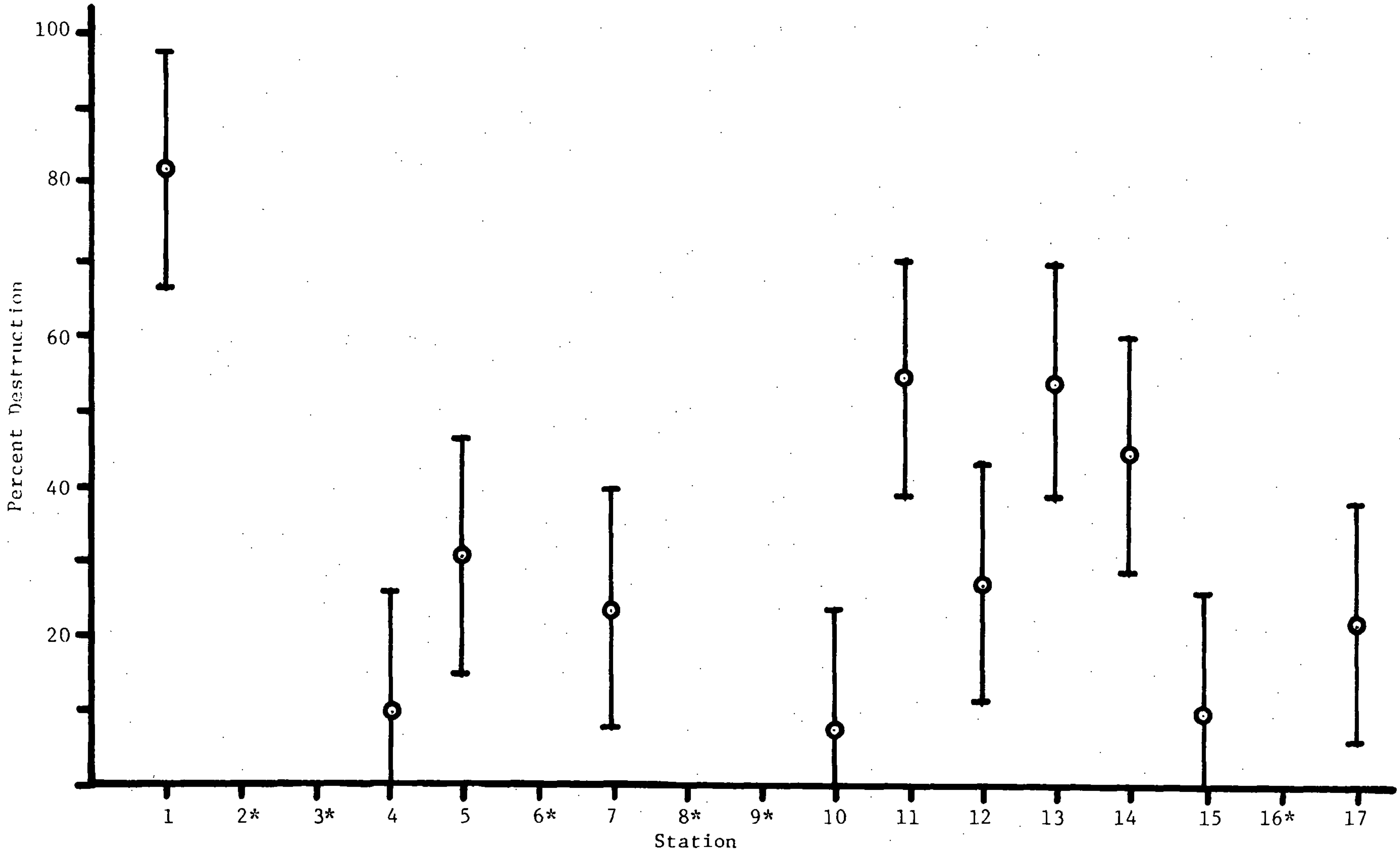


FIGURE A-5. MEAN PERCENT DESTRUCTION AND INTERVAL OF SIGNIFICANT DIFFERENCE (α=0.05) FOR LONG-TERM PANELS REMOVED FROM DECEMBER, 1975 THROUGH NOVEMBER, 1977** AT ELEVEN EXPOSURE PANEL STATIONS IN BARNEGAT BAY

* = Not included in analysis of variance due to insignificant data or lack of borer attack
** = Except March through July of each year due to extremely low attack
Station 4A not included, newly installed 1977

TABLE A-28. SEASONAL MEAN PERCENT OF TEREDINID ATTACK BY STATIONS

Station	1975	1976	1977
1	74.4	67.8	60.2
2	23.7	0.4	0.2
3	15.4	0.1	0.5
4	33.0	5.7	1.8
5	66.9	8.0	15.2
6	65.1	3.4	1.2
7	2.1*	20.1	39.8
8	3.5*	8.2	1.8
9	2.3*	1.2	0.3
10	23.7	1.8	5.3
11	63.6	27.2	59.0
12	39.6	17.4	16.5
13	46.8	42.4	38.2
14	57.3	36.0	27.5
15	13.4	5.6	0.8
16	6.6	0.0	0.0
17	44.4	9.4	0.2

Seasons: period when borers were present at any location

1975: July, 1975 - April, 1976
1976: July, 1976 - March, 1977
1977: July, 1977 - December, 1977

* Incomplete data

TABLE A-29. RANK OF STATIONS IN DESCENDING ORDER OF TEREDINID ATTACK*

1975	1976	1977
1	1	1
5	13	11
6	14	7
11	11	13
14	7	14
13	12	12
17	17	5
12	8	10
4	5	8
10	4	4
4	15	6
3	6	15
15	10	3
16	9	9
8	2	2
9	3	17
7	16	16

* From mean percentages, Table A-28

The 1975 ranking for Stations 7 and 9 is arbitrary as the panels at these locations were not submerged until after the heaviest period of reproductive activity. Their rankings for 1976 and 1977 is more realistic. Station 7 ranks in the upper third due to the presence of heavy attack by *Teredo bartschi*.

The six stations ranked in the top third were the same in 1976 and 1977, and all but two stations are beyond the influence of the thermal plume.

A factor analysis using the principal component method for rate of borer attack and water quality parameters was performed. Figures A-6 through A-8 are presented as visual aids to present the station groupings from this analysis and, as such, no inherent meanings are placed on the plots other than to note station clusters. Reference to Figures A-6 through A-8 shows that station groupings as a result of principal component analysis (using rates of borer attack and water quality parameters) are similar for 1976 and 1977. In both years, the stations north of Oyster Creek group tightly, while Stations 1, 2, 3, and 4 appear to be different. The similar groupings in the two years indicate no radical changes in the relationships in the water parameters or attack rates at any one station. As would be expected, Station 1, at the Inlet was always outside the cluster. Omitting Station 1 (outlier) would not affect the analysis since correlations between station pairs as a measure of similarity are used.

Mortality

Teredinid mortality was less in 1976 than in 1975. The greatest amount occurred at Station 11 at the mouth of Forked River, where up to 76 percent of more than 100 teredinids were dead in long-term panels removed from August through December, 1976. One hundred percent mortality occurred at Stations 2, 6, and 7, but at each of these stations the total number of teredinids per panel was ten or less (Table A-30).

Mortality in the long-term panels of the 1977 teredinid season was restricted to Stations 2, 5, 7, and 14. In September, 1977

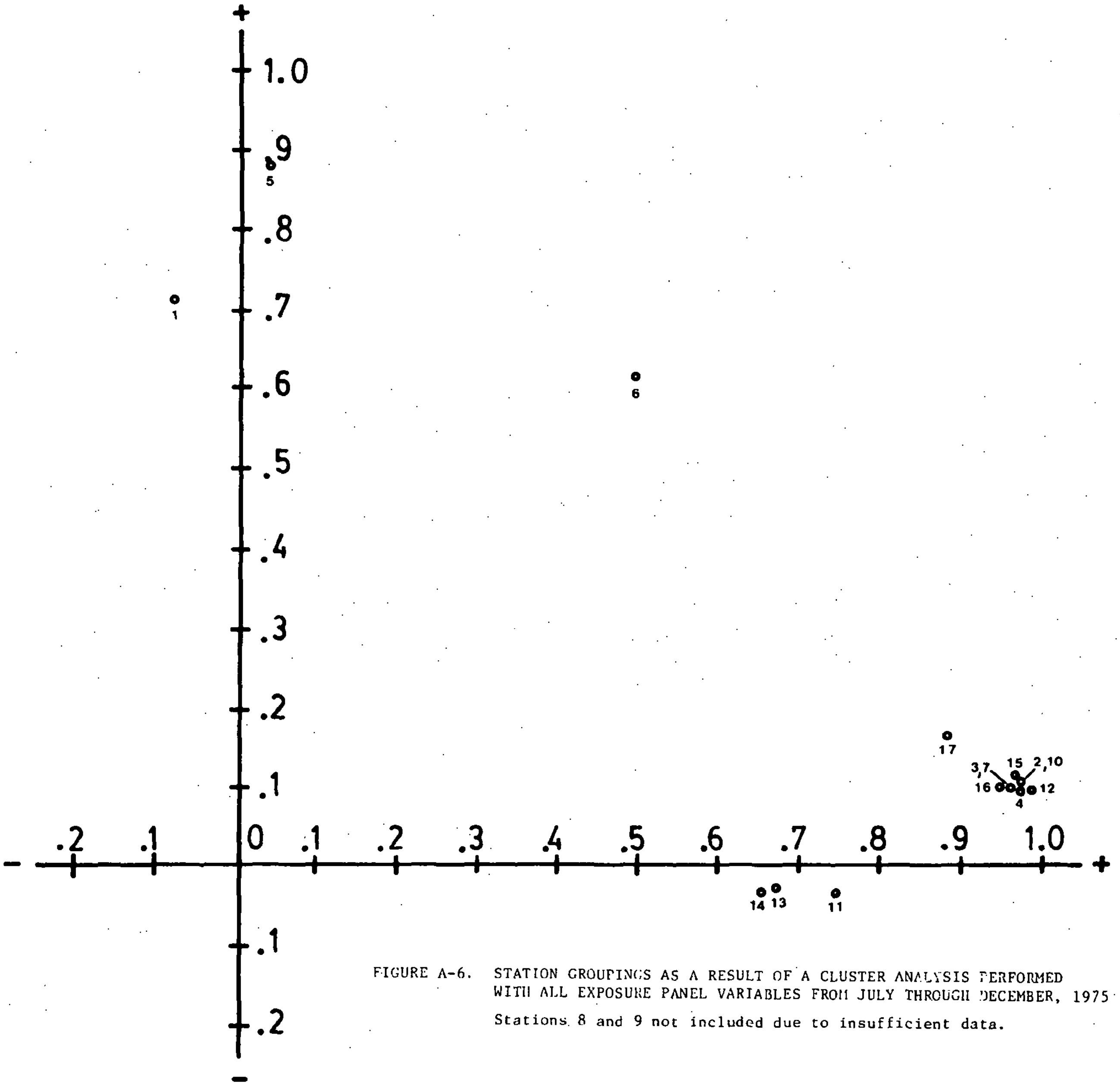


FIGURE A-6. STATION GROUPINGS AS A RESULT OF A CLUSTER ANALYSIS PERFORMED WITH ALL EXPOSURE PANEL VARIABLES FROM JULY THROUGH DECEMBER, 1975

Stations 8 and 9 not included due to insufficient data.

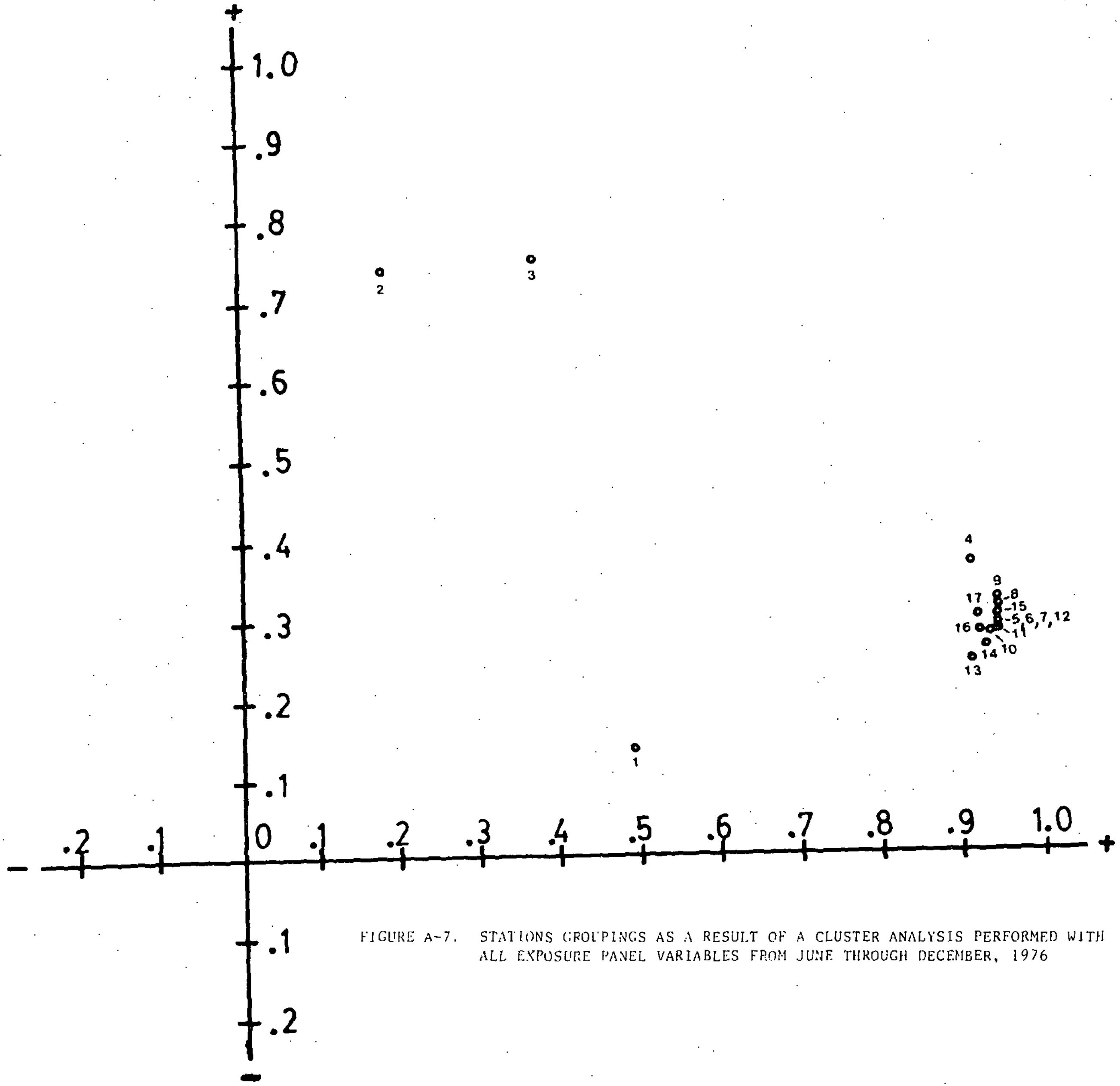


FIGURE A-7. STATIONS GROUPINGS AS A RESULT OF A CLUSTER ANALYSIS PERFORMED WITH ALL EXPOSURE PANEL VARIABLES FROM JUNE THROUGH DECEMBER, 1976

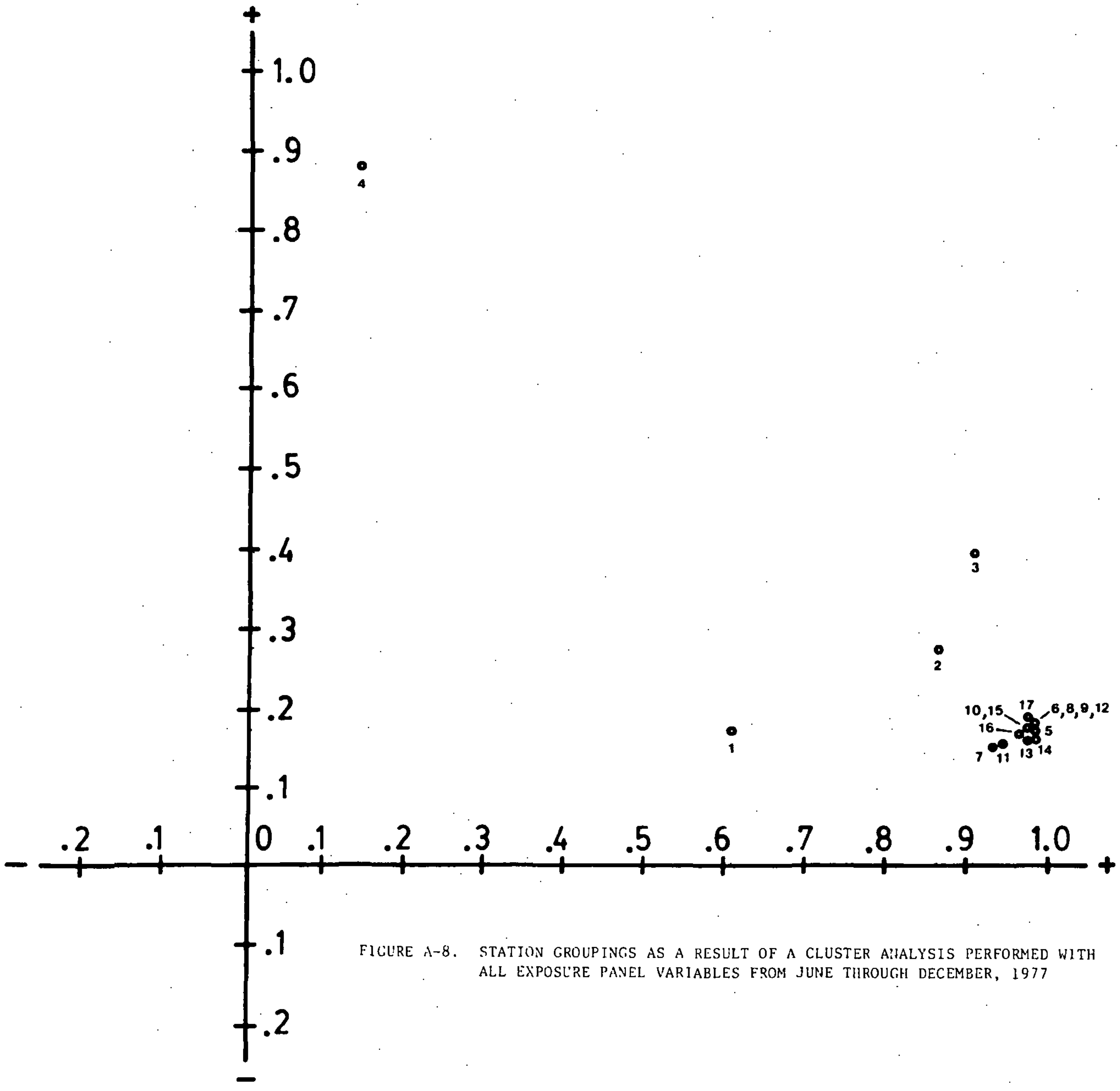


FIGURE A-8. STATION GROUPINGS AS A RESULT OF A CLUSTER ANALYSIS PERFORMED WITH ALL EXPOSURE PANEL VARIABLES FROM JUNE THROUGH DECEMBER, 1977

TABLE A-30. TEREDINID MORTALITY IN LONG-TERM PANELS REMOVED FROM EXPOSURE JULY, 1976, THROUGH DECEMBER, 1977

	Date Removed	Station	*Bankia gouldi*	*Teredo navalis*	*Teredo bartschi*	*Teredo* spp.	Total Dead	Total Specimens
1976 Season	8/11/76	11	4/6			0/22	4	28
	9/14/76	11	18/23	18/23		49/65	85	111
	10/13/76	7	1/4	2/3		2/2	5	9
		11	6/11	0/13		0/21	6	45
	11/9/76	5	1/4				1	4
		11	2/33	0/22		0/10	2	65
	12/7/76	2		1/1			1	1
		6	1/1				1	1
		7	1/3				1	4
		11	5/31	0/11		0/5	5	47
	2/8/77	7	0/1		1/4	3/3	4	8
		11	2/31	0/4		2/6	4	43*
		11**	0/42	1/11		0/5	1	58
	3/8/77	1		120/400+			120±	400±
		2		3/3		3/3	6	6
		6	1/1				1	1
1977 Season	9/13/77	5	3/6				3	6
		7	4/4		1/1	5/5	10	10
	10/11/77	2		1/1			1	1
		7	0/4		1/11	0/80	1	95
		14	0/9	1/1		0/3		13

dead/live
* = Includes 2 *T. furcifera*
** = January panel removed in February

three of six *Bankia gouldi* were dead in panels from Station 5, and all ten specimens, including four *Bankia gouldi* and one *Teredo bartschi* were dead in the long-term panel from Station 7. The short-term panel and subsequent long-term panels contained live specimens. In October, 1977 the only teredinid in the long-term panel from Station 2 and one *Teredo navalis* out of 13 species from Station 14 were dead.

Water temperatures never exceeded teredinid lethal limits during this period, but an abrupt drop in ambient temperature occurred throughout Barnegat Bay in October, 1976. One possible cause of the mortalities may be a weakening of the individuals due to the presence of certain pathological conditions. This possibility is presented in Appendix C.

Lengths of Teredinids

The species of teredinids present and the number that successfully settle have great influence upon the growth (length) of any one individual. Table A-31 gives the length in millimeters of the longest teredinid recorded in panels removed from each location from July, 1976, through December, 1977.

Although the long-term panels are exposed on a continuous six-month retrieval cycle, the 1976 teredinid set did not start until after June, 1976 panels were removed. Therefore, the length of the teredinids in panels removed in August was attained in two months. Specimens more than 100 millimeters long were present in panels from three Stations, 7, 8, and 13. Lengths from 17 to 80 millimeters were reached at nine locations. No borers were present in panels from Stations 3, 6, 10, 16, or 17.

The longest (105 mm) *Teredo navalis* recorded in 1976 was in the panels removed in October from Station 1. However panels removed in September from Station 1 contained *Teredo navalis* that attained a length of 92 millimeters in three months. The longest (140 mm) *T. navalis* in 1977 was also from Station 1 and was in a six-month panel although the panel removed in October contained a 130 millimeter specimen. Specimens of *T. navalis* attained lengths up to 19 millimeters in

TABLE A-31. LONGEST (MILLIMETER) TEREDINID RECORDED EACH MONTH DURING 1976-1977

Site	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	July	Aug.	Sept.	Oct.	Nov.	Dec.
Long-term																
1	3	43	90	105	88	95	((70))	((50))	7			2	83	130	115	140
2		17				24	((29))							23		
3	<1													70		1
4	<1	24	92	110	170	135		((70))			2	18	60	<1	165	
4A*													120	170		260
5	5	60	220	380	300			82				9	98	185	220	430
6			142	330		190	((130))	((125))								230
7	7	115	230	300	240	280	100	120			13	43	200	230	210	280
8	6	140	150	280	250	280							100			270
9		35		275												95
10			120	140		165						3	17	225	175	250
11	9	20	200	130	165	120	(120)	120	2	<1	<1	65	155	210	145	193
12		43	195	230	210	230	((95))	((45))			<1	23	95	150	195	230
13	5	120	185	210	220	190	(240)	70	1		2	44	150	220	210	260
14	6	80	235	230	260	270	((180))				12	30	145	245	280	300
15		65	160	140	200	180						4	43		120	
16																
17			6	80	110	150	((95))	((75))					1			
Short-term																
1	4	10	19	1	<1							3	26	2	<1	
2	<1	9														
3																
4	<1											2				
4A																
5	<1											5		<1		
6														1		
7	5		10								<1	6	40	9	<1	
8	5															
9												4				
10			2													
11	8		37								2	10				
12			1								<1	<1				
13	3	8	<1								2	3				
14	3	15									<1	12	38			
15																
16																
17											<1	<1				

* = Station 4A installed April, 1977
() = Panels removed February
(()) = Panels removed March

No borers were recorded in May or June removals

1976 and up 26 millimeters in 1977 in one month in the short-term panels removed September, 1976 and 1977. These are not unusual lengths for one-month exposures. Clapp (1925) noted that *T. navalis* often reaches a length of 10 millimeters in less than two weeks.

The largest *Bankia gouldi* were a 380 millimeter specimen in 1976 and a 430 millimeter specimen in 1977. Both were in panels removed from Station 5 in Oyster Creek. Specimens of *B. gouldi* attained lengths up to 26 millimeters in the short-term panels. The longest, 26 millimeters, was removed September, 1976 from Station 11. The extent of growth in one month was less than 25 percent that of the longest specimen (110 mm) in short-term panels exposed in 1975 (Richards et al., 1976).

The few *Teredo furcifera* identified in panels in the 1976 season attained lengths of 50 to 110 millimeters at Stations 4, 7, and 11. No *T. furcifera* from the 1977 set were present in panels removed through December, 1977 and none were identified in any short-term panels.

The longest *Teredo bartschi* recovered in 1976 was 65 millimeters, whereas in 1977 lengths up to 95 millimeters were attained in long-term panels and up to 40 millimeters in short-term panels. Station 7, Oyster Creek, was the only location to have this species in 1976.

Limnoria

Limnoria were present in panels from the four stations at the southern end of Barnegat Bay and at the Inlet. Table A-32 presents the numbers present each month from June, 1976, through December, 1977. April, 1977 was the only month when panels from all stations were free of *Limnoria*. *Limnoria tripunctata* was the only species present in the panels. Figure A-9 shows the average annual numbers of *Limnoria* tunnels in panels since the program began.

The attack in the panels from Stations 2 and 3, Manahawkin and Conklin Island, was heaviest in 1976. The attack at Barnegat Light, Station 1, increased steadily since 1975. The numbers of *Limnoria* tunnels in the panels from Station 4, Liberty Harbor, Waretown, rose sharply in 1977. In April, 1977 extensive *Limnoria* attack to untreated pilings was observed at Holiday Harbor, Waretown and an additional panel array (Station

TABLE A-32. NUMBER OF *Limnoria* TUNNELS IN PANELS EXPOSED 1976-1977

	Barnegat Light		Manahawkin		Conklin Island		Waretown		Waretown	
Month	P	C	P	C	P	C	P	C	P	C
June	12	0	21	28	9	4	16	3		
July	2	1	550	13	410	9	27	0		
Aug.	28	2	1075	105	530	0	14	2		
Sept.	80	5	600	27	670	4	17	0		
Oct.	110	4	780	1	530	0	41	0		
Nov.	66	0	290	0	195	0	158	0		
Dec.	19	0	160	0	0	0	0	0		
Jan.	((0))	NC	((285))	NC	((0))	NC	((1))	NC		
Feb.	((26))	NC	((53))	NC	((1))	NC	((0))	NC		
Mar.	5	0	1	0	0	0	0	0		
Apr.	0	0	0	0	0	0	0	0		
May	0	0	0	0	0	0	0	0	1	0
June	1	1	13	0	0	0	28	19	9	7
July	28	4	85	0	0	0	530	4	118	13
Aug.	67	21	115	6	127	0	1900	11	480	11
Sept.	230	16	45	1	95	0	130	1	875	47
Oct.	210	1	128	0	2	0	65	0	1400	0
Nov.	140	0	27	0	14	0	110	0	1300	0
Dec.	170	0	6	0	0	0	29	0	750	0

P = Long-term panel
C = Short-term panel
(())= Panel removed in March
NC = No short-term panel
No *Limnoria* at other panel exposure locations

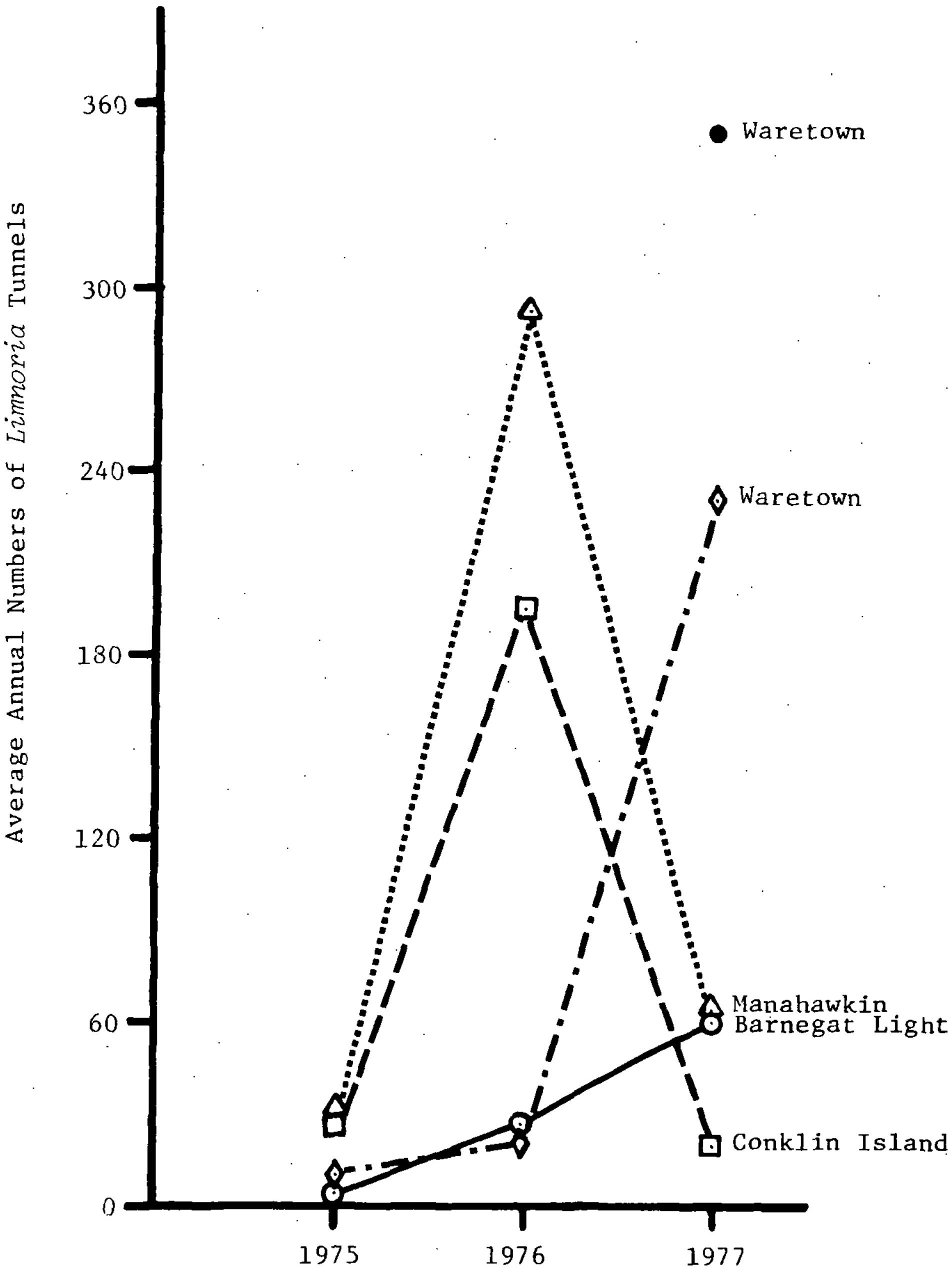


FIGURE A-9. AVERAGE ANNUAL NUMBERS OF *Limnoria* TUNNELS

4A) was submerged. Station 4A is between Liberty Harbor and Oyster Creek. The attack in the panels from this location in 1977 was greater than at the other locations.

No *Limnoria* were found in panels from other locations, and the creosoted panels continue to remain free of *Limnoria*.

Literature Cited

Bartsch, Paul. 1908. A New Shipworm from the United States. Proc. Biol. Soc. Washington 21(34):211-212.

Clapp W.F. 1923. A New Species of *Teredo* from Florida. Proc. Bos. Soc. Nat. Hist. 37(2):37-38.

Clapp, W.F. 1925. Notes on the stenomorphic form of the shipworm. Trans. Acad. Sci., St. Louis, 25(5):81-89, pl. 4-5.

Clapp, W.F. and R. Kenk. 1963. Marine Borers: An Annotated Bibliography. ACR-74, Office of Naval Research, Dept. of the Navy, Washington, D.C. 1136 pp.

Hoagland, K.E., M. Rochester, and L. Crockett. 1977. Analysis of Populations of Boring and Fouling Organisms in the Vicinity of the Oyster Creek Nuclear Generating Station with Discussion of Relevant Physical Parameters over the Period June 1 - August 31, 1977. Wetlands Interstate, Lehigh Univ., Stone Harbor, N.J.

Hoagland, K.E. and R.D. Turner. 1977. The Effects of Nuclear Power Plant Operations on Populations of Boring and Fouling Invertebrates. Tech. Prog. Rep. (AT(49-24)-0347). Second Quarterly Report to USNRC. Lehigh Univ., Stone Harbor, N.J.

Hollander, M. and D.A. Wilfe. 1973. Nonparametric Statistical Methods. John Wiley and Sons.

Menzies, R.J. 1951. A New Species of *Limnoria* (Crustacea:Isopoda) from Southern California. Bull. So. Calif. Acad. Sci. 50 (2):86-88.

Menzies, R.J. 1959. The identification and distribution of the species of *Limnoria*. In: Ray, D.L., Marine Boring and Fouing Organism. Univ. of Wash. Press. Seattle, Wash. 10-33 pp.

Miller, R.C. 1923. Variations in the Pallets of *Teredo navalis* in San Francisco Bay. Univ. of Cal. Pub. in Zoo., 22(8):401-414, pl. 19-20.

Nagabhushanan, R. 1961. The Growth Rates of the Shipworm, *Teredo furcillatus* Miller (*furcifera*). Science and Culture, 27: 206.

Neter, J. and W. Wasserman. 1974. Applied Linear Statistical Models. Richard D. Irwin, Inc.

Nie, Norman H., et al. 1975. Statistical Package for the Social Sciences. McGraw-Hill, Inc., 2nd edition.

Purushotham, A. and K. Satyanaroyana Rao. ca. 1971. The First Progress Report of the Committee for the Protection of Timber Against Marine Organisms Attack in the Indian Coastal Waters for the Period 1953 - 70. Jour. Timber Development Assoc. (India), Vol. XVII (3):1-74.

Quatrefages, A. de. 1849. Memoire sur le genre Taret (Teredo Lin.) Ann. des Sci. Nat. Zool., (3)11(Jan. 1):19-64, pl. 1-2.

Richards, B.R., A.E. Rehm, C.I. Belmore, and R.E. Hillman. 1976. Woodborer Study Associated with the Oyster Creek Generating Station. Annual Report for the Period June 1, 1975 to May 31, 1976 to Jersey Central Power & Light Comapny, Report No. 14729.

Shafto, S.S. 1974. The boring and fouling community of Barnegat Bay, New Jersey. Masters Thesis, Rutgers Univ., New Brunswick, N.J. 235 pp.

Turner, R.D. 1966. A Survey and Illustrated Catalogue of the Teredinidae. Mus. of Comp. Zoo., Harvard Univ., Cambridge, Mass. 265 pp.

Turner, R.D. 1971. Identification of Marine Wood-boring Molluscs. Chapter 1, Marine Borers, Fungi and Fouling Organisms of Wood. E.B.G. Jones and S.K. Eltringham, Editors. Organization for Ecomonic Cooperation and Development Paris, pp. 17-64.

Turner, R.D. 1973. Report on Marine Borers (Teredinidae) in Oyster Creek, Waretown, New Jersey. Mus. Comp. Zoo., Harvard Univ., Cambridge, Mass. First Report, April 3, 1973, 30 pp.

Turner, R.D. 1975. Bivalve Life History, Larval Behavior, Dispersal, and Identification. (Unpublished). Seminar, WFCL, Duxbury, Massachusetts, December, 1975.

Wallour, D.B. 1960. Marine Borer Activity in Test Boards Operated During 1959. 13th Progress Report, William F. Clapp Laboratories, Duxbury, Massachusetts, 1XXXX, 1-59.

Woodward-Envicon. 1974. The physical behavior of the thermal plume discharge from the Oyster Creek Nuclear Generating Station - Results of the 1974 thermal plume measurements.

APPENDIX B

APPENDIX B

MARINE BORER LARVAE

Introduction

Water temperature is a major factor controlling the distribution, reproduction, and growth rate of marine organisms (Gunter, 1957). The thermal effluent from the Oyster Creek Nuclear Electric Generating Stations is discharged into Oyster Creek. Because of this, marine organisms inhabiting Oyster Creek are, at times, exposed to temperatures that are higher than at other areas in the Barnegat Bay system.

As a result of this increase in water temperature a number of studies were initiated to determine to what extent the thermal effluent from the Oyster Creek station is affecting the reproductive behavior of the resident marine borer population in Oyster Creek and other areas in Barnegat Bay. This study addresses the distribution and density of teredinid larvae collected in the plankton at six locations in Barnegat Bay from June, 1975, through November, 1977.

Materials and Methods

Field Procedures

Six stations were established in Barnegat Bay (Figure B-1). Each station designation and its location is as follows:

Location	Approximate latitude and longitude
A. Mouth of Oyster Creek	Lat. 39° 48.5'N Long. 74° 10.2'W
B. South branch Forked River	Lat. 39° 49.2'N Long. 74° 12.2'W
C. Mouth of Forked River	Lat. 39° 49.7'N Long. 74° 10'W
D. Holly Park	Lat. 39° 53.2'N Long. 74° 08'W
E. Barnegat Beach	Lat. 39° 47'N Long. 74° 11'W

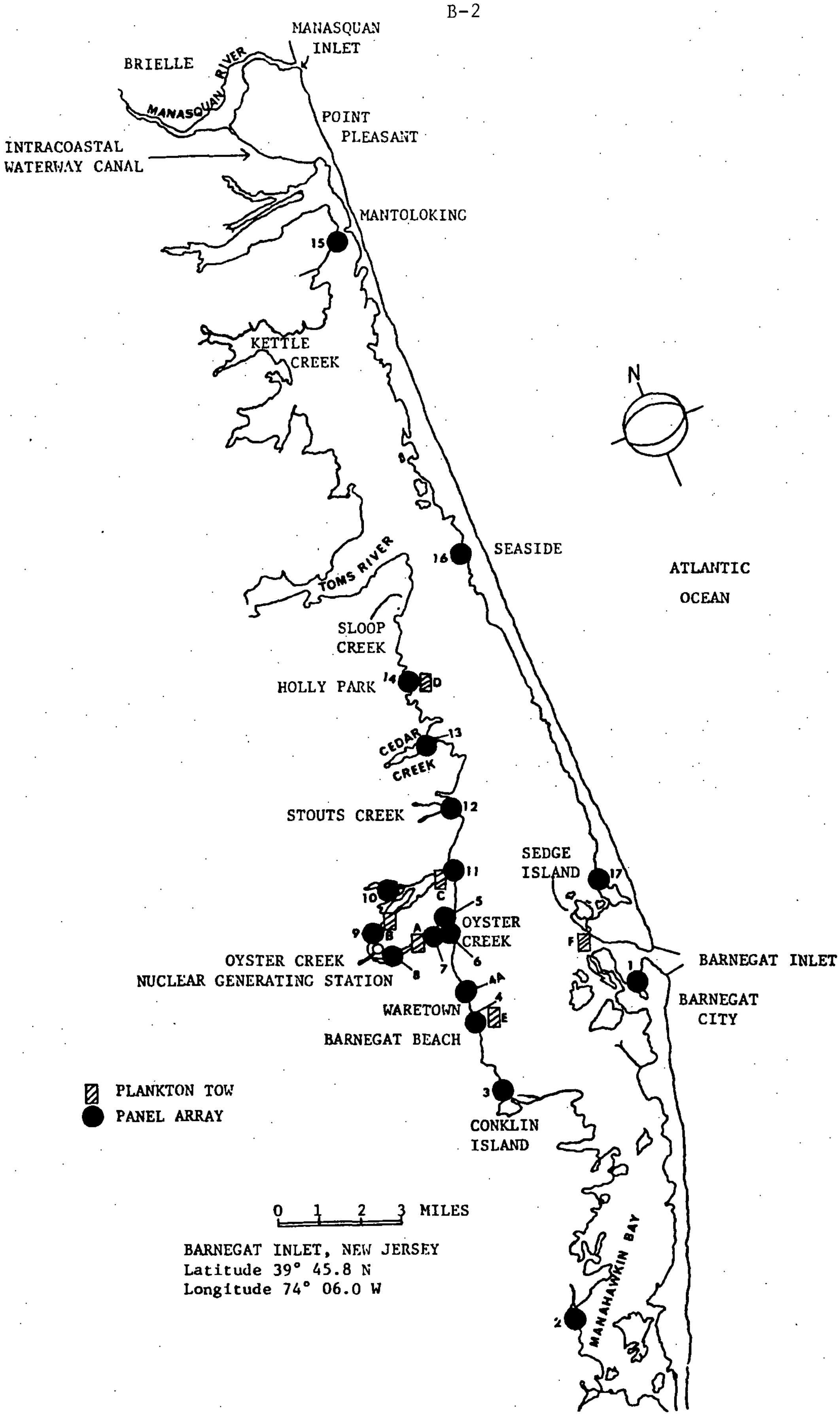


FIGURE B-1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHICAL LOCATIONS OF EXPOSURE PANELS AND PLANKTON TOWS

F. Between Barnegat Inlet and Oyster Creek Channel — Lat. 39° 46.2'N, Long. 74° 06.5'W

The methods presented in this report cover the period from June, 1976, through November, 1977. The methods employed from June, 1975, through May, 1976 are contained in the first annual report (Richards et al., 1976) and were the same as the methods presented below with the following exceptions: (1) for the June, 1975 plankton sampling a Clarke-Bumpus sampler was used, and (2) plankton sampling for teredinid larvae was only carried out once a month from June, 1975, through May, 1976.

Plankton samples were collected twice a month from June, 1976, through November, 1977 except during January and the first half of February, 1977 when Barnegat Bay was frozen over, and at Station F the last half of February, 1977 due to the absence of channel markers. During the first half of each month samples were collected by William F. Clapp Laboratories, Inc. staff: Jersey Central Power & Light Company personnel collected the samples during the last half of the month. All sampling dates, by station, are presented in Tables D-71 through D-76. Sampling techniques conformed to MARMAP standard procedures whenever possible.

Three replicate tows, each of ten minutes duration, were made at each station using a 20-centimeter Bongo frame equipped with 153 micrometer mesh nets, and flow meters (General Oceanic Model 2030). The flow meters were attached inside the mouth of each Bongo frame.

Each tow was a step oblique and was conducted by paying out the nets so that they gradually sank toward the bottom as the boat proceeded. When the nets approached the bottom they were raised to just below the surface. This process was repeated for the duration of the tow. The tow speed was between one and one and one-half knots.

When the nets were retrieved after each tow they were thoroughly washed so that all organisms clinging to the nets passed to the cod end. Each net sample was poured into a 1-liter polyethylene jar(s) and fixed with buffered formalin to a final concentration between 5 and 10 percent.

For each sample the flowmeter revolutions were recorded. Each sample was labelled with the appropriate field information and placed in a container for shipment to the laboratory.

Water Quality. Water temperature, salinity, pH, and dissolved oxygen were measured at each plankton station with a Hydrolab Model II B. The Hydrolab was calibrated prior to each day's use. Water quality parameters recorded by Jersey Central Power & Light Company personnel were made using a Yellow Springs Instruments recorder for salinity, dissolved oxygen, and temperature; pH was measured with instruments manufactured by Analytical Measurements; and depth was recorded with a Ray Jefferson depth meter.

Laboratory Procedures

Plankton Samples. Each field sample was poured into a graduated beaker to obtain the volume of the sample. The sample was stirred to obtain a homogenous mixture of the sample. Immediately after stirring, a 10-milliliter aliquot was removed for inspection. The 10-milliliter aliquot was placed in a rafting cell and inspected using a Bausch and Lomb Stereo Zoom dissecting microscope.

All teredinid larvae observed were removed from the rafting cell and placed in a small screw top vial and the vial labelled. The above procedure was repeated until five 10-milliliter aliquots had been withdrawn from the sample and inspected.

The number of teredinid larvae found in the aliquots was used to calculate the number present in each sample. The number thus obtained was used to calculate the number of teredinid larvae per cubic meter of seawater filtered as determined from flowmeter data.

After each field sample was inspected it was returned to the field sample jar and stored.

Results

The mean number of teredinid larvae captured per cubic meter of seawater filtered at plankton Stations A through F from June, 1975, through November, 1977, are presented in Table B-1. The thirty-month sampling program was divided into five time periods which encompass blocks of time from five to seven months. The separations were based on the presence of teredinid larvae captured at one or more stations. Teredinid larvae were captured from June through November, 1975; from June through October, 1976; and May through November, 1977 (Table B-1). Based on the available temperature data requirements for sexually mature teredinids to spawn, it can be assumed that the absence of teredinid larvae in the plankton from December, 1975, through May, 1976 and from November, 1976, through April, 1977 can probably be attributed to the lower water temperatures throughout the bay which caused a cessation of reproductive activity.

Of the seventeen months when teredinid larvae were captured, July, 1975 and November, 1977 were the only months when teredinid larvae were taken at each of the six plankton stations. Teredinid larvae were captured at five stations in October, 1975 and June and July, 1977; at four stations in August, 1975, June and September, 1976, and August and October, 1977. The mean number of larvae captured at each station for the months listed above and the remaining months when teredinid larvae were a component of the plankton community but captured at only one to three stations are presented in Table B-2.

Teredinid larvae were captured at Station F, 55 percent of the time during the three periods when larvae were captured at one or more stations. The percent of time when larvae were captured at the remaining stations were: Station A, 38 percent; Station B, 31 percent; Station C, 48 percent; Station D, 38 percent; and Station E, 45 percent. The mean number of teredinids captured per cubic meter at each of the above stations for the three time periods is presented in Table B-2.

The first sampling period in November, 1977 was the only time when the density of teredinid larvae ranged from 4 to 8 per cubic meter at three stations, A, B, and F (Table B-1). The mean number of teredinids captured per cubic meter at Stations A, B, and F were 4.47, 5.68, and 8.67, respectively.

TABLE B-1. MEAN NUMBER OF TEREDINIDS CAPTURED/M^3 DURING THOSE MONTHS WHEN TEREDINIDS WERE TAKEN AT ONE OR MORE OF THE SIX PLANKTON STATIONS IN 1975*, 1976**, AND 1977** BY SAMPLING PERIOD

	1975					1976									
	Jun	Jul	Aug	Oct	Nov	Jun		Jul		Aug		Sep		Oct	
Site	1	1	1	1	1	1	2	1	2	1	2	1	2	1	2
A	0.17	0.17	1.24	0	0	0	0	0	0	0	0	0	0.42	0	0
B	0	6.84	0.17	2.01	0	0	0	0	0	0	0	0	0	0	0.16
C	0	3.19	0.28	0.26	0.50	1.64	2.18	0.32	0	0	0	0	0.21	0	0.19
D	0	1.42	0	0.17	0.84	1.93	0.45	0	0	0	0	0	0	0	0.15
E	0	0.36	0	0.16	0.19	0	0.16	1.17	0	0.22	1.1	0.43	0.27	0	0
F	0	5.56	0.42	0.57	0.99	2.90	0	0.94	3.62	0	0	1.37	0	0	0

	1977													
	May		Jun		Jul		Aug		Sep		Oct		Nov	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2
A	0	0.12	0	0.51	0.16	0.22	0.20	0	0	0	0	0.11	4.47	0
B	0	0	0	0.30	0	0.11	0.40	0	0	0.13	0	0.19	5.68	0
C	0	0	0.14	0.70	0.17	0	0	0	0	0	0	0.10	0.62	0
D	0	0.41	0.15	0.43	0	0	0.30	0	0	0	0	0	0.12	0
E	0	0	0	0.16	0.33	0.54	0	0	0	0	0	0	0.52	0
F	0	0	0	0	0.50	0.57	0	0.10	0	0.11	3.54	2.36	8.67	

* = Plankton sampling conducted once a month
** = Plankton sampling conducted bimonthly during the first (1) and second (2) half of each month

TABLE B-2. MEAN NUMBER OF TEREDINID LARVAE CAPTURED PER CUBIC METER OF SEAWATER AND WATER TEMPERATURE AT PLANKTON STATIONS A THROUGH F FROM JUNE, 1975, THROUGH NOVEMBER, 1977*

Station	6/75	7/75	8/75	9/75	10/75	11/75	6/76	7/76	8/76	9/76	10/76	5/77	6/77	7/77	8/77	9/77	10/77	11/77
A	0.17	0.17	1.24	0	0	0	0	0	0	0.21	0	0.06	0.26	0.34	0.10	0	0.06	2.24
	25.0	29.0	29.5	25.0	20.0	17.5	26.3	25.5	29.5	20.1	14.1	18.2	21.6	24.2	29.0	22.2	17.0	12.1
B	0	6.84	0.17	0	2.01	0	0	0	0	0	0.08	0	0.15	0.06	0.20	0.07	0.10	2.84
	22.5	27.0	26.5	19.8	18.5	13.5	24.1	24.5	26.1	23.0	13.2	17.5	23.3	24.3	25.9	21.7	11.2	10.1
C	0	3.19	0.28	0.26	0.50	0	1.09	0.16	0	0.11	0.10	0	0.42	0.09	0	0	0.05	0.31
	22.5	27.0	25.5	22.0	18.0	14.0	24.4	24.1	27.0	21.6	14.2	17.1	21.6	24.9	25.9	22.3	14.2	10.1
D	0	1.42	0	0	0.17	0.84	1.19	0	0	0	0.08	0.21	0.29	0	0.15	0	0	0.06
	22.0	27.0	25.8	17.5	18.0	13.5	23.9	23.9	25.5	21.0	10.2	18.2	22.0	24.4	26.0	20.6	12.9	10.0
E	0	0.36	0	0	0.16	0.19	0.08	0.59	0.66	0.35	0	0	0.08	0.42	0	0	0	0.26
	22.0	28.0	26.3	22.0	17.3	13.5	22.8	23.5	25.5	21.0	12.0	17.3	21.2	24.6	25.5	21.9	13.8	10.3
F	0	5.56	0.42	0	0.57	0.99	1.45	2.29	0	0.69	0	0	0	0.54	0.16	0.06	2.95	21.72
	17.5	27.0	22.5	18.5	18.0	15.0	21.8	19.6	22.8	18.8	11.1	16.0	17.4	25.0	26.2	20.7	14.4	11.4

* Teredinid plankton were not captured from December, 1975, through May, 1976, and from November, 1976, through April, 1977. For the time periods listed above, plankton sampling and water quality were conducted once a month from June through November, 1975. From June, 1976, through November, 1977, plankton sampling and water quality were conducted bimonthly.

The largest number of teredinids ever recorded per cubic meter was obtained from the samples collected at Station F the second half of November, 1977. The mean was 34.77 teredinids per cubic meter.

The teredinids captured were probably *Teredo navalis*, since this teredinid has historically been dominant at Station 1 (Coast Guard Station), which is near Station F.

From June through November, 1975, teredinid larvae were captured on 20 of the 36 sampling efforts (sampling effort = 6 sampling periods times 6 stations), or 56 percent of the time (Table B-1). However, on 14 of the 20 sampling efforts the mean number of larvae taken per cubic meter was less than one. For the remaining 6 sampling efforts the mean number of teredinids captured per cubic meter ranged from 1.24 to 6.84; the latter value was from Station B in July, 1975.

During the second time period when larvae were present, June through October, 1976, there were 60 sampling efforts. Of the 60 sampling efforts teredinid larvae were taken on only 20, or 33 percent of the time. Of the 20 sampling efforts when teredinid larvae were captured, 11 of them, or 55 percent, had a mean of less than one larvae per cubic meter. The remaining 9 sampling efforts had more than one teredinid larvae per cubic meter, the number ranged from 1.1 to 3.62, the high value was obtained at Station F during July (Table B-1).

From May through November, 1977, teredinid larvae were captured on 35 of the 84 sampling efforts, or 42 percent of the time. For 29 of the 35 sampling efforts the mean number of teredinids per cubic meter was less than one. For the remaining 6 sampling efforts the mean number of teredinids ranged from 2.36 to 34.77; the latter value was from Station F during the last half of November.

The mean number of teredinid larvae captured at each of the six plankton stations, Stations A through F, for the three time periods when larvae were captured at one or more stations (Table B-2) were subjected to one factor analysis of variance and Duncan's Multiple Range Test to determine if there were significant differences in the number of teredinid larvae taken between stations.

The results of the analysis showed that there was no significant difference (alpha 0.1) in the mean number of larvae captured at Stations A, B, C, D, and E. Station F was significantly different than the other five stations. The mean number of larvae captured at Station F was 2.31 per cubic meter. For the remaining five stations the mean number of larvae per cubic meter was less than one (Figure B-2).

The high mean number of teredinid larvae captured per cubic meter at Station F relative to Stations A through E can be attributed to the large number of teredinids taken during the November, 1977 sampling. During the first sampling period in November, 8.67 teredinid larvae per cubic meter were captured. For the second sampling period, which occurred on November 29, a mean of 34.77 teredinid larvae per cubic meter were captured. This was the largest number of teredinids captured during the study at any station.

The flow meters were working properly during the plankton tows and the nets did not clog.

Based on the available data and the results from the statistical tests it appears that the Oyster Creek shipworm population is not releasing a significantly greater number of teredinid larvae into Barnegat Bay compared to the other areas along the west coast of the bay where plankton sampling was conducted.

The mean number of teredinid larvae captured per cubic meter of seawater filtered, and the mean seawater temperature at the six plankton stations, Stations A through F, from June through November, 1975; from June through October, 1976; and from May through November, 1977 (Table B-2) were subjected to analysis utilizing the Kendall and Spearman Correlation Coefficient (Sokal and Rohlf, 1969). The results of the analysis showed that there was no significant correlation between the number of larvae captured per cubic meter of seawater filtered and water temperature at any station or with all stations combined at an alpha of 0.5 (Table B-3).

Several of the exposure panel stations are in the vicinity of the teredinid plankton stations. The number of larvae captured each

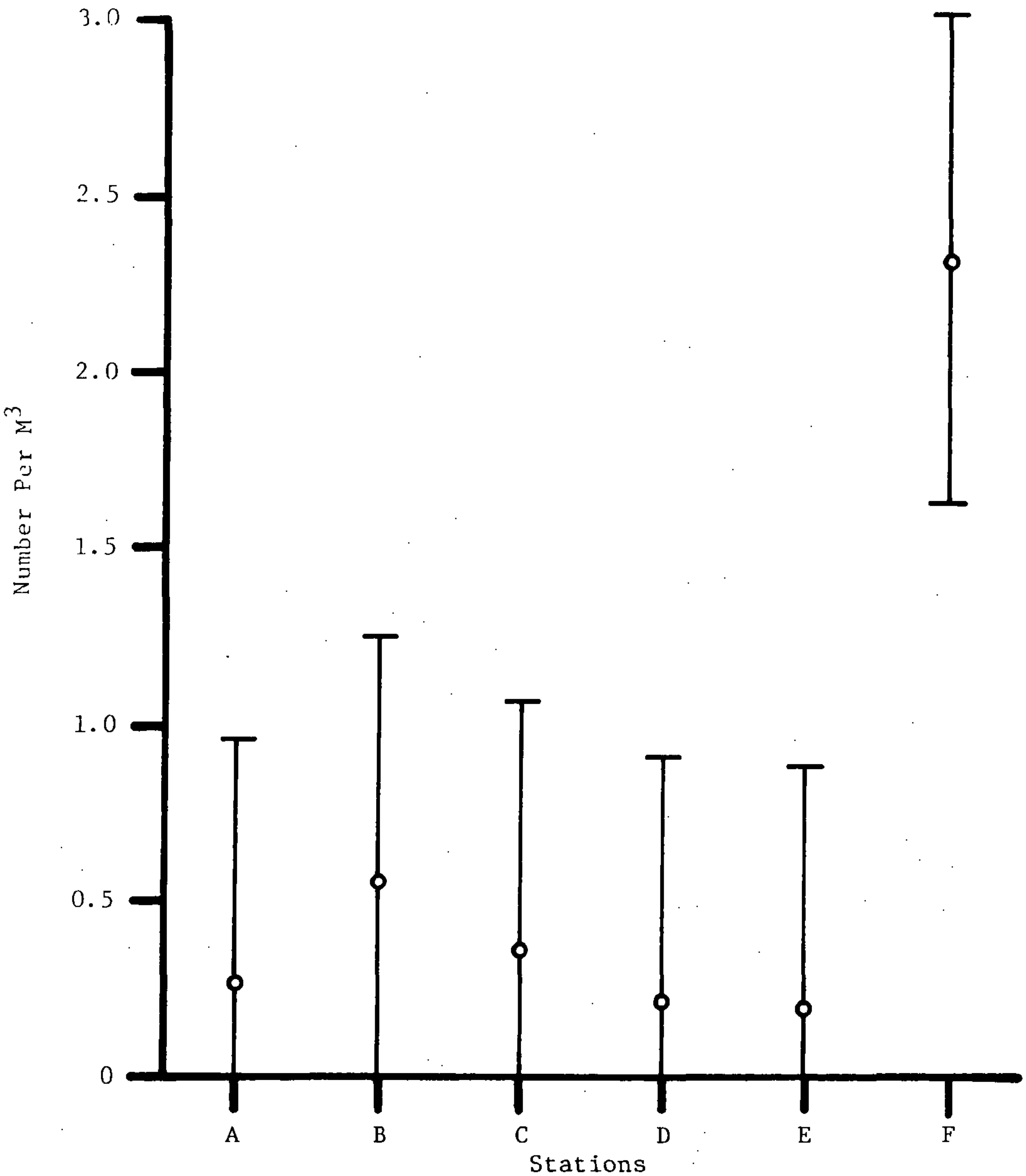


FIGURE B-2. MEAN NUMBER OF TEREDINIDS CAPTURED PER CUBIC METER AT SIX PLANKTON STATIONS, BARNEGAT BAY, DURING THOSE PERIODS WHEN TEREDINIDS WERE A COMPONENT OF THE PLANKTON COMMUNITY AND INTERVAL OF SIGNIFICANT DIFFERENCE (χ = 0.10) WITH DUNCAN MULTIPLE RANGE TEST

TABLE B-3. NUMERICAL VALUES OBTAINED FROM THE KENDALL AND SPEARMAN CORRELATION COEFFICIENTS FOR DETERMINING IF THERE WAS A SIGNIFICANT CORRELATION BETWEEN THE NUMBER OF LARVAE CAPTURES PER CUBIC METER OF SEA-WATER FILTERED AND WATER TEMPERATURE AT ANY STATION OR WITH ALL STATIONS COMBINED AT AN ALPHA OF 0.05

	Kendall[1]		Spearman[2]	
Station	Correlation	Significance	Correlation	Significance
A	0.1600	0.186	0.1973	0.224
B	0.1320	0.230	0.2031	0.218
C	0.0788	0.330	0.797	0.318
D	0.0518	0.386	0.0478	0.428
E	0.2096	0.121	0.2958	0.125
F	0.1637	0.180	0.2280	0.190

1 = Kendall Correlation Coefficient
All Stations: $\bar{X}$ # teredinids, $\bar{X}$ temperature - C
Correlation: 0.0997
Significance: 0.069

2 = Spearman Correlation Coefficient
All Stations: $\bar{X}$ # teredinids, $\bar{X}$ Temperature - C
Correlation: 0.1362
Significance: 0.087

month at these plankton stations and the number that settled on the short-term exposure panels are presented in Table B-4. Because of the nearness of some of the plankton stations to the exposure panel stations it was felt that a relationship might be present between the number of teredinid larvae taken in the plankton and the number settling on the short-term panels. However, an analysis of the data showed that sufficient information was not available to show that relationship.

A relative abundance ranking of plankton stations showing the density of teredinid larvae per cubic meter during the three time periods when teredinid larvae were captured is presented in Table B-5. For two of the three time segments Station A, mouth of Oyster Creek, ranked fifth on a scale from one to six. For the third time period Station A ranked third. The mean numbers of teredinid larvae captured per time period were 0.26, 0.04, and 0.44, respectively.

Station F produced the second highest number of teredinids per cubic meter during the first time period, and the highest number of teredinids per cubic meter during the second and third time periods. The mean numbers of teredinids captured per cubic meter of seawater for the three time periods were 1.26, 0.89, and 3.63, respectively.

Station B was ranked first for the first time period with 1.52 teredinid larvae per cubic meter, and sixth and second for the two remaining time periods. The mean number of larvae captured for the last two time periods were 0.02 and 0.49, respectively.

Station C was ranked third for the first and second time periods, and fourth for the last time segment. The mean number of teredinids captured during each time frame were 0.96, 0.29, and 0.12 per cubic meter, respectively.

Station D was ranked fourth for the first two time periods, and sixth for the last. The mean numbers of teredinids captured per cubic meter was 0.41, 0.25, and 0.10, respectively.

Station E was ranked last (sixth) for the first time period, second for the second time period, and fifth for the last. The mean

TABLE B-4. MEAN NUMBER OF TEREDINID LARVAE CAPTURED/M^3 IN PLANKTON* COMPARED WITH SETTLEMENT ON SHORT-TERM PANELS** FROM JUNE, 1975 THROUGH DECEMBER, 1977***

	1975							1976						1977						
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jun	Jul	Aug	Sep	Oct	Nov	May	Jun	Jul	Aug	Sep	Oct	Nov
Oyster Creek																				
Station A	0.17	0.17	1.24	0	0	0	0	0	0	0	0.21	0	0	0.06	0.26	0.34	0.10	0	0.06	
Station 5		845	2380	1310	24	0	3	0	2	0	0	0	0	0	0	0	3	0	1	0
Forked River-South Branch																				
Station B	0	6.84	0.17	0	2.01	0	0	0	0	0	0	0.08	0	0	0.15	0.06	0.20	0.07	0.10	
Station 10		0	1	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Forked River-Mouth																				
Station C	0	3.19	0.28	0	0.26	0.50	0	1.09	0.16	0	0.11	0.10	0	0	0.42	0.09	0	0	0.05	
Station 11		46	320	9	0	0	0	0	56	0	15	0	0	0	0	9	19	0	0	0
Holly Park																				
Station D	0	1.42	0	0	0.17	0.84	0	1.19	0	0	0	0.08	0	0.21	0.29	0	0.15	0	0	
Station 14		25	280	3	0	0	0	0	1	19	0	0	0	0	0	2	3	3	0	0
Waretown																				
Station E	0	0.36	0	0	0.16	0.19	0	0.08	0.59	0.66	0.35	0	0	0	0.08	0.42	0	0	0	
Station 4		4	2	0	0	0	0	0	2	0	0	0	0	0	0	1	2	0	0	0
Inlet																				
Station F	0	5.56	0.42	0	0.57	0.99	0	1.45	2.29	0	0.69	0	0	0	0	0.54	0.16	0.06	2.95	
Station 1		16	4250	3625	260	47	1	0	33	494	560	2	1	0	0	0	265	97	108	184

* = Lettered Stations - plankton larvae

** = Numbered Stations - settlement on short-term panels

*** = There were no plankton captured or settlement on short-term panels from January through May, 1976, and from December, 1976, through April 1977. Panels were first placed in water in June, 1975, therefore, teredinid larval settlement were not available for the month.

TABLE B-5. RELATIVE ABUNDANCE RANKING OF THE MEAN NUMBER OF TEREDINID LARVAE PER M^3 AT THE SIX PLANKTON STATIONS FROM JUNE, 1975, THROUGH NOVEMBER, 1977

Relative Abundance	6/75 through 11/75 (6 months)		12/75 through 5/76 (6 months)		6/76 through 10/76 (5 months)		11/76 through 4/77 (6 months)		5/77 through 11/77 (7 months)	
	Station	$\bar{X}$ #/M^3	Station	$\bar{X}$ #/M^3	Station	$\bar{X}$ #/M^3	Station	$\bar{X}$ #/M^3	Station	$\bar{X}$ #/M^3
1	B	1.52	No		F	0.89	No		F	3.63
2	F	1.26	Teredinids		E	0.34	Teredinids		B	0.49
3	C	0.96	Any		C	0.29	Any		A	0.44
4	D	0.41	Station		D	0.25	Station		C	0.12
5	A	0.26			A	0.04			E	0.11
6	E	0.12			B	0.02			D	0.10

numbers of teredinids captured per cubic meter were 0.12, 0.34, and 0.11, respectively.

The Oyster Creek power plant was not releasing a thermal effluent into Oyster Creek during the following periods, December 26, 1975 to March 11, 1976, and from May 1 through August 4, 1977. Thus, for the first time period the organisms inhabiting this body of water were subjected to normal winter-spring water temperatures for the area. During the second period organisms were subjected to ambient spring-summer water temperatures. As a result it was not possible to determine from plankton sampling whether the thermal effluent from power plant operations was causing an extension of the normal breeding season of teredinid populations occupying wooden structures in Oyster Creek for the above listed time periods.

There also was a shut-down of the Oyster Creek power plant from July 28 through 30, 1976. However, from this brief amount of time, and the available data, it is not possible to determine what effects, if any, it may have had on teredinids occupying Oyster Creek.

Water quality data are presented in Appendix D.

Literature Cited

Gunter, G. 1957. Temperature. pp. 159-184. In Treatise on Marine ecology and paleoecology. Vol. 1. 1296 p. J.W. Hedgepeth (ed.). The Geological Society of American Memoir 67. The Geological Society of America, New York, N.Y.

Sokal, R.R. and F.J. Rohlf. 1969. Biometry: The principles and practice of statistics in biological research. W.H. Freeman and Company, San Francisco, 776 p.

APPENDIX C

APPENDIX C

BORER DEVELOPMENTAL STATUS

Introduction

The role of temperature in regulating reproductive cycles in marine invertebrates is well-known (e.g., Loosanoff, 1942). The thermal plume from the Oyster Creek generating station, therefore, could have an effect on the normal reproductive cycles of the teredinid borers in those areas influenced by the plume.

Alteration of the normal cycles theoretically could occur in one or more ways. Initiation of gonadal development could be earlier than expected in the thermally-affected areas, resulting in earlier than normal spawning. Given the short time necessary for newly settled larvae to become sexually mature (Turner, 1966), some could settle and spawn within one season. Should the waters in a given area be warmer than those of surrounding areas not affected by the thermal plume, the breeding period might be extended well into the fall, and in addition, an extended breeding season might lead to two spawning peaks within a given year - one in the spring and one in the fall.

Such alterations in the normal reproductive cycles can be ascertained qualitatively through examination of the various stages of gonad development in the borers. Histological studies of gonads of the various teredine borers were begun, therefore, to assess the developmental stages of the gonads from borers in the areas affected by the thermal plume and compare those stages with those of gonads from borers in non-affected areas. Data from the first year's efforts (Richards et al., 1976) did not suggest any alteration in breeding patterns around Barnegat Bay. The studies continued and the second set of observations from August, 1976, through August, 1977 are reported below.

Materials and Methods

Teredine borers were removed from exposure panels in the laboratory, placed in Davidson's fixative for 24 hours and rinsed with

70 percent denatured ethanol. Portions of the shipworms containing the gonads were excised, and kept in 70 percent denatured ethanol until processing. For processing, the tissues were further dehydrated in ethanol, and then placed in two changes of methyl benzoate and cleared in three changes of xylene. They were embedded in Paraplast and sectioned at six microns. The slides were then stained in Harris' hematoxylin and eosin.

The slides were examined microscopically to determine the stage of gonad development at the time the exposure panels were removed from the water. Because the Teredinidae are bivalve mollusks, the characteristics of gonad development are similar to those of other bivalves and a classification of developmental stages used by other investigators examining gonads of various bivalves (e.g., Ropes and Stickney, 1965; Ropes, 1968; Holland and Chew, 1974) was suitable. The various phases of gonad development were characterized as follows:

Female Gonads

1. Early active phase - Ovogonia occurred at the periphery and within the alveolar walls; nuclei of ovogonia contained basophilic nucleoli. The alveolar walls were not completely contracted and lumina were evident in most gonads.

2. Late active phase - Large ovocytes were attached to the alveolar wall and protruded into the alveolar lumen. The ovocyte nucleus was large and contained a basophilic nucleolus.

3. Ripe phase - The shipworm was considered ripe when the number of ovocytes that had become detached from the alveolar wall and were free in the lumen of the alveolus exceeded the number still attached to the alveolar wall.

4. Partially spawned phase - A few ovocytes were still attached to the thickened alveolar wall, and some residual ripe ova remained in the alveolar lumen.

5. Spent phase - Alveoli were usually empty of ripe ovocytes and those that remained were undergoing cytolysis.

Male Gonads

1. Early active phase - Shipworms in the early active phase contained darkly staining spermatogonia in the thickened alveolar wall.

2. Late active phase - This phase was characterized by the proliferation and maturation of spermatocytes, most of which had migrated toward the center of the alveolus. A central lumen was present in the alveolus and occasionally a small number of spermatozoa were present in the lumen.

3. Ripe phase - In the ripe phase, the alveolar lumen was crowded with darkly stained spermatozoa.

4. Partially spawned phase - A small number of spermatozoa remained in the alveolar lumen.

5. Spent phase - Alveoli in the spent phase contained very few or no spermatozoa.

Hermaphroditic gonads were characterized according to the condition of both the ovocytes and spermatocytes within the various alveoli. The slides were numbered consecutively according to sample number, and gonad condition was noted for each sample. The phase designations of the gonads were correlated with the species and station designations only after the gonads were characterized. This tended to eliminate any possible bias for station or season.

Results and Discussion

During 1977, a total of 294 specimens of teredinid borers, representing samples collected from August, 1976, through August, 1977 were examined for stage of gonad development. An additional 212 specimens have been processed and are currently being examined.

As in 1976, no borers were recovered from regular exposure panels during the period from April through July, 1977, because of the six-month exposure schedule.

The number of specimens of each borer species and the stage of development at each sampling month are shown in Figures C-1 through C-7. Figure C-7 shows the most advanced stage of gonad development at each month for *Bankia gouldi*. Similar information is provided for *Teredo navalis* in Figure C-8.

The developmental stages for the borers recovered from the exposure panels are discussed below by species.

Bankia gouldi

Based on the most advanced stages of gonad development at each station, it appears as if spawning was initiated slightly earlier in 1976 at Stations 7 and 8 than at the other stations. The patterns of gonad development at Stations 7, 8, 13, 14, and 15 are generally similar however, with ripe gonads appearing at 13, 14, and 15 in August, and partially spent gonads at 7 and 8. Ripe gonads also were found at Station 5 in August, but by September, only early active gonads could be found.

Spring gonadal activity commences during a time when we do not recover shipworms from the regular panels because of the six-month exposure cycle. Thus, it is difficult to comment on whether operations of the power station induce an earlier breeding season at some stations. Two additional panels were installed at each exposure panel location in August, 1976 for over-wintering studies of possible early gonad development. These panels were removed and replaced in May and June, 1977. Teredinids were obtained at 3 locations, 1, 7, and 11. The specimens were dead and no results could be obtained. The panels installed in May and June, 1977 will be examined in May and June, 1978. There is no evidence, however, that there has been any significant increase in gonad activity at any station by March, 1977, and there probably should have been if spawning were going to start significantly sooner at any station.

Patterns, in general, are not very different from those developed the previous year.

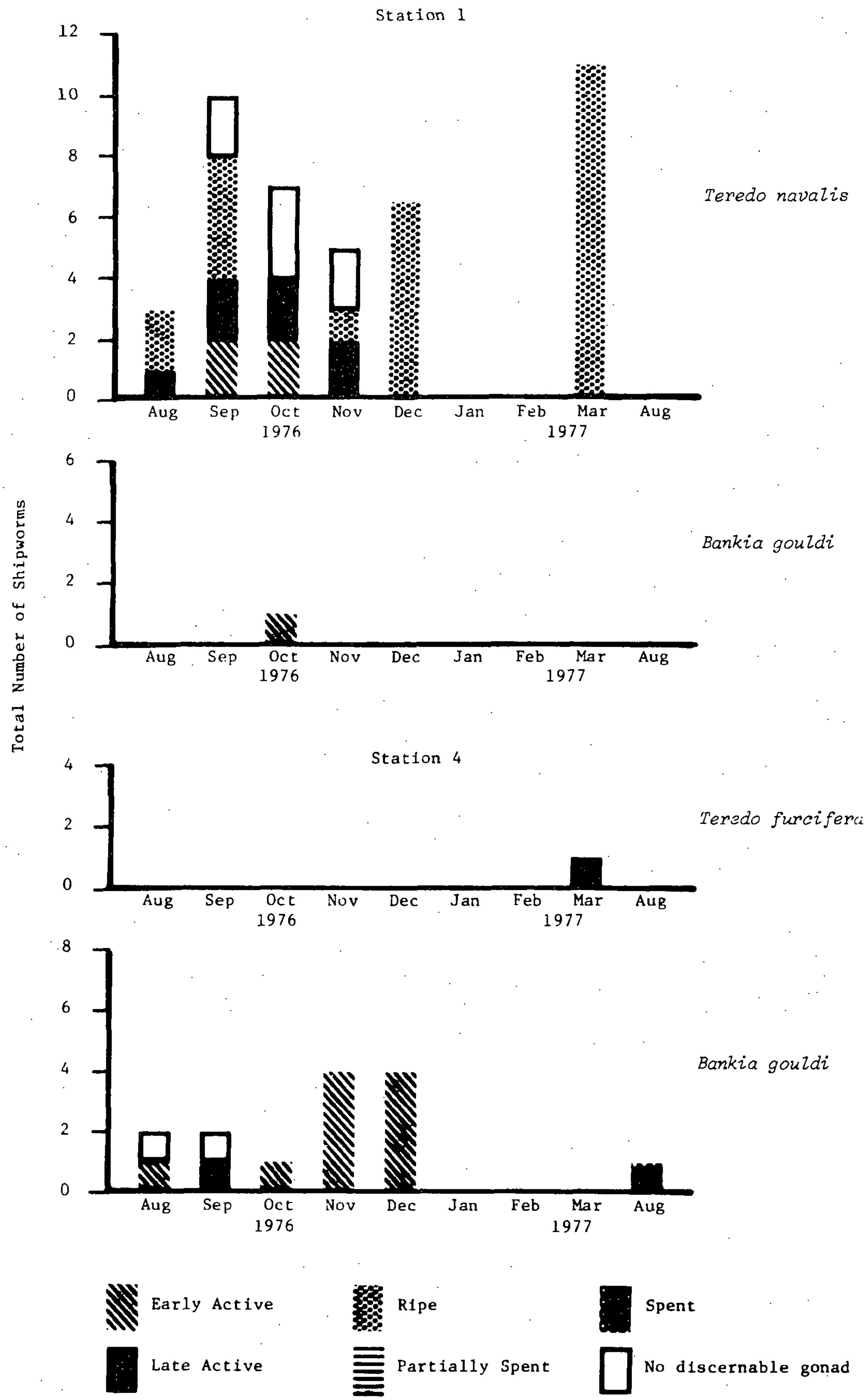


FIGURE C-1. NUMBER OF SPECIMENS AND STAGE OF GONAD DEVELOPMENT OF TEREDINE BORERS IN EXPOSURE PANELS AT STATIONS 1 AND 4 IN BARNEGAT BAY, NEW JERSEY FROM AUGUST, 1976, THROUGH AUGUST, 1977

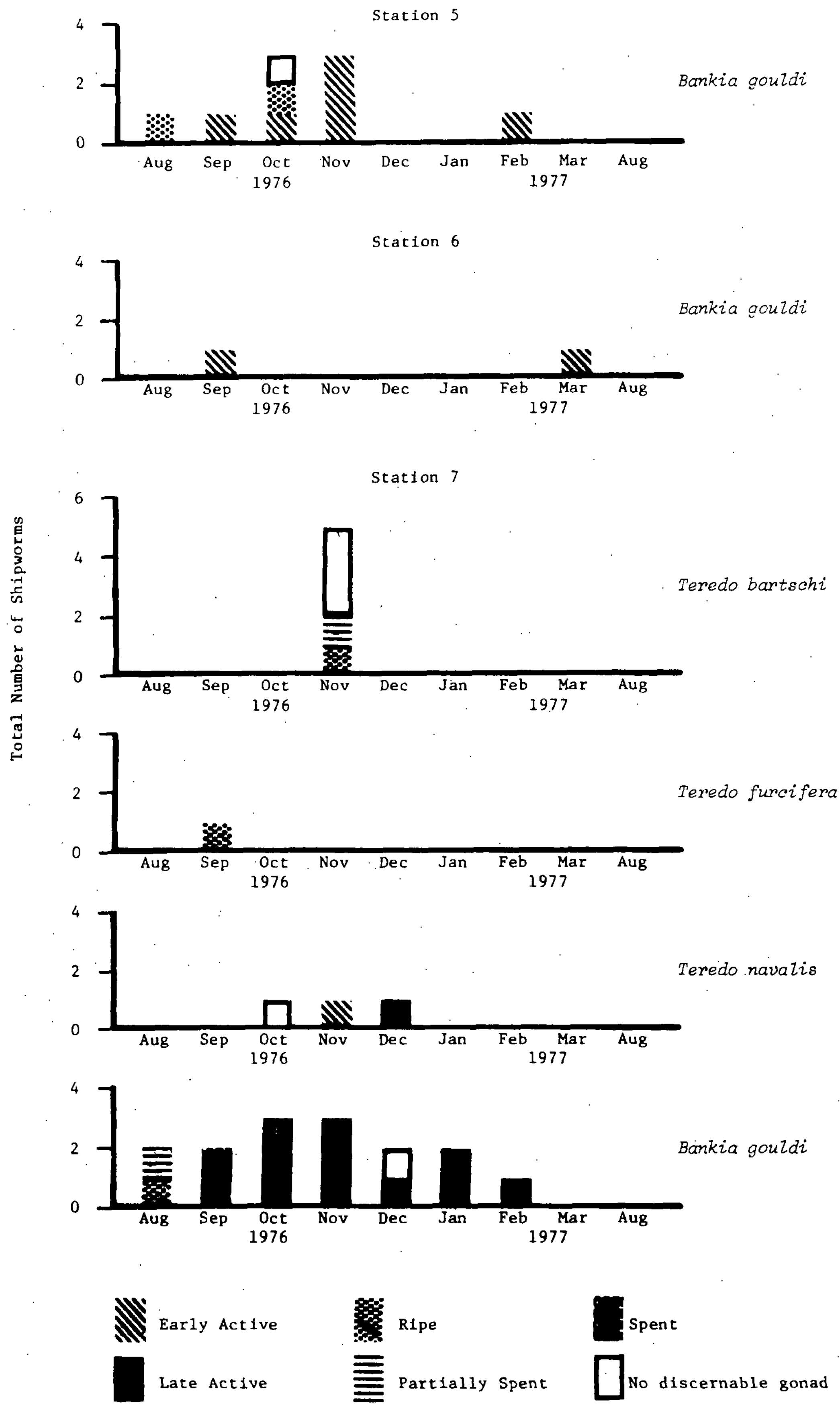


FIGURE C-2. NUMBERS OF SPECIMENS AND STAGE OF GONAD DEVELOPMENT OF TEREDINE BORERS IN EXPOSURE PANELS AT STATIONS 5, 6, AND 7 IN BARNEGAT BAY, NEW JERSEY FROM AUGUST, 1976 THROUGH AUGUST, 1977

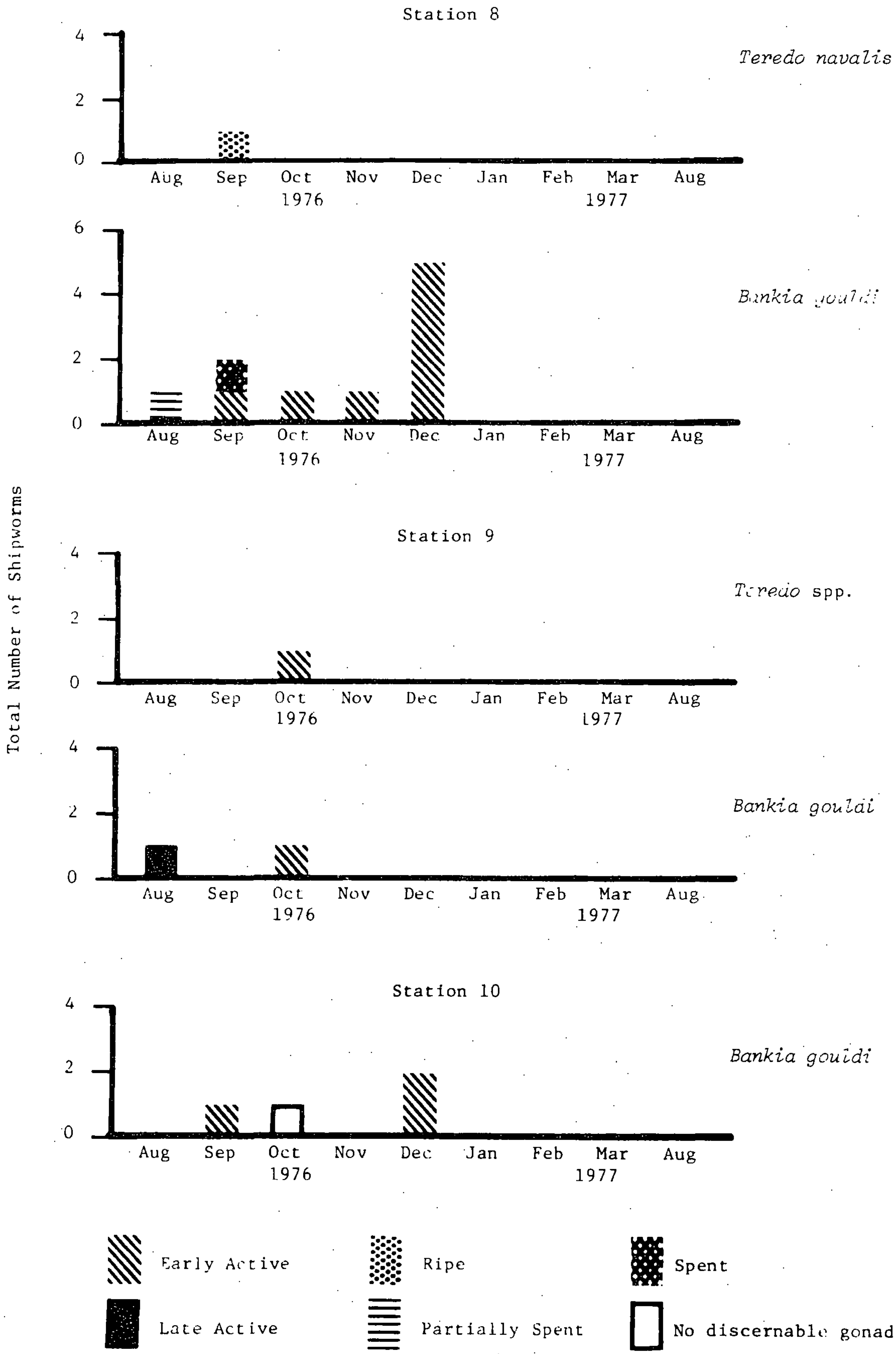


FIGURE C-3. NUMBERS OF SPECIMENS AND STAGE OF GONAD DEVELOPMENT OF TEREDINE BORERS IN EXPOSURE PANELS AT STATIONS 5, 6, AND 7 IN BARNEGAT BAY, NEW JERSEY FROM AUGUST, 1976, THROUGH AUGUST, 1977

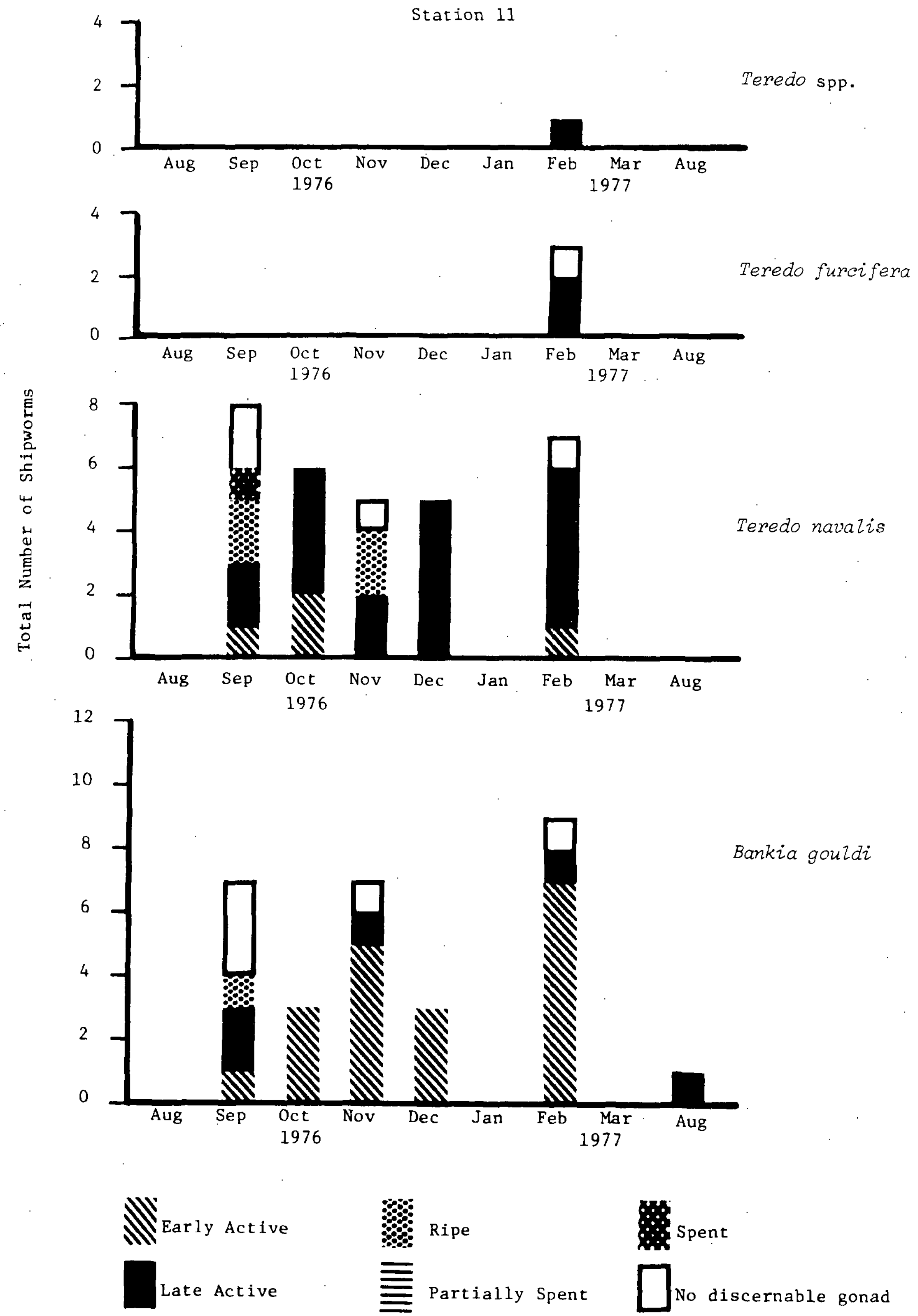


FIGURE C-4. NUMBERS OF SPECIMENS AND STAGE OF GONAD DEVELOPMENT OF TEREDINIE BORERS IN EXPOSURE PANELS AT STATION 11 IN BARNEGAT BAY, NEW JERSEY FROM AUGUST, 1976, THROUGH AUGUST, 1977

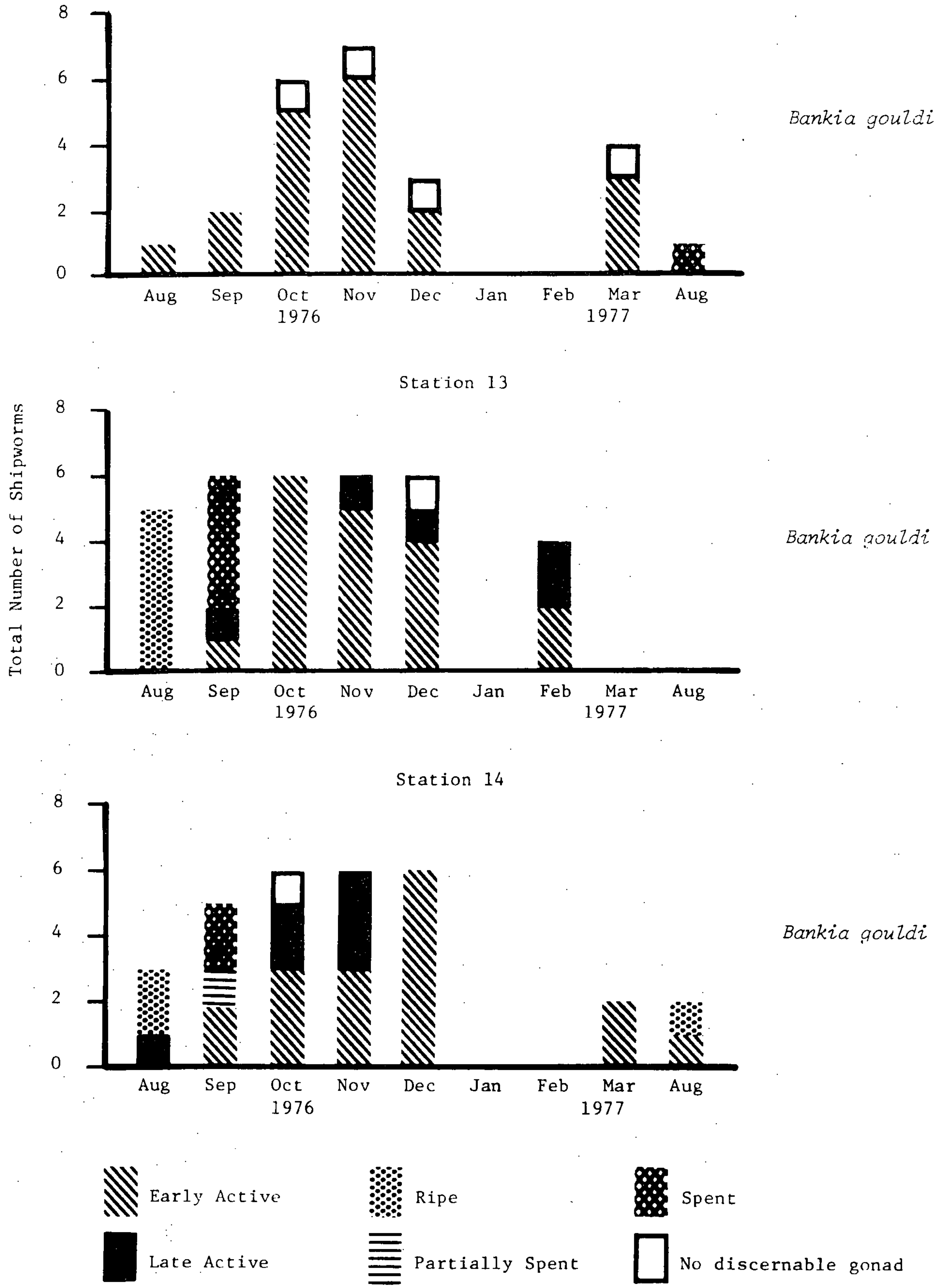


FIGURE C-5. NUMBERS OF SPECIMENS AND STAGE OF GONAD DEVELOPMENT OF TEREDINE BORERS IN EXPOSURE PANELS AT STATIONS 12, 13, AND 14 IN BARNEGAT BAY, NEW JERSEY FROM AUGUST, 1976, THROUGH AUGUST, 1977

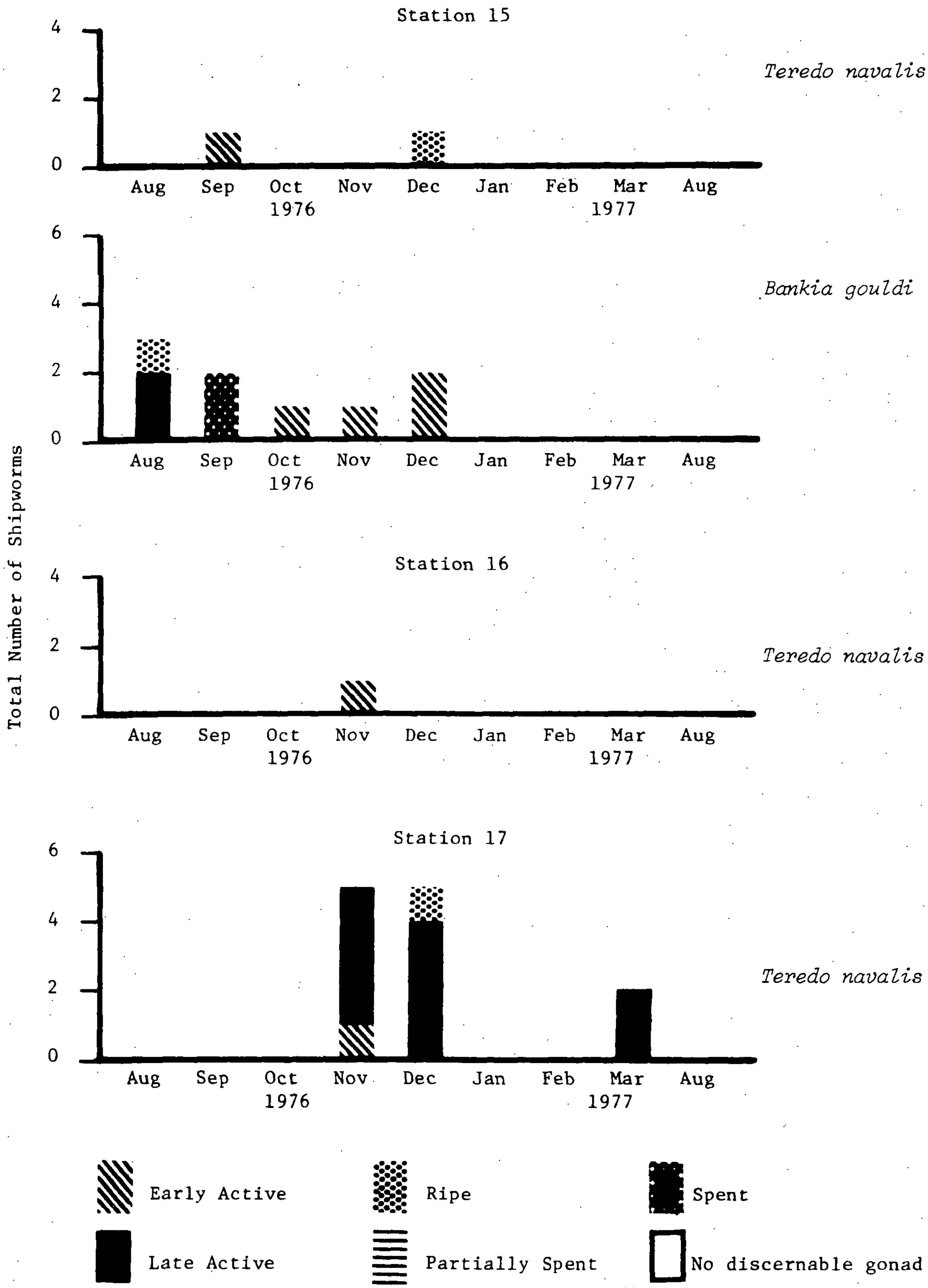


FIGURE C-6. NUMBERS OF SPECIMENS AND STAGE OF GONAD DEVELOPMENT OF TEREDINE BORERS IN EXPOSURE PANELS AT STATIONS 15, 16, AND 17 IN BARNEGAT BAY, NEW JERSEY FROM AUGUST, 1976, THROUGH AUGUST, 1977

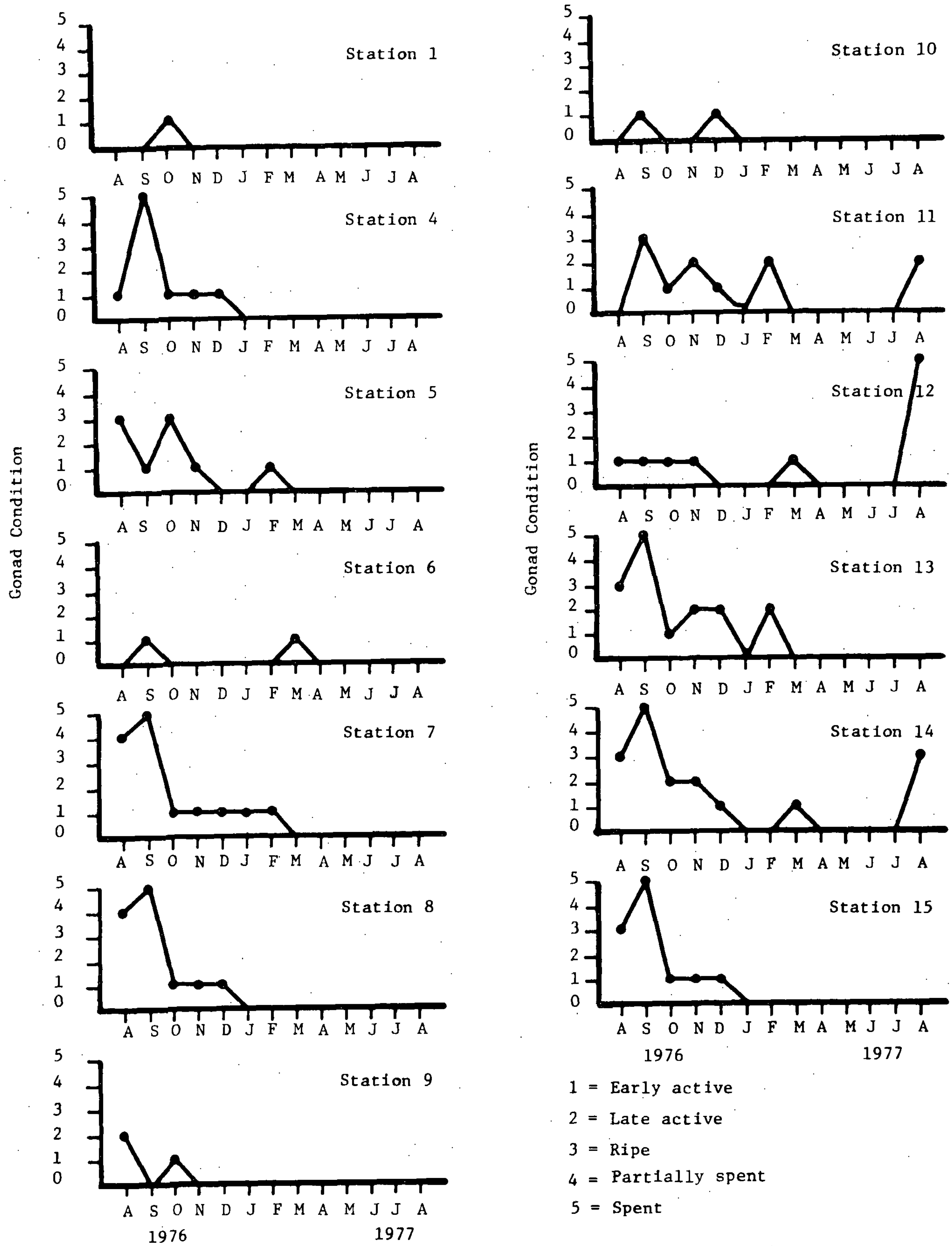


FIGURE C-7. MOST ADVANCED STAGE OF GONAD DEVELOPMENT IN Bankia gouldi EXTRACTED FROM EXPOSURE PANELS LOCATED IN BARNEGAT BAY, NEW JERSEY FROM AUGUST 1976 THROUGH AUGUST, 1977.

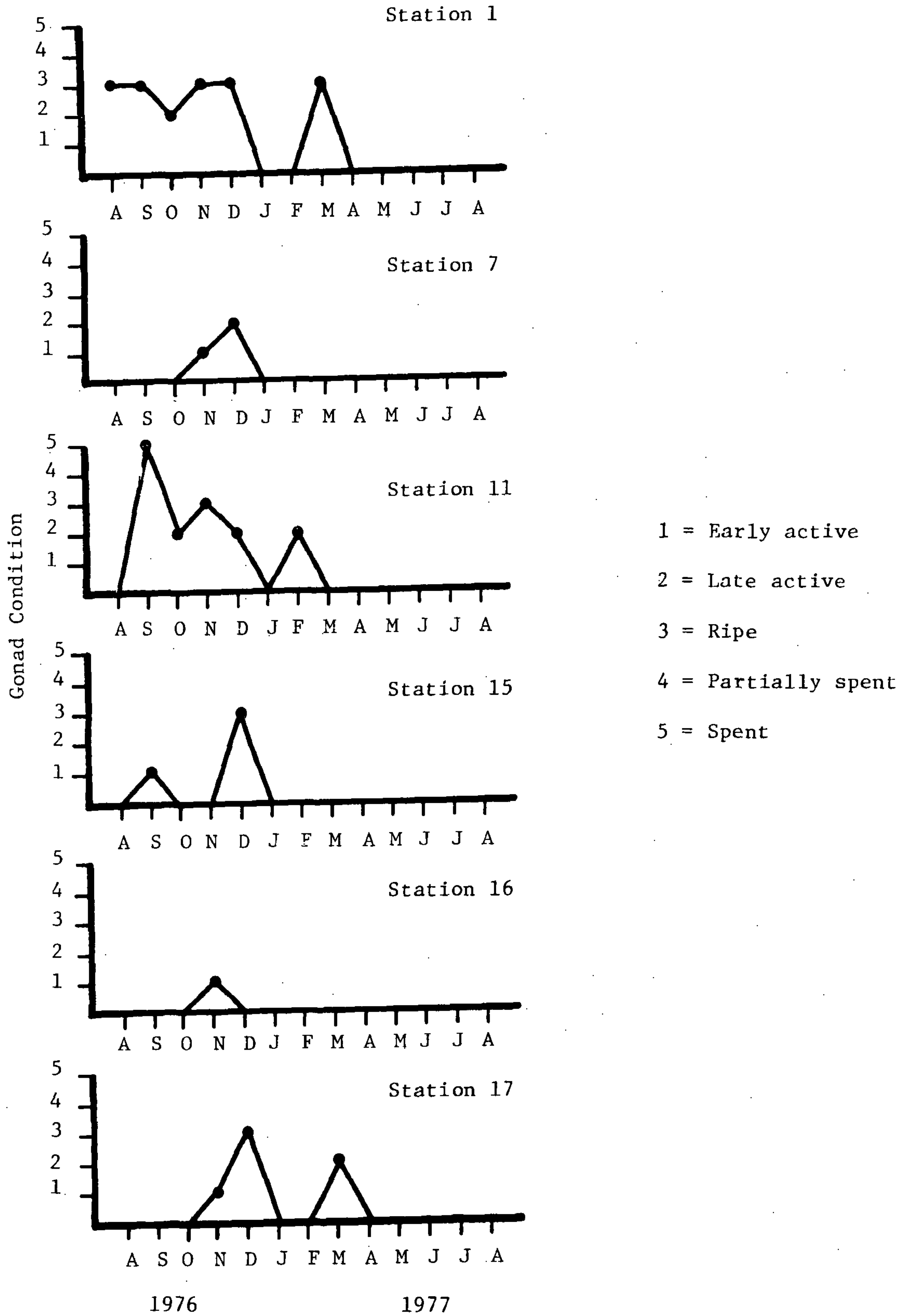


FIGURE C-8. MOST ADVANCED STAGE OF GONAD DEVELOPMENT IN Teredo navalis EXTRACTED FROM EXPOSURE PANELS LOCATED IN BARNEGAT BAY, NEW JERSEY FROM AUGUST 1976 THROUGH AUGUST 1977.

Teredo navalis

From August, 1976, through August, 1977, specimens of *Teredo navalis* were recovered from only six stations; Stations 1, 7, 11, 15, 16, and 17. This is a decrease of four stations since last year's report. Although spawning probably occurred at each of the six stations, only Station 11 produced specimens with spent gonads. Ripe gonads were found generally throughout the winter at Station 1; as late as December, 1976 at Stations 15 and 17; and in November at Station 11.

The gonad development patterns at the six stations were dissimilar throughout. The dissimilarity and possibly the decrease in the number of stations from which specimens were recovered might be related to the appearance of a protozoan parasite, tentatively identified as *Minchinia* sp., which occurs in specimens of *Teredo* from Barnegat Bay (Hillman, 1978) and other areas (Hillman, unpublished data). The distribution and abundance of the parasite does not appear to be related to power station operations although infected shipworms in the warm effluent could conceivably be subjected to greater stress from the parasite. Spores of the parasite have been found in all types of tissues examined, including the gonad. Tissue destruction is considerable in heavy infections, and spawning patterns could be affected both through increased mortality of the infected shipworms, or inability to spawn because of damaged gonads.

Teredo furcifera

Teredo furcifera specimens for gonad study were recovered only at Stations 4, 7, and 11, and then only rarely (Figures C-1, C-2, and C-4). Only one specimen was found with ripe gonads, and that was at Station 7 in September, 1976. The occurrence of ripe gonads in Sepember is consistent with our other observations, and does not necessarily indicate a power station effect on spawning patterns.

Teredo bartschi

Teredo bartschi specimens for gonad study occurred only at Station 7. Five specimens were recovered in November, 1976, one with ripe gonads, one with partially spent gonads, and three showing no discernable gonadal activity. Three more specimens were recovered in August, 1977, all of which showed gonads in the late active phase.

Teredo spp.

One unidentifiable specimen was recovered in October, 1976. It was in the early active phase of development.

The numbers of males, females, and hermaphrodites found each month are shown in Table C-1. As reported in the previous annual report (Richards et al., 1976) there tend to be more males in an exposure panel than would be found normally. This is because the teredinids, like many mollusks, are protandrous, maturing first to males, then changing to females. Many of the shipworms in the panels are relatively newly set and would tend to be males.

There is no indication from the data reported here that power station activities have significantly altered the breeding patterns or cycles of teredine borers in Barnegat Bay.

TABLE C-1. NUMBERS OF MALES, FEMALES, AND HERMAPHRODITES AMONG SPECIMENS OF TEREDINE BORERS FOUND IN EXPOSURE PANELS FROM THE BARNEGAT BAY AREA FROM AUGUST, 1976, THROUGH AUGUST, 1977

	Bankia gouldi			*Teredo navalis*			*Teredo furcifera*			*Teredo bartschi*			*Teredo* spp.		
	M	F	H	M	F	H	M	F	H	M	F	H	M	F	H
1976															
Aug	14	4			3										
Sep	12	16		1	12	3	1								
Oct	17	13		2	1	9							1		
Nov	19	15		1	2	10					1	1			
Dec	19	11		4	4	10									
1977															
Jan	1	1													
Feb	6	8			2	4			2						1
Mar	2	4		3	2	8			1						
Aug	5	3													

Literature Cited

Hillman, R.E. 1978. The occurrence of *Minchinia* sp. (Haplosporida, Haplosporidiidae) in species of the molluscan borer, *Teredo* from Barnegat Bay, New Jersey. J. Invert. Path. 31 (In press).

Holland, D.A. and K.K. Chew. 1974. Reproductive cycles of the Manila clam (*Venerupis japonica*), from Hood Canal, Washington. Proc. Natl. Shellf. Assoc. 64:53-58.

Loosanoff, V.L. 1942. Seasonal gonadal changes in the adult oysters, *Ostrea virginica*, of Long Island Sound. Biol. Bull. 82:195-206.

Nair, N.B. and M. Saraswathy. 1971. The biology of wood-boring teredinid molluscs. Adv. Mar. Biol. 9:335-509.

Richards, B.R., A.E. Rehm, C.I. Belmore, and R.E. Hillman. 1976. Wood-borer Study Associated with the Oyster Creek Generating Station. Battelle-Columbus Laboratories, William F. Clapp Laboratories, Inc. Ann. Rpt. to Jersey Central Power & Light Company for the Period June 1, 1975 to May 31, 1976.

Ropes, J.W. 1968. Reproductive cycle of the surf clam, *Spisula solidissima*, in offshore New Jersey. Biol. Bull. 135:349-365.

Ropes, J.W. and A.P. Stickney. 1965. Reproductive cycle of *Mya arenaria* in New England. Biol. Bull. 128:315-327.

Turner, R.D. 1966. A Survey and Illustrated Catalogue of the Teredinidae (Mollusca:Bivalvia). Mus. Comp. Zool., Harvard University, Cambirgde, Massachusetts. 265 pp.

APPENDIX D

APPENDIX D

WATER QUALITY

Introduction

Various water quality parameters were used to describe the physical-chemical environment at the exposure panel and plankton stations. These parameters, particularly water temperature and salinity, were used to define the minimum/maximum limits for the marine borers found in Barnegat Bay.

Materials and Methods

Water quality measurements were taken each month at the 18 exposure panel and six plankton stations (Figure D-1), with the following exceptions. In January, 1977, water quality values were only recorded at exposure panel Stations 5, 7, and 8. The remaining stations were frozen in. Exposure panel stations with the exception of Stations 5, 7, 8, 9, 11, and 13 were frozen in during the February, 1977 sampling effort, and water quality measurement were not taken.

Water quality parameters were recorded twice monthly at the six plankton stations from June, 1976, through November, 1977, with the following exceptions. During January and the first half of February, Barnegat Bay was frozen over. Water quality values were not recorded at Station F during the second half of February. The absence of channel markers during this period prevented safe boat travel to the Station F area.

Water temperature, salinity, pH, and dissolved oxygen were measured monthly at each exposure panel and plankton station by Battelle personnel with a Hydrolab Model II B. The Hydrolab was calibrated prior to each day's use. During the second half of the month, Jersey Central Power & Light Company staff measured water quality values at each of the six plankton stations, using a Yellow Springs Instrument recorded for salinity, dissolved oxygen, and temperature; pH was measured with an instrument manufactured by Analytical Measurements, and depth was recorded with a Ray Jefferson depth meter.

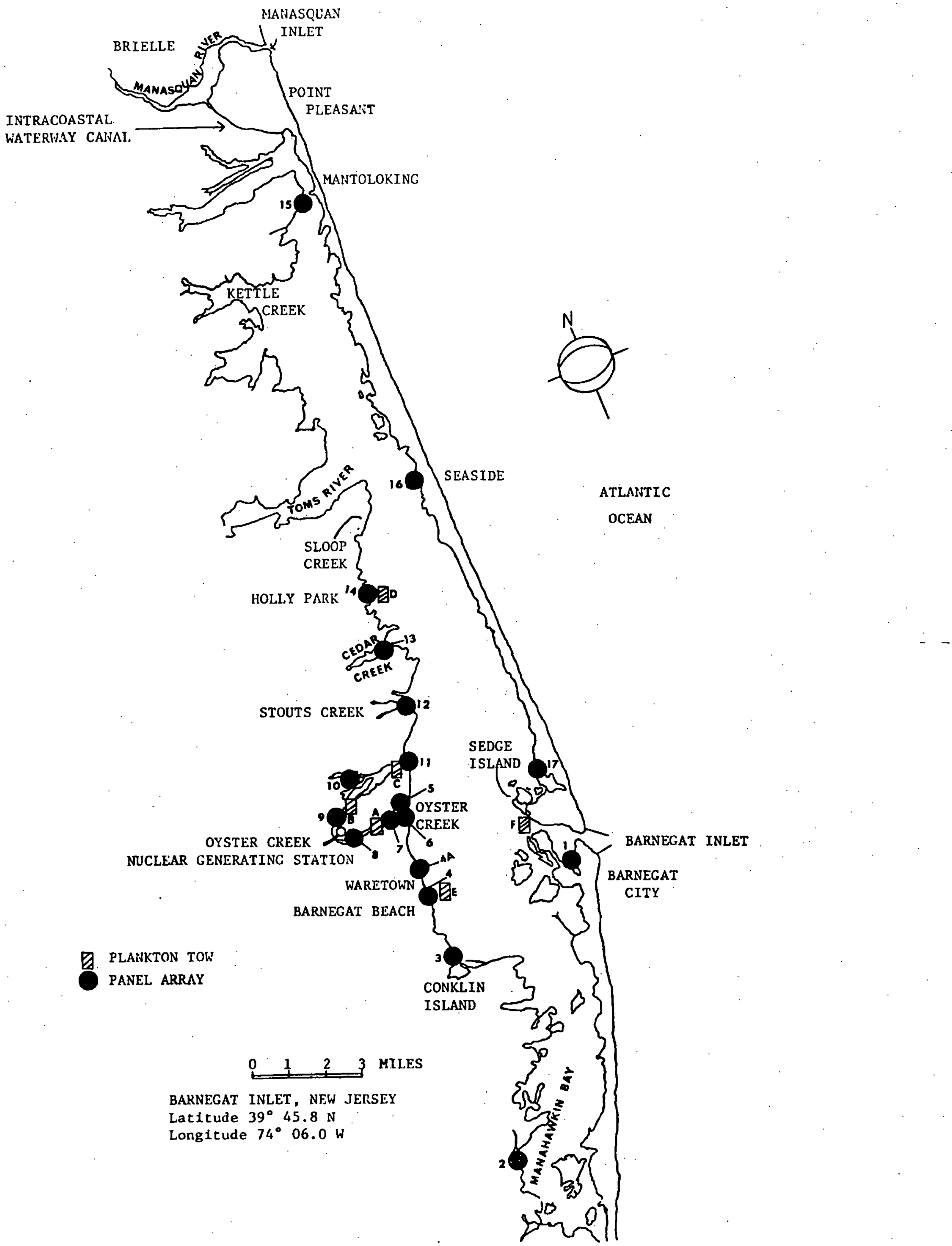


FIGURE D-1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHICAL LOCATIONS OF EXPOSURE PANELS AND PLANKTON TOWS

Results

The water quality values recorded each month at each of the exposure panel stations from June, 1976, through December, 1977, and each of the teredinid plankton stations from June, 1976, through November, 1977, are presented in Tables D-1 through D-51. Tables D-52 through D-76 give water quality values by station for each of the above tasks for the same time periods as shown above.

Table D-77 gives the mean salinity, temperature, and their standard deviation at each of the exposure panel stations for the periods from June, 1976, through December, 1977, and from January through December, 1977, and for the combined periods from June, 1976, through December, 1977. Salinity and temperature ranges are given for the combined periods only.

The oxygen and pH values recorded during the course of the study were within the range to support teredinids (Table D-78). The mean salinity values and the range recorded for each station from June, 1976, through December, 1977, are presented in Table D-78. Salinity did not appear to be a limiting factor at any of the exposure panel and plankton stations.

Figure D-2 shows the average water temperature at the Oyster Creek Railroad Bridge plotted at five day intervals. These temperature data were provided by Jersey Central Power & Light Company.

Based on the available salinity and seawater temperature data, it was not feasible to correlate those parameters with the settling of larvae on the short-term panels or the destruction of the long-term panels.

However, the salinities recorded at each of the exposure panel and plankton stations were in the range to support breeding populations of *Bankia gouldi*, *Teredo navalis*, *Teredo bartschi*, and *Teredo furcifera*and their larvae when they entered the plankton (Table D-78). The temperature tolerance range for *T. bartschi* and *T. furcifera* in Barnegat Bay is unknown. The summer water temperatured in Barnegat Bay were high enough to support subtropical species,

TABLE D-1. EXPOSURE PANEL STATIONS WATER QUALITY DATA, JUNE, 1976

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature - C°	O_2	pH
1	6/8/76	0820	1.5	27.8	19.0	8.0	7.8
			6	27.8	19.0	8.0	7.8
2	6/9/76	1305	1	21.3	24.5	8.3	7.7
3	6/9/76	1335	2.5	24.2	22.5	9.1	7.7
4	6/9/76	1410	3.5	20.6	21.5	7.2	7.7
5	6/9/76	1425	3	15.9	27.5	8.7	7.7
6	6/9/76	1440	1	22.8	28.5	8.2	7.7
7	6/9/76	1453	2	22.8	28.5	8.0	7.7
8	6/10/76	1600	1.5	22.8	28.5	8.0	7.7
			12	22.8	28.5	8.0	7.7
9	6/10/76	1030	1.5	24.2	22.0	8.3	7.7
			7	24.2	22.0	8.3	7.7
10	6/9/76	1220	3	20.6	22.0	6.0	7.7
11	6/9/76	0840	3	22.1	21.5	8.5	7.7
12	6/10/76	0725	4	16.6	22.5	8.9	7.7
13	6/10/76	0750	1	15.9	22.5	8.3	7.7
14	6/10/76	0815	1.5	19.2	22.5	8.2	7.7
15	6/10/76	1100	5	18.6	22.0	8.5	7.7
16	6/10/76	1015	4	16.6	22.0	2.5	7.7
17	6/10/76	0945	1	24.2	23.0	7.2	7.7

TABLE D-2. EXPOSURE PANEL STATIONS WATER QUALITY DATA, JULY, 1976

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature - C°	O_2	pH
1	7/14/76	0850	1.5	28.4	18.5	7.5	7.7
			6	28.4	18.5	7.0	7.7
2	7/13/76	0855	1.5	27.0	22.0	6.0	7.8
3	7/13/76	0925	3	27.0	23.5	4.7	7.8
4	7/13/76	0945	2.5	27.7	23.5	3.9	7.8
5	7/13/76	1005	4	24.9	27.0	5.2	7.8
6	7/13/76	1020	1	25.6	27.0	4.2	7.8
7	7/13/76	1045	1.5	26.3	26.5	6.3	7.8
			8	26.3	26.5	6.3	7.8
8	7/13/76	1100	1.5	27.0	27.0	6.9	7.8
			6	27.0	27.0	6.9	7.8
9	7/15/76	1130	1.5	27.7	22.0	8.0	7.7
			10	27.7	22.0	8.0	7.7
10	7/13/76	1215	1.5	21.3	24.5	5.9	7.8
11	7/15/76	1000	4	28.4	22.5	7.7	7.7
12	7/13/76	1237	2	25.6	24.0	7.5	7.8
13	7/13/76	1300	2	16.5	21.5	8.6	7.8
14	7/13/76	1325	1.5	23.4	22.0	8.4	7.8
15	7/15/76	1315	4	21.3	22.0	9.4	7.8
16	7/13/76	1505	2	22.7	22.5	4.5	7.8
17	7/13/76	1433	1.5	29.1	20.5	8.6	7.8

TABLE D-3. EXPOSURE PANEL STATIONS WATER QUALITY DATA AUGUST, 1976

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature - C°	O_2	pH
1	8/12/76	1230	1.5	27.7	23.5	8.2	7.9
			7	27.7	22.0	7.4	7.9
2	8/11/76	0935	1.5	22.7	23.5	6.1	7.9
3	8/11/76	1045	3	24.1	23.5	5.3	7.9
4	8/11/76	1040	4	26.3	23.0	6.7	7.9
5	8/12/76	1600	5	22.7	30.0	9.2	7.9
6	8/11/76	1135	1.5	21.3	27.5	6.7	7.9
7	8/11/76	1155	1	22.7	28.0	7.0	7.9
8	8/11/76	1300	7	23.4	29.0	8.3	7.9
9	8/12/76	*	1.5	24.1	26.0	8.0	7.9
			8	24.1	25.5	8.2	7.9
10	8/11/76	1500	2.5	6.4	26.0	7.3	7.9
11	8/12/76	1715	18	22.7	28.0	7.9	7.9
			5	22.7	28.0	7.9	7.9
12	8/11/76	1525	3	22.0	26.0	11.4	7.9
13	8/11/76	1355	1	10.4	26.5	7.6	7.9
14	8/11/76	1635	1.5	15.8	27.0	8.4	7.9
15	8/12/76	0805	3	18.5	24.5	8.2	7.9
16	8/11/76	1850	3	17.9	24.0	5.0	7.9
17	8/11/76	1820	2	24.9	25.0	10.4	7.9

* - Time not recorded

TABLE D-4. EXPOSURE PANEL STATIONS WATER QUALITY DATA, SEPTEMBER, 1976

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature C°	O_2	pH
1	9/15/76	1045	7	29.1	22.0	6.7	8.2
2	9/14/76	0820	1.5	27.7	21.5	9.1	7.9
3	9/14/76	0855	2	27.0	22.0	6.4	7.8
4	9/14/76	0915	2.5	26.3	22.5	6.4	7.8
5	9/15/76	1424	1.5	25.6	28.0	8.7	8.1
			10	25.6	26.5	7.1	8.0
6	9/14/76	1003	1.5	26.3	22.0	7.9	7.9
7	9/14/76	1027	4	24.9	27.0	6.7	7.8
8	9/14/76	1045	2	26.3	26.0	6.8	7.8
			10	26.3	26.0	6.8	7.8
9	9/15/76	0900	2	25.6	24.5	7.5	7.9
			6	25.6	24.5	7.5	7.9
10	9/14/76	1204	1	20.6	23.0	8.1	7.8
11	9/14/76	1137	1.5	26.3	23.0	8.6	7.8
12	9/14/76	1222	3	25.6	22.0	8.5	7.8
13	9/14/76	1257	1.5	22.7	24.0	8.9	7.9
14	9/14/76	1325	1	20.6	24.5	9.1	7.9
15	9/17/76	1015	3	19.9	22.0	7.8	7.9
16	9/14/76	1400	5	19.2	22.5	8.3	7.7
17	9/14/76	1445	3	29.9	22.5	8.3	7.8

TABLE D-5. EXPOSURE PANEL STATIONS WATER QUALITY DATA, OCTOBER, 1976

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature C°	O_2	pH
1	10/12/76	1045	1.5	29.9	15.0	8.75	7.8
			6	29.9	15.0	8.75	7.8
2	10/13/76	0735	1.5	27.7	13.0	9.6	7.5
3	10/13/76	0805	3	25.6	13.5	9.9	7.5
4	10/13/76	0827	4	25.6	14.0	9.7	7.5
5	10/12/76	1815	2	22.7	18.0	9.4	7.5
6	10/12/76	1825	2	23.4	20.0	7.7	7.5
7	10/12/76	1837	4	26.3	20.5	9.7	7.5
8	10/13/76	0853	2	25.6	21.0	10.4	7.5
			9	25.6	21.0	10.4	7.5
9	10/12/76	1440	2	27.7	16.5	10.4	7.5
			10	27.7	16.0	10.3	7.5
10	10/13/76	0957	4.5	24.1	15.5	7.3	7.5
11	10/13/76	0937	2	25.6	14.0	9.8	7.5
12	10/13/76	1017	3	25.6	15.0	9.8	7.5
13	10/12/76	1720	2	19.9	17.0	10.4	7.5
14	10/12/76	1043	1	23.4	15.0	9.7	7.5
15	10/13/76	1250	4	23.4	14.0	11.0	7.5
16	10/13/76	1124	2.5	19.9	13.0	10.1	7.5
17	10/13/76	1205	3	29.9	13.0	11.0	7.5

TABLE D-6. EXPOSURE PANEL STATIONS WATER QUALITY DATA, NOVEMBER, 1976

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature C°	O_2	pH
1	11/12/76	0810	6	28.4	5.5	13.4	7.7
2	11/9/76	0755	1	22.0	4.0	12.0	7.7
3	11/9/76	0835	2	22.0	3.0	13.0	7.6
4	11/9/76	0855	4	25.6	6.0	12.6	7.7
5	11/9/76	0915	1.5	23.4	9.5	11.1	7.7
6	11/9/76	0930	1	22.7	10.0	11.2	7.7
7	11/9/76	0945	2.5	23.4	10.5	11.0	7.8
8	11/9/76	1007	2	24.1	10.5	14.4	7.7
			10	24.1	10.5	14.4	7.7
9	11/11/76	1620	2	25.6	5.3	14.0	7.7
			8	25.6	5.3	14.0	7.7
10	11/9/76	1125	4	21.3	8.0	11.1	7.7
11	11/9/76	1103	2.5	24.1	5.5	14.2	6.6
12	11/9/76	1145	4	24.1	5.5	13.0	7.7
13	11/9/76	1205	1	11.1	3.7	11.2	7.6
14	11/9/76	1225	1	22.7	4.0	13.4	7.7
15	11/9/76	1303	1.5	15.2	4.5	12.6	7.7
16	11/9/76	1330	1.5	27.0	3.0	13.0	7.7
17	11/9/76	1417	3	23.4	4.1	12.4	7.7

TABLE D-7. EXPOSURE PANEL STATIONS WATER QUALITY DATA, DECEMBER, 1976*

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature C°	0_2	pH
1	12/8/76	0820	6	**	4.5	13.2	7.7
2	12/7/76	0813	2	26.3	1.5	13.8	7.7
3	12/7/76	0845	3	25.6	2.5	14.4	7.7
4	12/7/76	0907	4	23.6	3.5	13.6	7.7
5	12/7/76	0920	2	22.7	4.0	12.0	7.6
6	12/7/76	0935	1.5	22.7	7.0	12.2	7.7
7	12/7/76	0955	1.5	13.8	8.5	11.8	7.7
8	12/10/76	1220	2	15.2	5.5	14.0	7.6
			6	15.2	5.5	14.0	7.6
9	12/10/76	1340	6	21.3	4.5	12.9	7.5
10	12/7/76	1045	3	<1	4.0	12.4	7.7
11	12/7/76	1015	1.5	21.3	4.0	12.2	7.7
12	12/7/76	1105	2	11.1	2.0	12.2	7.7
13	12/7/76	1130	1	<1	3.0	12.2	7.7
14	12/8/76	1215	1	<1	1.0	14.8	7.7
15	12/7/76	1615	3	5.8	3.0	12.0	7.7
16	12/7/76	1500	3	4.6	4.0	12.2	7.7
17	12/7/76	1528	2	9.7	7.0	10.6	7.7

* Low salinities recorded at many of the stations was attributed to the heavy rain that occurred on December 7, 1976.

** A salinity of zero was recorded, and may have reflected a malfunction of the salinity circuit.

TABLE D-8. EXPOSURE PANEL STATIONS WATER QUALITY DATA, JANUARY, 1977*

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature C°	0_2	pH
5	1/19/77	1110	1.5	19.2	3.0	11.7	7.8
7	1/19/77	1130	3	19.9	3.0	12.3	7.8
8	1/19/77	1210	8	21.7	0.0	14.4	7.8
11	1/19/77	1222	1.5	21.7	0.0	14.4	7.8

* Stations 1, 2, 3, 4, 6, 9, 10, 12, 13, 14, 15, 16, and 17 were covered with ice, water quality was not taken.

TABLE D-9. EXPOSURE PANEL STATIONS WATER QUALITY DATA, FEBRUARY, 1977*

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature C°	O_2	pH
5	2/8/77	0925	1	23.4	3.0	14.2	7.6
7	2/8/77	1000	1	24.1	5.0	14.0	7.5
8	2/8/77	1040	6	23.4	5.5	15.4	7.5
9	2/8/77	1120	6	25.6	0.5	15.4	7.6
11	2/8/77	1130	1	24.9	1.0	15.4	7.6
13	2/8/77	1305	3	8.1	1.0	13.8	7.6

* Stations 1, 2, 3, 4, 6, 10, 12, 14, 15, 16, and 17 were covered with ice, water quality was not taken.

TABLE D-10. WATER QUALITY DATA AT EXPOSURE PANEL STATIONS, MARCH, 1977

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-C°	O_2	pH
1	3-10-77	1050	2	20.6	5.5	*	*
			11	20.6	5.0	*	*
2	3-8-77	0840	*	*	*	*	*
3	3-8-77	0920	*	*	*	*	*
4	3-8-77	1000	*	*	*	*	*
5	3-8-77	1020	1	*	14.0	*	*
6	3-8-77	1045	1	*	12.5	*	*
7	3-8-77	1100	2	11.8	15.0	*	*
8	3-8-77	1115	*	*	*	*	*
9	3-8-77	1140	*	*	*	*	*
10	3-10-77	1235	3	6.4	9.5	*	*
11	3-8-77	1225	*	*	*	*	*
12	3-8-77	1310	*	*	*	*	*
13	3-8-77	1340	*	*	*	*	*
14	3-8-77	1415	*	*	*	*	*
15	3-10-77	1540	2	*	9.5	*	*
16	3-8-77	1625	*	*	*	*	*
17	3-8-77	1545	*	*	*	*	*

* = Malfunction of hydrolab

TABLE D-11. WATER QUALITY DATA AT EXPOSURE PANEL STATIONS, APRIL, 1977

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-C°	O_2	pH
1	4-7-77	0914	8	27.7	16.5	12.8	*
2	4-5-77	1032	3	24.1	10.0	11.0	7.7
3	4-5-77	1116	3	22.7	10.0	10.2	7.6
4	4-5-77	1138	3	21.3	10.5	10.8	7.6
5	4-5-77	1210	2	19.2	13.7	10.6	5.9
6	4-5-77	1217	2	15.2	13.5	10.4	5.8
7	4-5-77	1239	2	15.2	14.0	11.0	5.9
8	4-5-77	1310	2	18.5	13.5	11.0	5.8
9	4-5-77	1340	2	22.0	10.5	10.3	5.9
10	4-7-77	1335	6	20.9	10.2	11.4	*
11	4-7-77	1521	4	23.4	9.6	11.2	*
12	No water quality data taken						
13	4-5-77	0935	1.5	6.9	9.4	11.2	5.35
14	4-7-77	1402	1.5	17.9	9.3	11.6	*
15	4-5-77	1610	3	18.0	10.3	10.4	5.9
16	4-5-77	1625	6	13.1	10.5	10.2	5.9
17	4-5-77	1537	1.5	22.7	9.4	7.6	5.9

* = pH probe unit malfunctioned

TABLE D-12. WATER QUALITY AT EXPOSURE PANEL STATIONS, MAY, 1977

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-C°	O_2	pH
1	5-3-77	1330	8	27.6	16.0	11.4	8.7
2	5-4-77	1430	4	27.6	16.5	8.2	8.2
3	5-4-77	1512	3	24.8	16.7	8.2	8.4
4	5-4-77	1600	4	24.7	16.5	10.8	8.4
4A	5-4-77	1617	2	24.3	17.2	10.1	8.3
5	5-4-77	1715	3	22.0	16.6	9.7	8.1
6	5-4-77	1700	3	22.0	16.3	11.8	8.4
7	5-4-77	1745	2	22.4	16.0	8.9	8.2
8	5-5-77	0800	3	22.1	16.0	9.0	8.2
9	5-5-77	0930	4	21.7	15.5	9.1	8.1
10	5-5-77	1030	4	21.0	16.7	7.9	7.6
11	5-5-77	1105	4	24.1	15.5	9.2	8.2
12	5-3-77	1630	4	23.8	16.5	11.2	8.0
13	5-5-77	1140	4	16.2	16.8	9.6	7.7
14	5-5-77	1325	5	18.5	15.6	10.2	8.2
15	5-5-77	1555	5	19.2	15.5	11.4	8.6
16	5-5-77	1525	4	16.5	16.5	10.5	8.6
17	5-5-77	1430	2	24.3	15.5	10.2	8.2

TABLE D-13. WATER QUALITY AT EXPOSURE PANEL STATIONS JUNE, 1977

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-C°	O_2	pH
1	6-7-77	1145	6.0	30.6	16.2	9.1	8.1
2	6-5-77	0900	4.0	27.4	19.3	9.1	8.1
3	6-6-77	0940	3.0	27.4	19.5	8.6	7.9
4	6-6-77	1000	4.0	28.3	19.5	6.8	-
4A	6-6-77	1025	3.0	28.4	19.5	8.9	7.9
5	6-6-77	1100	1.5	24.9	20.0	7.6	7.7
6	6-6-77	1115	2.0	25.7	20.0	8.0	7.6
7	6-6-77	1140	2.0	25.6	20.0	7.9	7.8
8	6-6-77	1205	6.0	24.9	19.5	8.4	7.9
9	6-6-77	1225	8.0	25.7	19.5	8.6	8.0
10	6-6-77	1320	4.0	24.3	21.0	7.1	7.6
11	6-6-77	1345	3.0	25.7	18.5	8.1	8.0
12	6-7-77	1435	7.0	26.3	18.3	7.5	7.9
13	6-6-77	1420	7.0	23.1	18.5	8.7	8.1
14	6-7-77	1359	6.0	23.5	19.0	9.3	8.1
15	6-6-77	1710	4.0	19.2	18.5	8.0	7.8
16	6-6-77	1645	3.0	19.9	19.5	7.2	7.6
17	6-6-77	1613	2.0	29.9	17.5	8.6	8.1

TABLE D-14. WATER QUALITY AT EXPOSURE PANEL STATIONS JULY, 1977

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-C°	O_2	pH
1	7-13-77	1030	6.0	26.0	23.5	8.7	8.4
2	7-12-77	0840	4.0	26.8	24.3	5.5	8.3
3	7-12-77	0920	3.0	27.7	24.4	6.1	8.2
4	7-12-77	0950	4.0	26.3	24.7	7.6	8.1
4A	7-12-77	1005	2.0	26.4	25.0	7.8	8.3
5	7-12-77	1025	2.0	25.3	24.9	7.8	8.3
6	7-12-77	1040	3.0	25.6	25.1	5.5	8.2
7	7-12-77	1055	3.0	24.7	24.6	7.6	8.2
8	7-12-77	1150	3.0	25.9	24.5	6.1	8.2
9	7-12-77	1134	8.0	25.7	24.5	7.2	8.2
10	7-12-77	1329	4.0	20.0	25.0	8.1	8.0
11	7-12-77	1253	2.0	12.1*	25.5	7.8	8.3
12	7-13-77	1420	6.0	25.6	26.0	8.6	8.0
13	7-12-77	1430	5.0	24.8	25.1	8.1	8.2
14	7-13-77	1300	4.0	25.6	25.0	6.4	8.3
15	7-12-77	1640	3.0	21.3	24.5	8.0	8.1
16	7-12-77	1605	2.0	18.6	25.0	5.7	7.9
17	7-12-77	1505	1.0	30.6	25.5	8.2	8.4

* = Heavy rain at the time salinity was recorded

TABLE D-15. WATER QUALITY AT EXPOSURE PANEL STATION AUGUST, 1977

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-C°	O_2	pH
1	8-10-77	1240	6.0	30.6	25.0	7.8	8.5
2	8-9-77	0730	1.0	29.9	27.5	5.4	7.9
3	8-9-77	0823	2.0	29.5	27.0	4.1	7.9
4	8-9-77	0850	4.0	29.9	27.0	2.6	7.9
4A	8-9-77	0908	4.0	29.9	28.0	6.3	7.9
5	8-9-77	0925	2.0	26.3	29.5	6.8	7.9
6	8-9-77	0940	2.0	27.7	29.5	4.9	8.0
7	8-9-77	0955	3.5	28.5	30.3	6.0	7.9
8	8-10-77	1005	8.0	28.4	32.0	6.4	7.9
9	8-10-77	0755	9.0	28.4	28.0	6.3	8.1
10	8-9-77	1205	2.5	22.0	23.0	8.1	6.0
11	8-9-77	1105	2.5	28.8	27.5	5.6	7.9
12	8-9-77	1230	3.0	27.4	28.0	8.0	8.1
13	8-9-77	1555	2.5	21.7	29.0	8.7	8.3
14	8-9-77	1610	1.0	22.7	30.0	8.5	8.2
15	8-11-77	0830	5.0	20.9	26.5	5.8	7.6
16	8-9-77	1700	5.0	19.9	28.0	4.3	7.4
17	8-9-77	1745	2.0	29.9	28.0	9.2	8.1

TABLE D-16. WATER QUALITY AT EXPOSURE PANEL STATIONS, SEPTEMBER, 1977

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temp.-°C	O_2	pH
1	9/14/77	1625	6	30.2	21.5	8.7	7.9
2	9/13/77	0850	2	21.3	20.0	6.8	7.5
3	9/13/77	0942	3	22.7	20.3	7.1	7.8
4	9/13/77	1015	3	26.3	20.7	7.4	7.8
4A	9/13/77	1033	3	27.7	21.7	9.4	8.2
5	9/13/77	1055	2.5	25.7	25.3	7.6	7.8
6	9/13/77	1108	2.0	26.1	25.5	8.9	7.9
7	9/13/77	1103	3	25.7	25.6	7.2	7.9
8	9/13/77	1201	4	25.6	25.5	7.5	8.0
9	9/13/77	1240	5	25.6	25.2	7.7	8.2
10	9/13/77	1414	4	25.6	22.0	6.0	7.7
11	9/13/77	1347	3.5	25.7	22.0	7.7	8.1
12	9/14/77	1635	6	25.2	22.0	7.1	7.8
13	9/13/77	1500	2.5	22.7	22.0	7.4	8.1
14	9/14/77	1310	3	22.7	21.0	7.1	7.9
15	9/13/77	1729	3	21.3	21.0	8.9	8.3
16	9/13/77	1652	4	17.9	21.0	8.3	8.0
17	9/13/77	1615	2	28.4	20.5	8.1	8.4

TABLE D-17. WATER QUALITY AT EXPOSURE PANEL STATIONS, OCTOBER, 1977

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temp.-°C	O_2	pH
1	10/12/77	1003	7	30.6	16.0	9.5	8.0
2	10/11/77	0850	4	19.0	13.9	9.7	7.9
3	10/11/77	0930	3	24.9	14.0	11.0	7.8
4	10/11/77	0948	3	27.0	15.0	9.6	7.8
4A	10/11/77	1010	2	25.6	15.8	7.5	7.2
5	10/11/77	1030	2	23.4	19.0	8.0	7.1
6	10/11/77	1050	2	23.4	19.1	8.1	7.6
7	10/11/77	1110	2	23.4	18.7	8.5	7.2
8	10/11/77	1140	5	24.1	18.5	9.3	7.9
9	10/11/77	1204	8	24.9	14.5	9.4	8.1
10	10/11/77	1352	2.5	22.0	16.5	7.4	7.6
11	10/11/77	1335	2.5	25.6	15.5	8.2	8.1
12	10/12/77	1407	6	24.1	16.0	9.9	7.9
13	10/11/77	1725	2.5	17.2	16.5	9.9	7.9
14	10/12/77	1237	5	21.3	14.5	8.7	8.0
15	10/11/77	1618	3	19.2	15.0	10.4	8.2
16	10/11/77	1543	2	11.1	15.0	9.7	8.0
17	10/11/77	1513	1.5	27.7	14.0	9.5	8.2

TABLE D-18. WATER QUALITY AT EXPOSURE PANEL STATIONS, NOVEMBER, 1977

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temp.-°C	O_2	pH
1	11/9/77	1000	2	27.4	14.0	9.4	7.9
2	11/8/77	0905	3	20.6	15.1	8.8	7.8
3	11/8/77	0930	5	18.5	15.3	7.4	7.7
4	11/8/77	1005	3	19.9	15.3	10.0	7.6
4-A	11/8/77	1030	3	21.4	15.3	7.8	7.8
5	11/8/77	1050	3	15.2	17.8	9.1	7.2
6	11/8/77	1105	3	14.5	18.0	7.6	7.1
7	11/8/77	1120	3	14.5	18.6	6.6	7.2
8	11/9/77	1530	4	17.2	19.4	7.8	7.8
9	11/9/77	1610	3	19.9	18.2	7.4	7.8
10	11/9/77	1645	4	17.9	18.8	7.9	7.8
11	11/8/77	1150	1	24.0	16.3	9.3	7.8
12	11/9/77	1220	2	21.7	14.5	8.1	7.8
13	11/8/77	1330	1	16.5	16.0	8.4	6.8
14	11/8/77	1355	2	21.3	14.5	8.7	7.9
15	11/8/77	1645	2	24.5	14.0	8.8	7.9
16	11/8/77	1610	2	17.5	14.5	8.5	7.7
17	11/8/77	1525	2	23.5	15.0	8.8	7.8

TABLE D-19. WATER QUALITY AT EXPOSURE PANEL STATIONS, DECEMBER, 1977

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-°C	O_2	pH
1	12/6/77	0925	7	28.4	8.7	8.9	7.8
2	12/6/77	1015	3	20.0	6.4	10.9	7.8
3	12/6/77	1054	3	20.8	6.7	10.6	8.1
4	12/6/77	1114	3	23.1	7.4	12.4	7.7
4-A	12/6/77	1135	3	25.2	7.7	9.4	8.0
5	12/6/77	1155	2	16.5	5.2	11.4	7.6
6	12/6/77	1204	3	16.2	10.5	10.4	7.5
7	12/6/77	1217	2	15.8	10.5	10.7	7.6
8	12/6/77	1325	8	18.5	10.5	11.6	7.8
9	12/6/77	1344	5	19.2	7.0	11.4	8.0
10	12/6/77	1422	3	17.5	7.5	10.0	7.3
11	12/6/77	1303	3	19.2	6.5	11.6	8.0
12	12/6/77	1440	3	17.2	5.5	11.4	7.8
13	12/6/77	1502	2	9.2	5.5	11.0	7.1
14	12/6/77	1527	3	17.9	5.5	11.0	7.9
15	12/7/77	0925	4	17.2	4.5	12.4	7.9
16	12/7/77	1647	3	13.2	6.0	12.4	7.8
17	12/7/77	1630	2.5	25.6	6.5	12.6	8.1

TABLE D-20. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, JUNE 8-9, 1976, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity -o/oo	Temperature - C°	O_2	pH	$\bar{X}$ # Teredinids/M^3
A	6/8/76	1325	1.5	24.2	20.0	9.0	7.8	0
			7	24.9	20.0	9.0	7.8	
B	6/9/76	1030	1.5	24.2	22.0	8.3	7.7	0
			7	24.2	22.0	8.3	7.7	
C	6/9/76	0840	1.5	22.1	21.5	8.5	7.7	1.64
			6	22.8	21.5	8.5	7.7	
D	6/8/76	1500	1.5	19.9	22.5	10.6	7.8	1.93
			4	19.9	22.5	10.6	7.8	
E	6/8/76	1140	1.5	24.9	20.5	9.5	7.8	0
			5	24.9	20.5	9.5	7.8	
F	6/8/76	0850	1.5	27.8	19.0	8.0	7.8	2.90
			12	27.8	19.0	8.1	7.8	

TABLE D-21. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, JUNE 22-23, 1976, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{X}$ # Teredinids/M^3
A	6/22/76	1650	2	18.0	32.5	8.4	7.5	0
			6	22.8	32.5	8.6	7.5	
B	6/23/76	1135	2	19.5	28.5	7.2	7.5	0
			8	18.2	28.0	7.2	7.5	
C	6/23/76	1035	2	22.9	27.5	9.6	7.5	2.18
			6.5	17.9	27.0	6.2	7.5	
D	6/23/75	0920	2	21.8	25.3	7.2	7.5	0.45
			4	17.0	24.8	6.3	7.5	
E	6/22/76	1520	2	25.5	25.0	13.3	7.0	0.16
			4.5	21.5	25.0	11.5	7.0	
F	6/22/76	1350	2	25.5	24.5	9.0	7.0	0
			15	21.8	24.5	10.8	7.0	

TABLE D-22. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, JULY 14-15, 1976, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{X}$ # Teredinids/M^3
A	7/14/76	1600	2	27.0	25.5	8.5	7.7	0
			8	28.4	22.5	7.5	7.7	
B	7/15/76	1030	1.5	27.7	22.0	8.0	7.7	0
			10	27.7	22.0	8.0	7.7	
C	7/15/76	0900	1.5	27.7	22.0	7.7	7.7	0.32
			7	28.4	22.0	7.7	7.7	
D	7/14/76	*	1.5	25.6	22.5	8.8	7.7	0
			7	25.6	22.0	8.8	7.7	
E	7/14/76	1155	1.5	29.1	22.0	8.5	7.7	1.17
			8	29.1	22.0	8.5	7.7	
F	7/14/76	1010	1.5	29.9	18.0	7.7	7.7	0.94
			6	29.9	18.0	7.7	7.7	

* - Time not recorded.

TABLE D-23. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, JULY 27-28, 1976, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{X}$ # Teredinids/M^3
A	7/28/76	1300	1.5	24.0	27.0	7.2	7.0	0
			6	23.8	27.0	7.1	7.0	
B	7/27/76	1515	1.5	24.0	27.0	7.4	7.5	0
			9	19.5	27.0	7.5	7.5	
C	7/27/76	1630	1.5	24.0	26.3	6.6	7.0	0
			7	23.0	26.0	7.0	7.0	
D	7/28/76	1140	1.5	19.5	26.0	7.2	7.0	0
			6	19.0	25.0	5.2	7.0	
E	7/28/76	1005	1.5	25.2	25.0	6.4	7.0	0
			7	26.0	25.0	5.2	7.0	
F	7/28/76	0850	1.5	18.0	21.0	7.0	7.5	3.62
			10	24.8	21.5	8.4	7.5	

TABLE D-24. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, AUGUST 12, 1976 AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{X}$ # Teredinids/M^3
A	8/12/76	1500	3	22.7	30.0	7.2	7.9	0
B	8/12/76	*	1.5	24.1	26.0	8.0	7.9	0
			8	24.1	25.5	8.2	7.9	
C	8/12/76	1715	1.5	22.7	28.0	7.9	7.9	0
			5	22.7	28.0	7.9	7.9	
D	8/12/76	1845	1.5	22.0	25.0	8.5	7.9	0
			6	22.0	25.0	8.5	7.9	
E	8/12/76	1400	1.5	26.3	25.0	9.0	7.9	0.22
			10	26.3	25.0	9.0	7.9	
F	8/12/76	1245	1.5	29.1	22.0	8.0	7.9	0
			6	29.1	22.0	7.8	7.9	

* - Time not recorded.

TABLE D-25. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, AUGUST 24-25, 1976, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{X}$ # Teredinids/M^3
A	8/24/76	1510	1.5	19.8	30.2	7.1	7.0	0
			4.5	19.6	28.2	6.2	7.0	
B	8/24/76	1310	1.5	17.8	26.2	6.5	7.0	0
			7	17.6	26.5	6.4	7.0	
C	8/24/76	1415	1.5	17.8	26.1	7.2	7.5	0
			6.5	18.1	26.0	7.1	7.5	
D	8/25/76	1105	1.5	17.5	26.0	6.0	7.0	0
			6	18.6	26.0	4.3	7.0	
E	8/25/76	0935	1.5	21.0	26.0	5.8	7.5	1.1
			7.5	20.7	26.0	4.9	7.5	
F	8/25/76	0825	1.5	23.7	23.0	4.1	7.5	0
			8	23.5	24.0	3.8	7.5	

TABLE D-26. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, SEPTEMBER 15-16, 1976, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{X}$ # Teredinids/M^3
A	9/15/76	1335	1.5	25.6	17.2	8.7	7.8	0
			12	25.6	17.2	8.4	7.8	
B	9/16/76	0900	2	25.6	24.5	7.5	7.9	0
			6	25.6	24.5	7.5	7.9	
C	9/16/76	0805	3	25.6	24.0	7.7	7.9	0
D	9/16/76	1000	4	20.6	24.5	9.1	7.9	0
E	9/15/76	1340	4	27.0	23.0	9.5	7.8	0.43
F	9/15/76	1120	1.5	30.6	20.0	7.2	7.9	1.37
			7	30.6	20.0	7.2	7.9	

TABLE D-27. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, SEPTEMBER 28-29, 1976. AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{X}$ # Teredinids/M^3
A	9/28/76	1625	1	16.5	25.0	8.2	7.8	0.42
			8.5	20.5	20.8	8.2	7.8	
B	9/28/76	1330	1	18.0	21.5	8.6	7.8	0.00
			8	18.1	21.5	8.2	7.8	
C	9/28/76	1435	1	19.8	20.2	7.1	7.7	0.21
			7.5	18.5	20.5	7.6	7.7	
D	9/29/76	1040	1	16.5	18.6	8.7	7.7	0.00
			6.5	19.5	19.8	9.2	7.7	
E	9/28/76	1535	1	20.2	20.0	8.5	7.8	0.27
			8	20.0	20.0	8.8	7.8	
F	9/29/76	0910	1	21.0	17.8	7.6	7.7	0.00
			11	19.3	17.5	7.7	7.7	

TABLE D-28. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, OCTOBER 12, 1976, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{X}$ # Teredinids/M^3
A	10/12/76	1000	4.5	26.3	19.0	10.2	7.5	0
B	10/12/76	1440	2	27.0	16.5	10.4	7.5	0
			10	27.7	16.0	10.3	7.5	
C	10/12/76	1400	1.5	27.7	17.0	10.2	7.5	0
			10	27.7	17.0	10.2	7.5	
D	10/12/76	1552	3	23.4	15.5	11.0	7.5	0
E	10/12/76	1340	1.5	26.3	15.0	10.2	7.5	0
			7	26.3	15.0	10.2	7.5	
F	10/12/76	1145	1.5	32.1	15.5	8.8	8.0	0
			6	32.1	15.5	8.8	8.0	

TABLE D-29. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, OCTOBER 28, 1976, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{X}$ # Teredinids/M^3
A	10/28/76	1450	1	13.0	12.2	9.1	7.5	0
			8.5	13.2	11.1	8.9	7.5	
B	10/28/76	1230	1	12.9	10.0	9.4	7.0	0.16
			10	13.2	10.2	9.5	7.0	
C	10/28/76	1355	1	13.1	11.2	8.6	7.0	0.19
			7.5	13.0	11.5	10.9	7.0	
D	10/28/76	1040	1	12.2	7.2	10.6	7.0	0.15
			6	12.2	7.8	11.1	7.0	
E	10/28/76	1550	1	13.1	9.0	8.6	7.5	0
			7	13.5	9.1	7.1	7.5	
F	10/28/76	0950	1	12.2	6.4	11.0	7.0	0
			15	12.5	6.8	10.6	7.0	

TABLE D-30. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, NOVEMBER 11-12, 1976, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{X}$ # Teredinids/M^3
A	11/12/76	1027	1.5	24.9	9.0	14.0	7.7	0
			6	24.9	9.0	14.0	7.7	
B	11/11/76	1620	2	25.6	5.3	14.0	7.7	0
			8	25.6	5.3	14.0	7.7	
C	11/11/76	1630	1.5	25.6	5.5	13.6	7.7	0
			4	25.6	5.5	13.6	7.7	
D	11/11/76	1445	1.5	22.7	5.5	13.6	7.7	0
			7	22.7	5.5	13.6	7.7	
E	11/12/76	0943	2	25.6	5.5	14.2	7.7	0
			5	25.6	5.5	14.2	7.7	
F	11/12/76	0825	1.5	27.7	6.0	14.4	7.7	0
			8	27.7	6.0	14.4	7.7	

TABLE D-31. WATER QUALITY AND THE MEAN NUMBER OF TEREDINIDS/M^3, NOVEMBER 23-24, 1976, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{X}$ # Teredinids/M^3
A	11/23/76	1500	1	15.9	8.9	12.3	7.5	0
			9	16.0	8.5	12.5	7.5	
B	11/23/76	1235	1	17.0	5.0	11.2	7.0	0
			8	17.0	4.8	11.8	7.0	
C	11/23/76	1355	1	17.0	4.8	11.7	7.8	0
			6	17.0	4.8	11.7	7.8	
D	11/24/76	0930	1	14.0	3.0	11.2	7.0	0
			6.5	13.5	3.0	11.4	7.0	
E	11/23/76	1600	1	17.0	5.5	10.9	7.0	0
			6	16.5	5.5	11.0	7.0	
F	11/24/76	0800	1	17.0	2.0	11.4		0
			13	14.5	2.0	11.4		

TABLE D-32. WATER QUALITY AND THE MEAN NUMBER OF TEREDINIDS/M^3, DECEMBER 10, 1976, AT THE SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{X}$ # Teredinids/M^3
A	12/10/76	1215	2	15.2	5.5	14.0	7.6	0
			8	15.2	5.5	14.0	7.6	
B	12/10/76	1340	6	21.3	4.5	12.9	7.5	0
C	12/10/76	1300	2	15.9	5.0	13.0	7.5	0
D	12/10/76	1500	6	20.6	1.5	14.2	7.5	0
E	12/10/76	1045	2	24.9	3.5	14.1	7.6	0
			5	24.9	3.5	14.1	7.6	
F	Plankton samples were not taken. Weather conditions were such that it was considered unsafe to travel across the bay to Station F.							

TABLE D-33. WATER QUALITY AND THE MEAN NUMBER OF TEREDINIDS/M^3, DECEMBER 21-22, 1976, AT THE SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temperature - C°	O_2	pH	$\bar{X}$ # Teredinids/M^3
A	12/21/76	1415	1	15.5	7.8	11.2	7.2	0
			6.5	15.0	7.8	11.1	7.2	
B	12/21/76	1215	1	15.0	6.0	10.9	7.4	0
			10.5	13.8	11.0	9.2	7.4	
C	12/21/76	1320	1	16.0	3.2	11.6	7.2	0
			6.5	14.5	3.5	11.6	7.2	
D	12/22/76	1115	1	13.8	0	12.2	7.3	0
			6.5	13.6	6.0	11.8	7.3	
E	12/22/76	1000	1	16.0	1.2	11.8	7.3	0
			7.5	16.8	1.8	12.0	7.3	
F	12/22/76	0850	1	18.0	1.5	11.4	7.2	0
			13	16.0	1.8	11.7	7.4	

TABLE D-34. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, FEBRUARY 24-25, 1977, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-C°	O_2	pH	$\bar{x}$ # *Teredo* Larvae per M^3
A	2-24-77	0935	1	17.6	6.0	12.6	7.0	0
			6	18.9	5.5	12.2	7.5	
B	2-24-77	1100	1	16.5	5.0	13.0	7.5	0
			8.5	17.0	5.0	12.8	7.5	
C	2-24-77	1200	1	17.5	5.5	13.2	7.0	0
			7	19.0	6.0	13.1	7.0	
D	Station iced in; no channel markers for navigation aids.							-
E	2-25-77	0925	1	18.7	5.5	11.5	7.5	0
			6.5	21.0	5.0	11.2	7.5	
F	No channel markers for navigation to station.							0

TABLE D-35. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, MARCH 9-10, 1977, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-C°	O_2	pH	$\bar{x}$ # *Teredo* Larvae per M^3
A	3-9-77	1210	*	*	*	*	*	0
B	3-9-77	1310	*	*	*	*	*	0
C	3-9-77		*	*	*	*	*	0
D	3-10-77	0845	*	*	*	*	*	0
E	3-9-77	1115	*	*	*	*	*	0
F	3-10-77	1050	2	20.6	5.5	*	*	0
			11	20.6	5.0	*	*	

* = Hydrolab malfunction

TABLE D-36. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, MARCH 29-30, 1977, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-C°	O_2	pH	$\bar{x}$ # *Teredo* Larvae per M^3
A	3-30-77	1445	1.0	20.5	15.2	10.4	7.0	0
			8.0	21.0	15.0	9.6	7.0	
B	3-29-77	1355	1	14.0	12.0	11.5	7.5	0
			8.5	12.0	13.2	11.0	7.5	
C	3-29-77	1500	1	18.8	10.5	11.0	7.5	0
			7	17.5	11.0	10.2	7.5	
D	3-29-77	1605	1	17.8	10.8	11.0	7.5	0
			6.5	17.2	11.0	10.5	7.5	
E	3-29-77	1705	1	24.0	10.0	10.8	7.6	0
			6.5	24.0	11.0	10.2	7.5	
F	3-30-77	0900	1	26.5	9.0	10.4	7.5	0
			10	25.5	9.2	10.0	7.5	

TABLE D-37. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, APRIL 6-7, 1977, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-C°	O_2	pH	$\bar{x}$ # *Teredo* Larvae per M^3
A	4-7-77	1221	1.5	23.1	11.5	11.4	*	0
			6	23.4	11.4	11.5	*	
B	4-6-77	1030	1.5	22.7	9.2	11.2	*	0
			10	23.1	9.0	11.6	*	
C	4-6-77	0905	3	24.0	9.0	11.6	*	0
D	4-7-77	1422	1.5	18.5	8.9	11.6	*	0
			5	18.5	8.9	11.6	*	
E	4-7-77	1113	1.5	25.7	8.5	11.4	*	0
			6	26.1	8.5	11.4	*	
F	4-7-77	0936	1.5	25.9	6.6	11.4	*	0
			9	25.9	6.8	11.4	*	

* = pH probe unit malfunctioned

TABLE D-38. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, APRIL 20, 1977, AT SIX STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-C°	O_2	pH	$\bar{x}$ # *Teredo* Larvae per M^3
A	4-20/77	1720	1	20.7	19.9	8.2	7.0	0
			7	20.9	19.8	8.1	7.0	
B	4-20-77	1525	1	21.0	16.5	9.2	7.5	0
			9	20.9	16.8	9.1	7.5	
C	4-20-77	1630	1	20.9	16.1	8.9	7.5	0
			6.5	20.9	16.1	8.6	7.5	
D	4-20-77	1400	1	16.8	16.0	9.2	7.8	0
			7	16.7	15.5	8.7	7.8	
E	4-20-77	1220	1	23.3	16.1	8.8	7.5	0
			6	23.3	16.0	8.0	7.5	
F	4-20-77	1120	1	28.2	10.8	10.6	7.8	0
			11.5	28.5	11.2	10.4	7.8	

TABLE D-39. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, MAY 3-5, 1977, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-C°	O_2	pH	$\bar{x}$ # *Teredo* Larvae per M^3
A	5-3-77	1205	1.5	21.6	16.5	8.5	8.3	0
			6	21.3	16.6	8.4	8.3	
B	5-5-77	1750	1.5	20.7	15.6	9.1	8.1	0
			10	21.1	15.4	9.1	8.1	
C	5-5-77	1855	1.5	24.3	15.0	9.3	8.3	0
			6	24.3	15.2	9.2	8.4	
D	5-3-77	1525	1.5	18.5	17.5	11.0	8.7	0
			5	20.9	17.1	11.0	8.6	
E	5-3-77	1256	1.5	25.3	16.3	10.0	8.6	0
			5.5	24.9	16.3	10.0	8.6	
F	5-3-77	1407	1.5	26.6	16.0	11.4	8.7	0
			9	27.6	16.0	11.4	8.7	

TABLE D-40. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, MAY 18-20, 1977, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-C°	O_2	pH	$\bar{x}$ # *Teredo* Larvae per M^3
A	5-18-77	1334	1.0	21.0	20.0	6.9	7.0	0.12
			9.0	22.0	19.5	6.0	7.0	
B	5-19-77	1055	1.0	21.0	19.3	7.2	7.5	0
			11.0	21.0	19.5	7.3	7.5	
C	5-19-77	1210	1.0	22.3	19.0	7.7	7.5	0
			6.5	22.0	19.0	7.8	7.5	
D	5-20-77	1025	1.0	18.0	19.0	7.6	7.5	0.41
			6.5	12.5	19.0	6.3	7.5	
E	5-20-77	0915	1.0	24.5	18.4	8.0	7.5	0
			6.0	25.0	18.0	8.0	7.5	
F	5-20-77	0815	1.0	25.2	16.0	7.7	7.8	0
			10.5	25.6	16.0	7.7	7.8	

TABLE D-41. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, JUNE 7, 1977, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-C°	O_2	pH	$\bar{x}$ # *Teredo* Larvae per M^3
A	6-7-77	1653	1.5	28.1	17.8	9.8	8.2	0
			6.0	28.1	17.8	9.8	8.2	
B	6-7-77	1557	6.0	27.0	18.4	9.2	8.2	0
C	6-7-77	1740	1.5	26.7	18.1	9.4	8.1	0.14
			5.0	26.7	18.1	9.4	8.1	
D	6-7-77	1414	1.5	23.4	19.0	9.3	8.1	0.15
			6.0	23.4	19.0	9.3	8.1	
E	6-7-77	1055	1.5	25.9	17.3	8.7	8.0	0
			5.0	28.3	17.3	8.6	8.2	
F	6-7-77	1200	1.0	30.6	16.2	9.1	8.1	0
			8.0	30.6	16.2	9.1	8.1	

TABLE D-42. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, JUNE 28, 1977, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-C°	O_2	pH	$\bar{x}$ # *Teredo* Larvae per M^3
A	6-28-77	1445	1.0	25.0	25.5	7.8	8.3	0.51
			7.5	24.9	25.3	7.4	8.3	
B	6-28-77	1045	1.0	30.0	25.5	6.4	7.7	0.30
			8.0	24.2	26.0	4.8	7.7	
C	6-28-77	1150	1.0	15.8	25.0	6.7	8.1	0.70
			7.5	15.5	25.0	5.9	8.1	
D	6-28-77	1310	1.0	21.0	25.0	6.3	8.2	0.43
			6.0	21.0	25.0	6.0	8.2	
E	6-28-77	1605	1.0	25.5	25.0	7.5	6.8	0.16
			6.0	25.0	25.0	7.2	6.8	
F	6-28-77	1750	1.0	28.4	17.5	8.4	6.6	0
			7.0	27.2	17.5	8.5	6.6	

TABLE D-43. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, JULY 13, 1977, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-C°	O_2	pH	$\bar{x}$ # *Teredo* Larvae per M^3
A	7-13-77	0845	4.0	26.3	24.5	6.5	8.1	0.16
B	7-13-77	1500	1.5	27.4	25.3	7.0	8.2	0
			8.0	27.4	25.3	7.0	8.2	
C	7-13-77	1553	1.5	27.6	25.9	8.1	8.2	0.17
			6.0	27.6	25.9	8.1	8.1	
D	7-13-77	1314	3.0	25.1	25.5	7.9	8.3	0
E	7-13-77	1008	2.0	25.4	24.8	8.1	8.4	0.33
F	7-13-77	1107	1.5	26.0	25.0	8.1	8.4	0.50
			14.0	26.0	24.5	8.0	8.4	

TABLE D-44. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, JULY 27-28, 1977, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-C°	O_2	pH	$\bar{x}$ # *Teredo* Larvae per M^3
A	7-27-77	1630	1.0	25.5	24.0	8.1	7.0	0.22
			7.5	24.9	24.0	7.0	7.0	
B	7-27-77	1130	1.0	25.5	23.2	7.6	6.9	0.11
			8.5	25.0	23.3	7.8	6.9	
C	7-27-77	1245	1.0	23.8	23.8	7.2	6.8	0
			6.3	21.0	23.9	7.1	6.8	
D	7-27-77	1405	1.0	24.8	23.9	8.2	6.8	0
			6.5	24.5	23.8	7.1	6.8	
E	7-27-77	1530	1.0	28.5	24.5	9.1	6.9	0.54
			5.0	28.5	24.5	8.9	6.9	
F	7-28-77	0845	1.0	24.2	28.5	8.3	6.9	0.57
			6.5	24.1	22.0	8.7	6.9	

TABLE D-45. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, AUGUST 9-10, 1977, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temp.-°C	O_2	pH	$\bar{X}$ # Teredinid Larvae per M^3
A	8/10/77	1015	6	28.4	32	5.9	7.9	0.20
B	8/10/77	0755	3	28.4	28	6.1	8.1	0.40
			9	28.4	28	6.3	8.1	
C	8/10/77	0910	5	28.4	29	6.7	8.1	0
D	8/10/77	1410	2	25.6	27.0	7.9	8.2	0.30
			7	25.6	27.0	7.9	8.2	
E	8/9/77	1445	5	29.9	28.0	4.6	8.3	0
F	8/10/77	1255	10	29.9	26.0	7.1	8.1	0

TABLE D-46. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, AUGUST 24AND 26, 1977, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temp.-°C	O_2	pH	$\bar{X}$ # Teredinid Larvae per M^3
A	8/24/77	1610	1	22.0	26.0	6.1	6.8	0
				20.5	29.0	5.3	6.8	
B	8/26/77	1240	1	23.8	24.0	8.4	6.8	0
			8.5	23.8	23.5	8.4	6.8	
C	8/26/77	1340	1	24.8	24.5	9.2	6.9	0
			6.5	20.0	24.2	8.5	6.9	
D	8/26/77	1135	1	17.5	24.0	8.5	6.9	0
			5	16.5	25.8	8.4	6.9	
E	8/24/77	1705	1	24.5	24.5	6.0	6.9	0
			6.5	25.0	24.0	6.5	6.9	
F	8/24/77	1450	1	24.5	26.5	6.8	6.9	0.10
			10	24.7	26.2	6.8	6.9	

TABLE D-47. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, SEPTEMBER 14, 1977, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temp.-°C	O_2	pH	$\overline{X}$ # Teredinid Larvae per M^3
A	9/14/77	0906	1	25.7	22.2	7.3	8.0	0
			6	25.7	22.0	7.2	8.0	
B	9/14/77	1108	1	25.6	23.3	6.9	8.0	0
			8	25.6	23.3	7.3	8.0	
C	9/14/77	1004	1	26.1	23.7	6.9	8.0	0
			6	26.1	23.7	7.5	8.0	
D	9/14/77	1243	1	22.7	21.0	7.0	7.9	0
			4	22.7	21.0	7.1	7.9	
E	9/14/77	1523	2	25.7	21.6	8.5	7.9	0
F	9/14/77	1639	1.5	25.7	21.1	8.5	7.8	0
			12	25.7	20.0	8.6	7.8	

TABLE D-48. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, SEPTEMBER 27-28, 1977, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity - o/oo*	Temp.-°C	O_2	pH	$\bar{X}$ # Teredinid Larvae per M^3
A	9/27/77	1820	1	-	23.5	7.2	6.9	0
			5	-	21.0	6.5	6.9	
B	9/28/77	1020	1	-	20.0	6.9	6.8	0.13
			8.5	-	20.0	6.6	6.8	
C	9/28/77	1125	1	-	21.0	7.4	6.9	0
			6.5	-	20.8	6.2	6.9	
D	9/28/77	0915	1	-	20.0	7.0	7.0	0
			5	-	20.5	5.2	7.0	
E	9/27/77	1730	1	-	22.0	6.7	6.9	0
			6.5	-	22.1	6.6	6.9	
F	9/27/77	1625	1	-	21.0	7.6	7.0	0.11
			10	-	20.5	7.8	7.0	

*Salinometer non-functional.

TABLE D-49. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, OCTOBER 12, 1977, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temp.-°C	O_2	pH	$\overline{X}$ # Teredinid Larvae per M^3
A	10/12/77	1036	1	23.4	19.6	10.0	7.9	0
			6	26.3	15.5	9.0	8.0	
B	10/12/77	1451	1.5	23.4	15.5	9.7	8.0	0
			6	23.4	15.5	9.7	8.1	
C	10/12/77	1616	1.5	25.6	15.3	10.0	8.1	0
			6	27.7	15.5	9.4	8.1	
D	10/12/77	1311	1.5	21.3	14.3	9.6	8.1	0
			5	21.9	14.4	9.4	8.1	
E	10/12/77	0903	1	24.9	15.5	9.0	8.0	0
			6	25.6	15.0	8.5	8.0	
F	10/12/77	1021	1	31.7	16.3	9.0	8.1	3.54
			12	32.0	16.5	9.2	8.1	

TABLE D-50. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, OCTOBER 19, 1977, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity - o/oo*	Temp.-°C	O_2	pH**	$\bar{X}$ # Teredinid Larvae per M^3
A	10/19/77	1555	1	-	16.8	8.5	-	0.11
			6.5	-	16.2	8.1	-	
B	10/19/77	1335	1	-	13.9	8.9	-	0.19
			9.5	-	13.9	8.4	-	
C	10/19/77	1455	1	-	13.0	8.8	-	0.10
			6.5	-	13.0	8.3	-	
D	10/19/77	1204	1	-	11.5	9.5	-	0
			6	-	11.5	7.9	-	
E	10/19/77	1035	1	-	12.5	5.0	-	0
			6.5	-	12.0	5.5	-	
F	10/19/77	0920	1	-	12.5	7.2	-	2.36
			9	-	12.2	7.8	-	

* Salinometer non-functional
** pH meter non-functional

TABLE D-51. WATER QUALITY AND MEAN NUMBER OF TEREDINIDS/M^3, NOVEMBER 9 AND 29-30, AT SIX PLANKTON STATIONS IN BARNEGAT BAY

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-°C	O_2	pH	$\bar{X}$ # Teredinid larvae per M^3
A	11/9/77	1411	1	20.6	17.6	8.2	7.6	4.47
			6	25.6	14.1	7.9	7.9	
B	11/9/77	1240	1	17.3	15.0	8.8	7.5	5.68
			8	21.0	14.8	8.5	7.8	
C	11/9/77	1326	1	22.0	15.2	9.8	7.9	0.62
			6	23.4	14.6	9.6	7.9	
D	11/9/77	1112	1	20.0	14.5	8.9	7.9	0.12
			2	22.7	14.5	8.7	7.9	
E	11/9/77	0819	1	20.6	15.2	9.6	7.8	0.52
			7	24.3	14.5	8.8	7.7	
F	11/9/77	1007	1	23.7	14.8	8.9	7.9	8.67
			12	24.2	14.8	9.1	7.9	
A	11/30/77	1113	1	*	8.5	*	*	0
			8		8.5			
B	11/30/77	0910	1	*	5.5	*	*	0
			7		5.0			
C	11/30/77	1020	1	*	5.5	*	*	0
			4.5		5.0			
D	11/29/77	1545	1	*	5.0	*	*	0
			6.5		6.0			
E	11/29/77	1432	1	*	5.5	*	*	0
			5		6.0			
F	11/29/77	1315	1	*	8.0	*	*	34.77
			5		7.8			

* Malfunction of salinity, oxygen, and pH equipment

TABLE D-52. EXPOSURE PANEL STATION 1, WATER QUALITY DATA FROM JUNE, 1976, THROUGH DECEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temperature - °C	O_2	pH
6/8/76	0820	1.5	27.8	19.0	8.0	7.8
		6	27.8	19.0	8.0	7.8
7/14/76	0850	1.5	28.4	18.5	7.5	7.7
		6	28.4	18.5	7.0	7.7
8/12/76	1230	1.5	27.7	23.5	8.2	7.9
		7	27.7	22.0	7.4	7.9
9/15/76	1045	7	29.1	22.0	6.7	8.2
10/12/76	1045	1.5	29.9	15.0	8.8	7.8
		6	29.9	15.0	8.8	7.8
11/12/76	0810	6	28.4	5.5	13.4	7.7
12/8/76	0820	6	*	4.5	13.2	7.7
January, 1977 Panel Station Frozen In						
February, 1977 Panel Station Frozen In						
3/10/77	1050	2	20.6	5.5	*	*
		11	20.6	5.0		
4/7/77	0914	8	27.7	16.5	12.8	*
5/3/77	1330	8	27.6	16.0	11.4	8.7
6/7/77	1145	6	30.6	16.2	9.1	8.1
7/13/77	1030	6	26.0	23.5	8.7	8.4
8/10/77	1240	6	30.6	25.0	7.8	8.5
9/14/77	1625	6	30.2	21.5	8.7	7.9
10/12/77	1003	7	30.6	16.0	9.5	8.0
11/9/77	1000	2	27.4	14.0	9.4	7.9
12/6/77	0925	7	28.4	8.7	8.9	7.8

*Hydrolab malfunction.

TABLE D-53. EXPOSURE PANEL STATION 2, WATER QUALITY DATA FROM JUNE, 1976, THROUGH DECEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temperature - °C	O_2	pH
6/9/76	1305	1	21.3	24.5	8.3	7.7
7/13/76	0855	1.5	27.0	22.0	6.0	7.8
8/11/76	0935	1.5	22.7	23.5	6.1	7.9
9/14/76	0820	1.5	27.7	21.5	9.1	7.9
10/13/76	0735	1.5	27.7	13.0	9.6	7.5
11/9/76	0755	1	22.0	4.0	12.0	7.7
12/7/76	0813	2	26.3	1.5	13.8	7.7
January, 1977 Panel Station Frozen In						
February, 1977 Panel Station Frozen In						
3/8/77	0840	*	*	*	*	*
4/5/77	1032	3	24.1	10.0	11.0	7.7
5/4/77	1430	4	27.6	16.5	8.2	8.2
6/5/77	0900	4	27.4	19.3	9.1	8.1
7/12/77	0840	4	26.8	24.3	5.5	8.3
8/9/77	0730	1	29.9	27.5	5.4	7.9
9/13/77	0850	2	21.3	20.0	6.8	7.5
10/11/77	0850	4	19.0	13.9	9.7	7.9
11/8/77	0905	3	20.6	15.1	8.8	7.8
12/6/77	1015	3	20.0	6.4	10.9	7.8

*Hydrolab malfunction.

TABLE D-54. EXPOSURE PANEL STATION 3, WATER QUALITY DATA FROM JUNE, 1976, THROUGH DECEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temperature - °C	O_2	pH
6/9/76	1335	2.5	24.2	22.5	9.1	7.7
7/13/76	0925	3	27.0	23.5	4.7	7.8
8/11/76	1045	3	24.1	23.5	5.3	7.9
9/14/76	0855	2	27.0	22.0	6.4	7.8
10/13/76	0805	3	25.6	13.5	9.9	7.5
11/9/76	0835	2	22.0	3.0	13.0	7.6
12/7/76	0845	3	25.6	2.5	14.4	7.7
January, 1977 Panel Station Frozen In						
February, 1977 Panel Station Frozen In						
3/8/77	0920	*	*	*	*	*
4/5/77	1116	3	22.7	10.0	10.2	7.6
5/4/77	1512	3	24.8	16.7	8.2	8.4
6/6/77	0940	3	27.4	19.5	8.6	7.9
7/12/77	0920	3	27.7	24.4	6.1	8.2
8/9/77	0823	2	29.5	27.0	4.1	7.9
9/13/77	0942	3	22.7	20.3	7.1	7.8
10/11/77	0930	3	24.9	14.0	11.0	7.8
11/8/77	0930	5	18.5	15.3	7.4	7.7
12/6/77	1054	3	20.8	6.7	10.6	8.1

*Hydrolab malfunction.

TABLE D-55. EXPOSURE PANEL STATION 4, WATER QUALITY DATA FROM JUNE, 1976, THROUGH DECEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temperature - °C	O_2	pH
6/9/76	1410	3.5	20.6	21.5	7.2	7.7
7/13/76	0945	2.5	27.7	23.5	3.9	7.8
8/11/76	1040	4	26.3	23.0	6.7	7.9
9/14/76	0915	2.5	26.3	22.5	6.4	7.8
10/13/76	0827	4	25.6	14.0	9.7	7.5
11/9/76	0855	4	25.6	6.0	12.6	7.7
12/7/76	0907	4	23.6	3.5	13.6	7.7
January, 1977 Station Frozen In						
February, 1977 Station Frozen In						
3/8/77	1000	*	*	*	*	*
4/5/77	1138	3	21.3	10.5	10.8	7.6
5/4/77	1600	4	24.7	16.5	10.8	8.4
6/6/77	1000	4	28.3	19.5	6.8	*
7/12/77	0950	4	26.3	24.7	7.6	8.1
8/9/77	0850	4	29.9	27.0	2.6	7.9
9/13/77	1015	3	26.3	20.7	7.4	7.8
10/11/77	0948	3	27.0	15.0	9.6	7.8
11/8/77	1005	3	19.9	15.3	10.0	7.6
12/6/77	1114	3	23.1	7.4	12.4	7.7

*Hydrolab malfunction.

TABLE D-56. EXPOSURE PANEL STATION 4A*, WATER QUALITY DATA FROM MAY, 1977, THROUGH DECEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temperature - °C	O_2	pH
5/4/77	1617	2	24.3	17.2	10.1	8.3
6/6/77	1025	3	28.4	19.5	8.9	7.9
7/12/77	1005	2	26.4	25.0	7.8	8.3
8/9/77	0908	4	29.9	28.0	6.3	7.9
9/13/77	1033	3	27.7	21.7	9.4	8.2
10/11/77	1010	2	25.6	15.8	7.5	7.2
11/8/77	1030	3	21.4	15.3	7.8	7.8
12/6/77	1135	3	25.2	7.7	9.4	8.0

*Station 4A was established in April, 1977.

TABLE D-57. EXPOSURE PANEL STATION 5, WATER QUALITY DATA FROM JUNE, 1976, THROUGH DECEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temperature - °C	O_2	pH
6/9/76	1425	3	15.9	27.5	8.7	7.7
7/13/76	1005	4	24.9	27.0	5.2	7.8
8/12/76	1600	5	22.7	30.0	9.2	7.9
9/15/76	1424	1.5	25.6	28.0	8.7	8.1
		10	25.6	26.5	7.1	8.0
10/12/76	1815	2	22.7	18.0	9.4	7.5
11/9/76	0915	1.5	23.4	9.5	11.1	7.7
12/5/76	0920	2	22.7	4.0	12.0	7.6
1/19/77	1110	1.5	19.2	3.0	11.7	7.8
2/28/77	0925	1	23.4	3.0	14.2	7.6
3/8/77	1020	1	*	14.0	*	*
4/5/77	1210	2	19.2	13.7	10.6	5.9
5/4/77	1715	3	22.0	16.6	9.7	8.1
6/6/77	1100	1.5	24.9	20.0	7.6	7.7
7/12/77	1025	2	25.3	24.9	7.8	8.3
8/9/77	0925	2	26.3	29.5	6.8	7.9
9/13/77	1055	2.5	25.7	25.3	7.6	7.8
10/11/77	1030	2	23.4	19.0	8.0	7.1
11/8/77	1050	3	15.2	17.8	9.1	7.2
12/6/77	1155	2	16.5	5.2	11.4	7.6

*Hydrolab malfunction.

TABLE D-58. EXPOSURE PANEL STATION 6, WATER QUALITY DATA FROM JUNE, 1976, THROUGH DECEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temperature - °C	O_2	pH
6/9/76	1440	1	22.8	28.5	8.2	7.7
7/13/76	1020	1	25.6	27.0	4.2	7.8
8/11/76	1135	1.5	21.3	27.5	6.7	7.9
9/14/76	1003	1.5	26.3	22.0	7.9	7.9
10/12/76	1825	2	23.4	20.0	7.7	7.5
11/9/76	0930	1	22.7	10.0	11.2	7.7
12/7/76	0935	1.5	22.7	7.0	12.2	7.7
January, 1977 Station Frozen In						
February, 1977 Station Frozen In						
3/8/77	1045	1	*	12.5	*	*
4/5/77	1217	2	15.2	13.5	10.4	5.8
5/4/77	1700	3	22.0	16.3	11.8	8.4
6/6/77	1115	2	25.7	20.0	8.0	7.6
7/12/77	1040	3	25.6	25.1	5.5	8.2
8/9/77	0940	2	27.7	29.5	4.9	8.0
9/13/77	1108	2	26.1	25.5	8.9	7.9
10/11/77	1050	2	23.4	19.1	8.1	7.6
11/8/77	1105	3	14.5	18.0	7.6	7.1
12/6/77	1204	3	16.2	10.5	10.4	7.5

*Hydrolab malfunction.

TABLE D-59. EXPOSURE PANEL STATION 7, WATER QUALITY DATA FROM JUNE, 1976, THROUGH DECEMBER, 1976

Date	Time	Depth in Feet	Salinity - o/oo	Temperature - °C	O_2	pH
6/9/76	1453	2	22.8	28.5	8.0	7.7
7/13/76	1045	1.5	26.3	26.5	6.3	7.8
		8	26.3	26.5	6.3	7.8
8/11/76	1155	1	22.7	28.0	7.0	7.9
9/14/76	1003	1.5	26.3	22.0	7.9	7.9
10/12/76	1837	4	26.3	20.5	9.7	7.5
11/9/76	0945	2.5	23.4	10.5	11.0	7.8
12/7/76	0955	1.5	13.8	8.5	11.8	7.7
1/19/77	1130	3	19.9	3.0	12.3	7.8
2/8/77	1000	1	24.1	5.0	14.0	7.5
3/8/77	1100	2	11.8	15.0	*	*
4/5/77	1239	2	15.2	14.0	11.0	5.9
5/4/77	1745	2	22.4	16.0	8.9	8.2
6/6/77	1140	2	25.6	20.0	7.9	7.8
7/12/77	1055	3	24.7	24.6	7.6	8.2
8/9/77	0955	3.5	28.5	30.3	6.0	7.9
9/13/77	1103	3	25.7	25.6	7.2	7.9
10/11/77	1110	2	23.4	18.7	8.5	7.2
11/8/77	1120	3	14.5	18.6	6.6	7.2
12/6/77	1217	2	15.8	10.5	10.7	7.6

*Hydrolab malfunction.

TABLE D-60. EXPOSURE PANEL STATION 8, WATER QUALITY DATA FROM JUNE, 1976, THROUGH DECEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temperature - °C	O_2	pH
6/10/76	1600	1.5	22.8	28.5	8.0	7.7
		12	22.8	28.5	8.0	7.7
7/13/76	1100	1.5	27.0	27.0	6.9	7.8
		6	27.0	27.0	6.9	7.8
8/11/76	1300	7	23.4	29.0	8.3	7.9
9/14/76	1045	2	26.3	26.0	6.8	7.8
		10	26.3	26.0	6.8	7.8
10/13/76	0853	2	25.6	21.0	10.4	7.5
		9	25.6	21.0	10.4	7.5
11/9/76	1007	2	24.1	10.5	14.4	7.7
		10	24.1	10.5	14.4	7.7
12/10/76	1220	2	15.2	5.5	14.0	7.6
		6	15.2	5.5	14.0	7.6
1/19/77	1210	8	21.7	0.0	14.4	7.8
2/8/77	1040	6	23.4	5.5	15.4	7.5
3/8/77	1115	*	*	*	*	*
4/5/77	1310	2	18.5	13.5	11.0	5.8
5/5/77	0800	3	22.1	16.0	9.0	8.2
6/6/77	1205	6	24.9	19.5	8.4	7.9
7/12/77	1150	3	25.9	24.5	6.1	8.2
8/10/77	1005	8	28.4	32.0	6.4	7.9
9/13/77	1201	4	25.6	25.5	7.5	8.0
10/11/77	1140	5	24.1	18.5	9.3	7.9
11/9/77	1530	4	17.2	19.4	7.8	7.8
12/6/77	1325	8	18.5	10.5	11.6	7.8

*Hydrolab malfunction.

TABLE D-61. EXPOSURE PANEL STATION 9, WATER QUALITY DATA FROM JUNE, 1976, THROUGH DECEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temperature - °C	O_2	pH
6/10/76	1030	1.5	24.2	22.0	8.3	7.7
		7	24.2	22.0	8.3	7.7
7/15/76	1130	1.5	27.7	22.0	8.0	7.7
		10	27.7	22.0	8.0	7.7
8/12/76	-	1.5	24.1	26.0	8.0	7.9
		8	24.1	25.5	8.2	7.9
9/15/76	0900	2	25.6	24.5	7.5	7.9
		6	25.6	24.5	7.5	7.9
10/12/76	1440	2	27.7	16.5	10.4	7.5
		10	27.7	16.0	10.3	7.5
11/11/76	1620	2	25.6	5.3	14.0	7.7
		8	25.6	5.3	14.0	7.7
12/10/76	1340	6	21.3	4.5	12.9	7.5
January, 1977 Station Frozen In						
2/8/77	1120	6	25.6	0.5	15.4	7.6
3/8/77	1140	*	*	*	*	*
4/5/77	1340	2	22.0	10.5	10.3	5.9
5/5/77	0930	4	21.7	15.5	9.1	8.1
6/6/77	1225	8	25.7	19.5	8.6	8.0
7/12/77	1134	8	25.7	24.5	7.2	8.2
8/10/77	0755	9	28.4	28.0	6.3	8.1
9/13/77	1240	5	25.6	25.2	7.7	8.2
10/11/77	1204	8	24.9	14.5	9.4	8.1
11/9/77	1610	3	19.9	18.2	7.4	7.8
12/6/77	1344	5	19.2	7.0	11.4	8.0

*Hydrolab malfunction.

TABLE D-62. EXPOSURE PANEL STATION 10, WATER QUALITY DATA FROM JUNE, 1976, THROUGH DECEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temperature - °C	O_2	pH
6/9/76	1220	3	20.6	22.0	6.0	7.7
7/13/76	1215	1.5	21.3	24.5	5.9	7.8
8/11/76	1500	2.5	6.4	26.0	7.3	7.9
9/14/76	1204	1	20.6	23.0	8.1	7.8
10/13/76	0957	4.5	24.1	15.5	7.3	7.5
11/9/76	1125	4	21.3	8.0	11.1	7.7
12/7/76	1045	3	<1*	4.0	12.4	7.7
January, 1977 Panel Frozen In						
February, 1977 Panel Frozen In						
3/10/77	1235	3	6.4	9.5	**	**
4/7/77	1335	6	20.9	10.2	11.4	**
5/5/77	1030	4	21.0	16.7	7.9	7.6
6/6/77	1320	4	24.3	21.0	7.1	7.6
7/12/77	1329	4	20.0	25.0	8.1	8.0
8/9/77	1205	2.5	22.0	23.0	8.1	6.0
9/13/77	1414	4	25.6	22.0	6.0	7.7
10/11/77	1352	2.5	22.0	16.5	7.4	7.6
11/9/77	1645	4	17.9	18.8	7.9	7.8
12/6/77	1422	3	17.5	7.5	10.0	7.3

TABLE D-63. EXPOSURE PANEL STATION 11, WATER QUALITY DATA FROM JUNE, 1976, THROUGH DECEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temperature - °C	O_2	pH
6/9/76	0840	3	22.1	21.5	8.5	7.7
7/15/76	1000	4	28.4	22.5	7.7	7.7
8/12/76	1715	1.5	22.7	28.0	7.9	7.9
		5	22.7	28.0	7.9	7.9
9/14/76	1204	1	20.6	23.0	8.1	7.8
10/13/76	0937	2	25.6	14.0	9.8	7.5
11/9/76	1103	2.5	24.1	5.5	14.2	6.6
12/7/76	1015	1.5	21.3	4.0	12.2	7.7
1/19/77	1222	1.5	21.7	0.0	14.4	7.8
2/8/77	1130	1	24.9	1.0	15.4	7.6
3/8/77	1225	*	*	*	*	*
4/7/77	1521	4	23.4	9.6	11.2	*
5/5/77	1105	4	24.1	15.5	9.2	8.2
6/6/77	1345	3	25.7	18.5	8.1	8.0
7/12/77	1253	2	12.1**	25.5	7.8	8.3
8/9/77	1105	2.5	28.8	27.5	5.6	7.9
9/13/77	1347	3.5	25.7	22.0	7.7	8.1
10/11/77	1335	2.5	25.6	15.5	8.2	8.1
11/8/77	1150	1	24.0	16.3	9.3	7.8
12/6/77	1303	3	19.2	6.5	11.6	8.0

*Hydrolab malfunction.

**Heavy rain at the time salinity was recorded.

TABLE D-64. EXPOSURE PANEL STATION 12, WATER QUALITY DATA FROM JUNE, 1976, THROUGH DECEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temperature - °C	O_2	pH
6/10/76	0725	4	16.6	22.5	8.9	7.7
7/13/76	1237	2	25.6	24.0	7.5	7.8
8/11/76	1525	3	22.0	26.0	11.4	7.9
9/14/76	1222	3	25.6	22.0	8.5	7.8
10/13/76	1017	3	25.6	15.0	9.8	7.5
11/9/76	1145	4	24.1	5.5	13.0	7.7
12/7/76	1105	2	11.1	2.0	12.2	7.7
January, 1977 Station Frozen In						
February, 1977 Station Frozen In						
3/8/77	1310	*	*	*	*	*
4/77	No Water Quality Taken					
5/3/77	1630	4	23.8	16.5	11.2	8.0
6/7/77	1435	7	26.3	18.3	7.5	7.9
7/13/77	1420	6	25.6	26.0	8.6	8.0
8/9/77	1230	3	27.4	28.0	8.0	8.1
9/14/77	1635	6	25.2	22.0	7.1	7.8
10/12/77	1407	6	24.1	16.0	9.9	7.9
11/9/77	1220	2	21.7	14.5	8.1	7.8
12/6/77	1440	3	17.2	5.5	11.4	7.8

*Hydrolab malfunction.

TABLE D-65. EXPOSURE PANEL STATION 13, WATER QUALITY DATA FROM JUNE, 1976, THROUGH DECEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temperature - °C	O_2	pH
6/10/76	0750	1	15.9	22.5	8.3	7.7
7/13/76	1300	2	16.5	21.5	8.6	7.8
8/11/76	1355	1	10.4	26.5	7.6	7.9
9/14/76	1257	1.5	22.7	24.0	8.9	7.9
10/12/76	1720	2	19.9	17.0	10.4	7.5
11/9/76	1205	1	11.1	3.7	11.2	7.6
12/7/76	1130	1	<1*	3.0	12.2	7.7
January, 1977 Panel Station Frozen In						
2/8/77	1305	3	8.1	1.0	13.8	7.6
3/8/77	1340	*	*	*	*	*
4/5/77	0935	1.5	6.9	9.4	11.2	5.4
5/5/77	1140	4	16.2	16.8	9.6	7.7
6/6/77	1420	7	23.1	18.5	8.7	8.1
7/12/77	1430	5	24.8	25.1	8.1	8.2
8/9/77	1555	2.5	21.7	29.0	8.7	8.3
9/13/77	1500	2.5	22.7	22.0	7.4	8.1
10/11/77	1725	2.5	17.2	16.5	9.9	7.9
11/8/77	1330	1	16.5	16.0	8.4	6.8
12/6/77	1502	2	9.2	5.5	11.0	7.1

*Hydrolab malfunction.

TABLE D-66. EXPOSURE PANEL STATION 14, WATER QUALITY DATA FROM JUNE, 1976, THROUGH DECEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temperature - °C	O_2	pH
6/10/76	0815	1.5	19.2	22.5	8.2	7.7
7/13/76	1325	1.5	23.4	22.0	8.4	7.8
8/11/76	1635	1.5	15.8	27.0	8.4	7.9
9/14/76	1325	1	20.6	24.5	9.1	7.9
10/12/76	1043	1	23.4	15.0	9.7	7.5
11/9/76	1225	1	22.7	4.0	13.4	7.7
12/8/76	1215	1	<1*	1.0	14.8	7.7
January, 1977 Station Frozen In						
February, 1977 Station Frozen In						
3/8/77	1415	**	**	**	**	**
4/7/77	1402	1.5	17.9	9.3	11.6	**
5/5/77	1325	5	18.5	15.6	10.2	8.2
6/7/77	1359	6	23.5	19.0	9.3	8.1
7/13/77	1300	4	25.6	25.0	6.4	8.3
8/9/77	1610	1	22.7	30.0	8.5	8.2
9/14/77	1310	3	22.7	21.0	7.1	7.9
10/12/77	1237	5	21.3	14.5	8.7	8.0
11/8/77	1355	2	21.3	14.5	8.7	7.9
12/6/77	1527	3	17.9	5.5	11.0	7.9

*Low Salinity attributed to heavy rain.

**Hydrolab malfunction.

TABLE D-67. EXPOSURE PANEL STATION 15, WATER QUALITY DATA FROM JUNE, 1976, THROUGH DECEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temperature - °C	O_2	pH
6/10/76	1100	5	18.6	22.0	8.5	7.7
7/15/76	1315	4	21.3	22.0	9.4	7.8
8/12/76	0805	3	18.5	24.5	8.2	7.9
9/17/76	1015	3	19.9	22.0	7.8	7.9
10/13/76	1250	4	23.4	14.0	11.0	7.5
11/9/76	1303	1.5	15.2	4.5	12.6	7.7
12/7/76	1615	3	5.8	3.0	12.0	7.7
January, 1977 Panel Station Frozen In						
February, 1977 Panel Station Frozen In						
3/10/77	1540	2	*	9.5	*	*
4/5/77	1610	3	18.0	10.3	10.4	5.9
5/5/77	1555	5	19.2	15.5	11.4	8.6
6/6/77	1710	4	19.2	18.5	8.0	7.8
7/12/77	1640	3	21.3	24.5	8.0	8.1
8/11/77	0830	5	20.9	26.5	5.8	7.6
9/13/77	1729	3	21.3	21.0	8.9	8.3
10/11/77	1618	3	19.2	15.0	10.4	8.2
11/8/77	1645	2	24.5	14.0	8.8	7.9
12/7/77	0925	4	17.2	4.5	12.4	7.9

*Hydrolab malfunction.

TABLE D-68. EXPOSURE PANEL STATION 16, WATER QUALITY DATA FROM JUNE, 1976, THROUGH DECEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temperature - °C	O_2	pH
6/10/76	1015	4	16.6	22.0	2.5	7.7
7/13/76	1505	2	22.7	22.5	4.5	7.8
8/11/76	1850	3	17.9	24.0	5.0	7.9
9/14/76	1400	5	19.2	22.5	8.3	7.7
10/13/76	1124	2.5	19.9	13.0	10.1	7.5
11/9/76	1330	1.5	27.0	3.0	13.0	7.7
12/7/76	1500	3	4.6	4.0	12.2	7.7
January, 1977 Panel Station Frozen In						
February, 1977 Panel Station Frozen In						
3/8/77	1625	*	*	*	*	*
4/5/77	1625	6	13.1	10.5	10.2	5.9
5/5/77	1525	4	16.5	16.5	10.5	8.6
6/6/77	1645	3	19.9	19.5	7.2	7.6
7/12/77	1605	2	18.6	25.0	5.7	7.9
8/9/77	1700	5	19.9	28.0	4.3	7.4
9/13/77	1652	4	17.9	21.0	8.3	8.0
10/11/77	1543	2	11.1	15.0	9.7	8.0
11/8/77	1610	2	17.5	14.5	8.5	7.7
12/7/77	1647	3	13.2	6.0	12.4	7.8

*Hydrolab malfunction.

TABLE D-69. EXPOSURE PANEL STATION 17, WATER QUALITY DATA FROM JUNE, 1976, THROUGH DECEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temperature - °C	O_2	pH
6/10/76	0945	1	24.2	23.0	7.2	7.7
7/13/76	1433	1.5	29.1	20.5	8.6	7.8
8/11/76	1820	2	24.9	25.0	10.4	7.9
9/14/76	1445	3	29.9	22.5	8.3	7.8
10/13/76	1205	3	29.9	13.0	11.0	7.5
11/9/76	1417	3	23.4	4.1	12.4	7.7
12/7/76	1528	2	9.7	7.0	10.6	7.7
January, 1977 Panel Station Frozen In						
February, 1977 Panel Station Frozen In						
3/8/77	1545	*	*	*	*	*
4/5/77	1537	1.5	22.7	9.4	7.6	5.9
5/5/77	1430	2	24.3	15.5	10.2	8.2
6/6/77	1613	2	29.9	17.5	8.6	8.1
7/12/77	1505	1	30.6	25.5	8.2	8.4
8/9/77	1745	2	29.9	28.0	9.2	8.1
9/13/77	1615	2	28.4	20.5	8.1	8.4
10/11/77	1513	1.5	27.7	14.0	9.5	8.2
11/8/77	1525	2	23.5	15.0	8.8	7.8
12/7/77	1630	2.5	25.6	6.5	12.6	8.1

*Hydrolab malfunction.

TABLE D-70. WATER QUALITY AT EXPOSURE PANEL STATIONS, DECEMBER, 1977

Station	Date	Time	Depth in Feet	Salinity-o/oo	Temp.-°C	O_2	pH
1	12/6/77	0925	7	28.4	8.7	8.9	7.8
2	12/6/77	1015	3	20.0	6.4	10.9	7.8
3	12/6/77	1054	3	20.8	6.7	10.6	8.1
4	12/6/77	1114	3	23.1	7.4	12.4	7.7
4-A	12/6/77	1135	3	25.2	7.7	9.4	8.0
5	12/6/77	1155	2	16.5	5.2	11.4	7.6
6	12/6/77	1204	3	16.2	10.5	10.4	7.5
7	12/6/77	1217	2	15.8	10.5	10.7	7.6
8	12/6/77	1325	8	18.5	10.5	11.6	7.8
9	12/6/77	1344	5	19.2	7.0	11.4	8.0
10	12/6/77	1422	3	17.5	7.5	10.0	7.3
11	12/6/77	1303	3	19.2	6.5	11.6	8.0
12	12/6/77	1440	3	17.2	5.5	11.4	7.8
13	12/6/77	1502	2	9.2	5.5	11.0	7.1
14	12/6/77	1527	3	17.9	5.5	11.0	7.9
15	12/7/77	0925	4	17.2	4.5	12.4	7.9
16	12/7/77	1647	3	13.2	6.0	12.4	7.8
17	12/7/77	1630	2.5	25.6	6.5	12.6	8.1

TABLE D-71. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE AT PLANKTON STATION A, FROM JUNE, 1976, THROUGH NOVEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temp. - °C	O_2	pH	X # Teredinid Larvae per M^3
6/8/76	1325	1.5	24.2	20.0	9.0	7.8	0
		7	24.9	20.0	9.0	7.8	
6/22/76	1650	2	18.0	32.5	8.4	7.5	0
		6	22.8	32.5	8.6	7.5	
7/14/76	1600	2	27.0	25.5	8.5	7.7	0
		8	28.4	22.5	7.5	7.7	
7/28/76	1300	1.5	24.0	27.0	7.2	7.0	0
		6	23.8	27.0	7.1	7.0	
8/12/76	1500	3	22.7	30.0	7.2	7.9	0
8/24/76	1510	1.5	19.8	30.2	7.1	7.0	0
		4.5	19.6	28.2	6.2	7.0	
9/15/76	1335	1.5	25.6	17.2	8.7	7.8	0
		12	25.6	17.2	8.4	7.8	
9/28/76	1625	1	16.5	25.0	8.2	7.8	0.42
		8.5	20.5	20.8	8.2	7.8	
10/12/76	1000	4.5	26.3	19.0	10.2	7.5	0
10/28/76	1450	1	13.0	12.2	9.1	7.5	0
		8.5	13.2	11.1	8.9	7.5	
11/12/76	1027	1.5	24.9	9.0	14.0	7.7	0
		6	24.9	9.0	14.0	7.7	
11/23/76	1500	1	15.9	8.9	12.3	7.5	0
		9	16.0	8.5	12.5	7.5	
12/10/76	1215	2	15.2	5.5	14.0	7.6	0
		8	15.2	5.5	14.0	7.6	
12/21/76	1415	1	15.5	7.8	11.2	7.2	0
		6.5	15.0	7.8	11.1	7.2	
No Plankton Sampling January and First Part of February, 1977. Bay Frozen.							
2/24/77	0935	1	17.6	6.0	12.6	7.0	0
		6	18.9	5.5	12.2	7.5	
3/9/77	1210	*	*	*	*	*	0
3/30/77	1445	1	20.5	15.2	10.4	7.0	0
		8	21.0	15.0	9.6	7.0	
4/7/77	1221	1.5	23.1	11.5	11.4	*	0
		6	23.4	11.4	11.5	*	

TABLE D-71. (continued)

Date	Time	Depth in Feet	Salinity - o/oo	Temp. - °C	O_2	pH	$\bar{X}$ # Teredinid Larvae per M^3
4/20/77	1720	1	20.7	19.9	8.2	7.0	0
		7	20.9	19.8	8.1	7.0	
5/3/77	1205	1.5	21.6	16.5	8.5	8.3	0
		6	21.3	16.6	8.4	8.3	
5/18/77	1334	1	21.0	20.0	6.9	7.0	0.12
		9	22.0	19.5	6.0	7.0	
6/7/77	1653	1.5	28.1	17.8	9.8	8.2	0
		6	28.1	17.8	9.8	8.2	
6/28/77	1445	1	25.0	25.5	7.8	8.3	0.51
		7.5	24.9	25.3	7.4	8.3	
7/13/77	0845	4	26.3	24.5	6.5	8.1	0.16
7/27/77	1630	1	25.5	24.0	8.1	7.0	0.22
		7.5	24.9	24.0	7.0	7.0	
8/10/77	1015	6	28.4	32.0	5.9	7.9	0.20
8/24/77	1610	1	22.0	26.0	6.1	6.8	0
		5	20.5	29.0	5.3	6.8	
9/14/77	0906	1	25.7	22.2	7.3	8.0	0
		6	25.7	22.0	7.2	8.0	
9/27/77	1820	1	**	23.5	7.2	6.9	0
		5	**	21.0	6.5	6.9	
10/12/77	1036	1	23.4	19.6	10.0	7.9	0
		6	26.3	15.5	9.0	8.0	
10/19/77	1555	1	**	16.8	8.5	***	0.11
		6.5	**	16.2	8.1	***	
11/9/77	1411	1.5	20.6	17.2	8.2	7.6	4.47
		6	25.6	14.1	7.9	7.9	
11/30/77	1200	1	-	8.5	****	-	0
		8	-	8.5	****	-	

* = Hydrolab malfunction
** = Salinometer non-functional
*** = pH meter non-functional
**** = Dissolved oxygen system non-functional

TABLE D-72. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE AT PLANKTON STATION B, FROM JUNE, 1976, THROUGH NOVEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temp. - °C	O_2	pH	X # Teredinid Larvae per M^3
6/9/76	1325	1.5	24.2	20.0	9.0	7.8	0
		7	24.9	20.0	9.0	7.8	
6/23/76	1135	2	19.5	28.5	7.2	7.5	0
		8	18.2	28.0	7.2	7.5	
7/15/76	1030	1.5	27.7	22.0	8.0	7.7	0
		10	27.7	22.0	8.0	7.7	
7/27/76	1515	1.5	24.0	27.0	7.4	7.5	0
		9	19.5	27.0	7.5	7.5	
8/12/76	-	1.5	24.1	26.0	8.0	7.9	0
		8	24.1	25.5	8.2	7.9	
8/24/76	1310	1.5	17.8	26.2	6.5	7.0	0
		7	17.6	26.5	6.4	7.0	
9/16/76	0900	2	25.6	24.5	7.5	7.9	0
		6	25.6	24.5	7.5	7.9	
9/28/76	1330	1	18.0	21.5	8.6	7.8	0
		8	18.1	21.5	8.2	7.8	
10/12/76	1440	2	27.0	16.5	10.4	7.5	0
		10	27.7	16.0	10.3	7.5	
10/28/76	1230	1	12.9	10.0	9.4	7.0	0.16
		10	13.2	10.2	9.5	7.0	
11/11/76	1620	2	25.6	5.3	14.0	7.7	0
		8	25.6	5.3	14.0	7.7	
11/23/76	1235	1	17.0	5.0	11.2	7.0	0
		8	17.0	4.8	11.8	7.0	
12/10/76	1340	6	21.3	5.4	12.9	7.5	0
12/21/76	1215	1	15.0	6.0	10.9	7.4	0
		10.5	13.8	11.0	9.2	7.4	
No Plankton Sampling January and First Part of February, 1977. Bay Frozen.							
2/24/77	1100	1	16.5	5.0	13.0	7.5	0
		8.5	17.0	5.0	12.8	7.5	
3/9/77	1310	*	*	*	*	*	0
3/29/77	1355	1	14.0	12.0	11.5	7.5	0
		8.5	12.0	13.2	11.0	7.5	
4/6/77	1030	1.5	22.7	9.2	11.2	*	0
		10	23.1	9.0	11.6	*	

TABLE D-72. (continued)

Date	Time	Depth in Feet	Salinity - o/oo	Temp. - °C	O_2	pH	X # Teredinid Larvae per M^3
4/20/77	1525	1	21.0	16.5	9.2	7.5	0
		9	20.9	16.8	9.1	7.5	
5/5/77	1750	1.5	20.7	15.6	9.1	8.1	0
		10	21.1	15.4	9.1	8.1	
5/19/77	1055	1	21.0	19.3	7.2	7.5	0
		11	21.0	19.5	7.3	7.5	
6/7/77	1557	6	27.0	18.4	9.2	8.2	0
6/28/77	1045	1	30.0	25.5	6.4	7.7	0.30
		8	24.2	26.0	4.8	7.7	
7/13/77	1500	1.5	27.4	25.3	7.0	8.2	0
		8	27.4	25.3	7.0	8.2	
7/27/77	1130	1	25.5	23.2	7.6	6.9	0.11
		8.5	25.0	23.3	7.8	6.9	
8/10/77	0755	3	28.4	28.0	6.1	8.1	0.40
		9	28.4	28.0	6.3	8.1	
8/26/77	1240	1	23.8	24.0	8.4	6.8	0
		8.5	23.8	23.5	8.4	6.8	
9/14/77	1108	1	25.6	23.3	6.9	8.0	0
		8	25.6	23.3	7.3	8.0	
9/28/77	1020	1	**	20.0	6.9	6.8	0.13
		8.5	**	20.0	6.6	6.8	
10/12/77	1451	1.5	23.4	15.5	9.7	8.0	0
		6	23.4	15.5	9.7	8.1	
10/19/77	1335	1	**	13.9	8.9	***	0.19
		9.5	**	13.9	8.4	***	
11/9/77	1240	0	17.3	15.0	8.8	7.5	5.68
		8	21.0	14.8	8.5	7.8	
11/30/77	0950	1	**	5.5	****	***	0
		7	**	5.0	****	***	

* = Hydrolab malfunction
** = Salinometer non-functional
*** = pH meter non-functional
**** = Dissolved oxygen system non-functional

TABLE D-73. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE AT PLANKTON STATION C, FROM JUNE, 1976, THROUGH NOVEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temp. - °C	O_2	pH	X # Teredinid Larvae per M^3
6/9/76	0840	1.5	22.1	21.5	8.5	7.7	0
		6	22.8	21.5	8.5	7.7	
6/23/76	1035	2	22.9	27.5	9.6	7.5	2.18
		6.5	17.9	27.0	6.2	7.5	
7/15/76	0900	1.5	27.7	22.0	7.7	7.7	0.32
		7	28.4	22.0	7.7	7.7	
7/27/76	1630	1.5	24.0	26.3	6.6	7.0	0
		7	23.0	26.0	7.0	7.0	
8/12/76	1715	1.5	22.7	28.0	7.9	7.9	0
		5	22.7	28.0	7.9	7.9	
8/24/76	1415	1.5	17.8	26.1	7.2	7.5	0
		6.5	18.1	26.0	7.1	7.5	
9/16/76	0805	3	25.6	24.0	7.7	7.9	0
9/28/76	1435	1	19.8	20.2	7.1	7.7	0.21
		7.5	18.5	20.5	7.6	7.7	
10/12/76	1400	1.5	27.7	17.0	10.2	7.5	0
		10	27.7	17.0	10.2	7.5	
10/28/76	1355	1	13.1	11.2	8.6	7.0	0.19
		7.5	13.0	11.5	10.9	7.0	
11/11/76	1630	1.5	25.6	5.5	13.6	7.7	0
		4	25.6	5.5	13.6	7.7	
11/23/76	1355	1	17.0	4.8	11.7	7.8	0
		6	17.0	4.8	11.7	7.8	
12/10/76	1300	2	15.9	5.0	13.0	7.5	0
12/21/76	1320	1	16.0	3.2	11.6	7.2	0
		6.5	14.5	3.5	11.6	7.2	
No Plankton Sampling January and First Part of February, 1977. Bay Frozen.							
2/24/77	1200	1	17.5	5.5	13.2	7.0	0
		7	19.0	6.0	13.1	7.0	
3/9/77	-	*	*	*	*	*	0
3/29/77	1500	1	18.8	10.5	11.0	7.5	0
		7	17.5	11.0	10.2	7.5	
4/6/77	0905	3	24.0	9.0	11.6	*	0

TABLE D-73. (continued)

Date	Time	Depth in Feet	Salinity - o/oo	Temp. - °C	O_2	pH	X # Teredinid Larvae per M^3
4/20/77	1630	1	20.9	16.1	8.9	7.5	0
		6.5	20.9	16.1	8.9	7.5	
5/5/77	1855	1.5	24.3	15.0	9.3	8.3	0
		6	24.3	15.2	9.2	8.4	
5/19/77	1210	1	22.3	19.0	7.7	7.5	0
		6.5	22.0	19.0	7.8	7.5	
6/7/77	1740	1.5	26.7	18.1	9.4	8.1	0.14
		5	26.7	18.1	9.4	8.1	
6/28/77	1150	1	15.8	25.0	6.7	8.1	0.70
		7.5	15.5	25.0	5.9	8.1	
7/13/77	1553	1.5	27.6	25.9	8.1	8.2	0.17
		6	27.6	25.9	8.1	8.1	
7/27/77	1245	1	23.8	23.8	7.2	6.8	0
		6.3	21.0	23.9	7.1	6.8	
8/10/77	0910	5	28.4	29.0	6.7	8.1	0
8/26/77	1340	1	24.8	24.5	9.2	6.9	0
		6.5	20.0	24.2	8.5	6.9	
9/14/77	1004	1	26.1	23.7	6.9	8.0	0
		6	26.1	23.7	7.5	8.0	
9/28/77	1125	1	**	21.0	7.4	6.9	0
		6.5	**	20.8	6.2	6.9	
10/12/77	1616	1.5	25.6	15.3	10.0	8.1	0
		6	27.7	15.5	9.4	8.1	
10/19/77	1455	1	*	13.0	8.8	***	0.10
		6.5	*	13.0	8.3	***	
11/9/77	1326	0	22.0	15.2	9.8	7.9	0.62
		6	23.4	14.6	9.6	7.9	
11/30/77	1100	1	**	5.5	****	***	0
		4.5	**	5.0	****	***	

* = Hydrolab malfunction
** = Salinometer non-functional
*** = pH meter non-functional
**** = Dissolved oxygen system non-functional

TABLE D-74. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE AT PLANKTON STATION D, FROM JUNE, 1976, THROUGH NOVEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temp. - °C	O_2	pH	$\bar{X}$ # Teredinid Larvae per M^3
6/8/76	1500	1.5	19.9	22.5	10.6	7.8	1.93
		4	19.9	22.5	10.6	7.8	
6/23/76	0920	2	21.8	25.3	7.2	7.5	0.45
		4	17.0	24.8	6.3	7.5	
7/14/76	-	1.5	25.6	22.5	8.8	7.7	0
		7	25.6	22.0	8.8	7.7	
7/28/76	1140	1.5	19.5	26.0	7.2	7.0	0
		6.5	19.0	25.0	5.2	7.0	
8/12/76	1845	1.5	22.0	25.0	8.5	7.9	0
		6	22.0	25.0	8.5	7.9	
8/25/76	1105	1.5	17.5	26.0	6.0	7.0	0
		6	18.6	26.0	4.3	7.0	
9/16/76	1000	4	20.6	24.5	9.1	7.9	0
9/29/76	1040	1	16.5	18.6	8.7	7.7	0
		6.5	19.5	19.8	9.2	7.7	
10/12/76	1552	3	23.4	15.5	11.0	7.5	0
10/28/76	1040	1	12.2	7.2	10.6	7.0	0.15
		6	12.2	7.8	11.1	7.0	
11/11/76	1445	1.5	22.7	5.5	13.6	7.7	0
		7	22.7	5.5	13.6	7.7	
11/24/76	0930	1	14.0	3.0	11.2	7.0	0
		6.5	13.5	3.0	11.4	7.0	
12/10/76	1500	6	20.6	1.5	14.2	7.5	0
12/22/76	1115	1	13.8	1	12.2	7.3	0
		6.5	13.6	6.0	11.8	7.3	
No Plankton Sampling January and First Part of February, 1977. Bay Frozen. Station Iced In, and No Channel Markers for Navigation End of February.							
3/10/77	0845	*	*	*	*	*	0
3/29/77	1605	1	17.8	10.8	11.0	7.5	0
		6.5	17.2	11.0	10.5	7.5	
4/7/77	1422	1.5	18.5	8.9	11.6	*	0
		5	18.5	8.9	11.6	*	
4/20/77	1400	1	16.8	16.0	9.2	7.8	0
		7	16.7	15.5	8.7	7.8	

TABLE D-74. (continued)

Date	Time	Depth in Feet	Salinity - o/oo	Temp. - °C	O_2	pH	$\bar{X}$ # Teredinid Larvae per M^3
5/3/77	1525	1.5	18.5	17.5	11.0	8.7	0
		5	20.9	17.1	11.0	8.6	
5/20/77	1025	1	18.0	19.0	7.6	7.5	0.41
		6.5	12.5	19.0	6.3	7.5	
6/7/77	1414	1.5	23.4	19.0	9.3	8.1	0.15
		6	23.4	19.0	9.3	8.1	
6/28/77	1310	1	21.0	25.0	6.3	8.2	0.43
		6	21.0	25.0	6.0	8.2	
7/13/77	1314	3.0	25.1	25.5	7.9	8.3	0
7/27/77	1405	1	24.8	23.9	8.2	6.8	0
		6.5	24.5	23.8	7.1	6.8	
8/10/77	1410	2	25.6	27.0	7.9	8.2	0.30
		7	25.6	27.0	7.9	8.2	
8/26/77	1135	1	17.5	24.0	8.5	6.9	0
		5	16.5	25.8	8.4	6.9	
9/14/77	1243	1	22.7	21.0	7.0	7.9	0
		4	22.7	21.0	7.1	7.9	
9/28/77	0915	1	**	20.0	7.0	7.0	0
		5	**	20.5	5.2	7.0	
10/12/77	1311	1.5	21.3	14.3	9.6	8.1	0
		5	21.9	14.4	9.4	8.1	
10/19/77	1204	1	**	11.5	9.5	***	0
		6	**	11.5	7.9	***	
11/9/77	1112	0	20.0	14.5	8.9	7.9	0.12
		2	22.7	14.5	8.7	7.9	
11/29/77	1620	1	**	5.0	****	***	0
		6.5	**	6.0	****	***	

* = Hydrolab non-functional
** = Salinometer non-functional
*** = pH meter non-functional
**** = Dissolved oxygen non-functional

TABLE D-75. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE AT PLANKTON STATION E, FROM JUNE, 1976, THROUGH NOVEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temp. - °C	O_2	pH	$\bar{X}$ # Teredinid Larvae per M^3
6/8/76	1140	1.5	24.9	20.5	9.5	7.8	0
		5	24.9	20.5	9.5	7.8	
6/22/76	1520	2	25.5	25.0	13.3	7.0	0.16
		4.5	21.5	25.0	11.5	7.0	
7/14/76	1155	1.5	29.1	22.0	8.5	7.7	1.17
		8	29.1	22.0	8.5	7.7	
7/28/76	1005	1.5	25.2	25.0	6.4	7.0	0
		7.5	26.0	25.0	5.2	7.0	
8/12/76	1400	1.5	26.3	25.0	9.0	7.9	0.22
		10	26.3	25.0	9.0	7.9	
8/25/76	0935	1.5	21.0	26.0	5.8	7.5	1.1
		7.5	20.7	26.0	4.9	7.5	
9/15/76	1340	4	27.0	23.0	9.5	7.8	0.43
9/28/76	1535	1	20.2	20.0	8.5	7.8	0.27
		8	20.0	20.0	8.8	7.8	
10/12/76	1340	1.5	26.3	15.0	10.2	7.5	0
		7	26.3	15.0	10.2	7.5	
10/28/76	1550	1	13.1	9.0	8.6	7.5	0
		7	13.5	9.1	7.1	7.5	
11/12/76	0943	2	25.6	5.5	14.2	7.7	0
		5	25.6	5.5	14.2	7.7	
11/23/76	1600	1	17.0	5.5	10.9	7.0	0
		6	16.5	5.5	11.0	7.0	
12/10/76	1045	2	24.9	3.5	14.1	7.6	0
		5	24.9	3.5	14.1	7.6	
12/22/76	1000	1	16.0	1.2	11.8	7.3	0
		7.5	16.8	1.8	12.0	7.3	
No Plankton Sampling January and First Part of February, 1977. Bay Frozen.							
2/25/77	0925	1	18.7	5.5	11.5	7.5	0
		6.5	21.0	5.0	11.2	7.5	
3/9/77	1115	*	*	*	*	*	0
3/9/77	1705	1	24.0	10.0	10.8	7.6	0
		6.5	24.0	11.0	10.2	7.5	
4/7/77	1113	1.5	25.7	8.5	11.4	*	0
		6	26.1	8.5	11.4	*	

TABLE D-75. (continued)

Date	Time	Depth in Feet	Salinity - o/oo	Temp. - °C	O_2	pH	$\bar{X}$ # Teredinid Larvae per M^3
4/20/77	1220	1	23.3	16.1	8.8	7.5	0
		6	23.3	16.0	8.0	7.5	
5/3/77	1256	1.5	25.3	16.3	10.0	8.6	0
		5.5	24.9	16.3	10.0	8.6	
5/20/77	0915	1	24.5	18.4	8.0	7.5	0
		6	25.0	18.0	8.0	7.5	
6/7/77	1055	1.5	25.9	17.3	8.7	8.0	0
		5	28.3	17.3	8.6	8.2	
6/28/77	1605	1	25.5	25.0	7.5	6.8	0.16
		6	25.0	25.0	7.2	6.8	
7/13/77	1008	2	25.4	24.8	8.1	8.4	0.33
7/27/77	1530	1	28.5	24.5	9.1	6.9	0.5
		5	28.5	24.5	8.9	6.9	
8/9/77	1445	5	29.9	28.0	4.6	8.3	0
8/24/77	1705	1	24.5	24.5	6.0	6.9	0
		6.5	25.0	24.0	6.5	6.9	
9/14/77	1523	2	25.7	21.6	8.5	7.9	0
9/27/77	1730	1	**	22.0	6.7	6.9	0
		6.5	**	22.1	6.6	6.9	
10/12/77	0903	1	24.9	15.5	9.0	8.0	0
		6	25.6	15.0	8.5	8.0	
10/19/77	1035	1	**	12.5	5.0	***	0
		6.5	**	12.0	5.5	***	
11/9/77	0819	0	20.6	15.2	9.6	7.8	0.52
		7	24.3	14.5	9.0	7.5	
11/29/77	1515	1	**	5.5	****	***	0
		5	**	6.0	****	***	

* = Hydrolab non-functional
** = Salinometer non-functional
*** = pH meter non-functional
**** = Dissolved oxygen system non-functional

TABLE D-76. WATER QUALITY AND INCIDENCE OF TEREDINID LARVAE AT PLANKTON STATION F, FROM JUNE, 1976, THROUGH NOVEMBER, 1977

Date	Time	Depth in Feet	Salinity - o/oo	Temp. - °C	O_2	pH	X # Teredinid Larvae per M^3
6/8/76	0850	1.5	27.8	19.0	8.0	7.8	2.90
		12	27.8	19.0	8.1	7.8	
6/22/76	1350	2	25.5	24.5	9.0	7.0	0
		15	21.8	24.5	10.8	7.0	
7/14/76	1010	1.5	29.9	18.0	7.7	7.7	0.94
		6	29.9	18.0	7.7	7.7	
7/28/76	0850	1.5	18.0	21.0	7.0	7.5	3.63
		10	24.8	21.5	8.4	7.5	
8/12/76	1245	1.5	29.1	22.0	8.0	7.9	0
		6	29.1	22.0	7.8	7.9	
8/25/76	0825	1.5	23.7	23.0	4.1	7.5	0
		8	23.5	24.0	3.8	7.5	
9/15/76	1120	1.5	30.6	20.0	7.2	7.9	1.37
		7	30.6	20.0	7.2	7.9	
9/26/76	0910	1	21.0	17.8	7.6	7.7	0
		11	19.3	17.5	7.7	7.7	
10/12/76	1145	1.5	32.1	15.5	8.8	8.0	0
		6	32.1	15.5	8.8	8.0	
10/28/76	0950	1	12.2	6.4	11.0	7.0	0
		15	12.5	6.8	10.6	7.0	
11/12/76	0825	1.5	27.7	6.0	14.4	7.7	0
		8	27.7	6.0	14.4	7.7	
11/24/76	0800	1	17.0	2.0	11.4	7.0	0
		13	14.5	2.0	11.4	7.0	
12/10/76	Plankton Samples were not taken. Weather conditions prevented safe travel across the bay.						
12/22/76	0850	1	18.0	1.5	11.4	7.2	0
		13	16.0	1.8	11.7	7.4	
No Plankton Sampling January and February, 1977. Bay Frozen. Last Part of February Channel Markers Missing.							
3/10/77	1050	2	20.6	5.5	*	*	0
		11	20.6	5.0	*	*	
3/30/76	0900	1	26.5	9.0	10.4	7.5	0
		10	26.5	9.2	10.0	7.5	
4/7/77	0936	1.5	25.9	6.6	11.4	*	0
		9	25.9	6.8	11.4	*	

TABLE D-76. (continued)

Date	Time	Depth in Feet	Salinity - o/oo	Temp. - °C	O_2	pH	$\bar{X}$ # Teredinid Larvae per M^3
4/20/77	1120	1	28.2	10.8	10.6	7.8	0
		11.5	28.5	11.2	10.4	7.8	
5/3/77	1407	1.5	26.6	16.0	11.4	8.7	0
		9	27.6	16.0	11.4	8.7	
5/20/77	0815	1	25.2	16.0	7.7	7.8	0
		10.5	25.6	16.0	7.7	7.8	
6/7/77	1200	1	30.6	16.2	9.1	8.1	0
		8	30.6	16.2	9.1	8.1	
6/28/77	1750	1	28.4	17.5	8.4	6.6	0
		7	27.2	17.5	8.5	6.6	
7/13/77	1107	1.5	26.0	25.0	8.1	8.4	0.50
		14	26.0	24.5	8.0	8.4	
7/28/77	0845	1	24.2	28.5	8.3	6.9	0.57
		6.5	24.1	22.0	8.7	6.9	
8/10/77	1255	10	29.9	26.0	7.7	8.1	0.22
8/24/77	1450	1	24.5	26.5	6.8	6.9	0.10
		10	24.7	26.2	6.8	6.9	
9/14/77	1639	1.5	25.7	21.1	8.5	7.8	0
		12	25.7	20.0	8.6	7.8	
9/27/77	1625	1	**	21.0	7.6	7.0	0.11
		10	**	20.5	7.8	7.0	
10/12/77	1021	1	31.7	16.3	9.0	8.1	3.54
		12	32.0	16.5	9.2	8.1	
10/19/77	0920	1	**	12.5	7.2	***	2.36
		9	**	12.2	7.8	***	
11/9/77	1007	0	23.7	14.8	8.9	7.9	8.67
		12	24.2	14.8	9.1	7.9	
11/29/77	1315	1	**	8.0	****	***	34.77
		5	**	7.8	****	***	

* = Hydrolab non-functional
** = Salinometer non-functional
*** = pH meter non-functional
**** = Dissolved oxygen system non-functional

TABLE D-77. MEAN TEMPERATURE, SALINITY, AND THEIR STANDARD DEVIATION FROM JUNE THROUGH DECEMBER, 1976, AND FROM JANUARY THROUGH DECEMBER, 1977, AND FOR THE COMBINED PERIODS; AND RANGE FOR THE COMBINED PERIODS AT THE EIGHTEEN EXPOSURE PANEL STATIONS

	Temperature - C				Salinity o/oo			
Station	1976	1977	1976-1977	Range 1976-1977	1976	1977	1976-1977	Range 1976-1977
1	15.2	16.2	15.8	4.5-25.0	28.6	27.0	27.6	20.6-30.6
	7.4	6.2	6.5		.8	4.5	3.6	
2	15.7	17.0	16.4	1.5-27.5	25.0	24.1	24.5	19.0-29.9
	9.6	6.6	7.8		2.8	4.0	3.4	
3	15.8	17.1	16.5	2.5-27.0	25.1	24.3	24.7	18.5-29.5
	9.6	6.5	7.7		1.8	3.5	2.8	
4	16.3	17.4	16.9	3.5-27.0	25.1	25.2	25.2	19.9-29.9
	8.5	6.3	7.1		2.3	3.3	2.8	
4A*	-	18.8	18.8	7.7-28.0	-	26.1	26.1	21.4-29.9
	-	6.3	6.3		-	2.6	2.6	
5	20.4	16.0	17.6	3.0-30.0	22.6	21.9	22.2	15.2-26.3
	10.1	8.7	9.3		3.2	3.8	3.5	
6	20.3	19.0	19.5	7.0-29.5	23.5	21.8	22.6	14.5-27.7
	8.7	6.2	7.0		1.8	5.2	4.0	
7	21.4	16.8	18.5	3.0-30.3	22.9	21.0	21.7	11.8-28.5
	8.5	8.1	8.3		4.3	5.4	5.0	
8	21.1	16.8	18.5	0.0-32.0	23.5	22.8	23.0	15.2-28.4
	9.4	9.2	9.2		4.0	3.5	3.6	
9	17.1	16.3	16.7	0.5-28.0	25.2	23.9	24.4	19.2-28.4
	8.9	8.6	8.5		2.2	3.0	2.7	
10	17.6	17.0	17.2	4.0-26.0	16.3	19.8	18.4	<1.0-25.6
	8.6	6.1	7.0		9.2	5.3	7.1	
11	16.9	14.4	15.4	0.0-28.0	24.4	23.2	23.7	12.1-28.8
	9.3	9.2	9.0		2.5	4.4	3.8	
12	16.7	18.4	17.6	2.0-28.0	21.5	23.9	22.8	11.1-27.4
	9.5	7.1	8.1		5.6	3.2	4.5	
13	16.9	16.0	16.4	1.0-29.0	13.8	16.6	15.5	<1.0-24.8
	9.7	8.7	8.8		7.5	6.6	6.9	
14	16.6	17.2	16.9	1.0-30.0	17.9	21.3	19.8	<1.0-25.6
	10.3	7.6	8.6		8.3	2.7	5.9	
15	16.0	15.9	16.0	3.0-26.5	17.5	20.1	19.0	5.8-24.5
	9.0	6.9	7.5		5.8	2.2	4.2	
16	15.9	17.3	16.7	3.0-28.0	18.3	16.4	17.2	4.6-27.0
	9.2	6.9	7.7		6.9	3.2	5.1	
17	16.4	16.9	16.7	4.1-28.0	24.4	27.0	25.9	9.7-30.6
	8.4	7.0	7.4		7.1	3.0	5.1	

* = Station 4A was established in April, 1977. Water quality was first taken in May, 1977.

TABLE D-78. KNOWN WATER QUALITY RANGES FOR TEREDINIDS PRESENT IN BARNEGAT BAY

Species	Temperature - C	Salinity - o/oo	O_2	pH	Reference
Teredo navalis					
Adult	2-35	5-32	-	-	Turner, 1973
release larvae	13-30	-	-	-	Turner, 1973
Adults				4-5	Mawatari, 1950
			Lab 0.98 mg/l Natural 9.59-10.30 mg/l		Roch, F., 1932
Bankia gouldi					
Adult	5-23	10-35			Turner, 1973
spawn	17.5-30				Turner, 1973
	16-20				Scheltema and Truitt, 1954
Adult		14-35	>2-3		Allen, 1924
Teredo furcifera					
Adult	24-33	15			Karande, 1968
Teredo bartschi					
No information found in literature.					

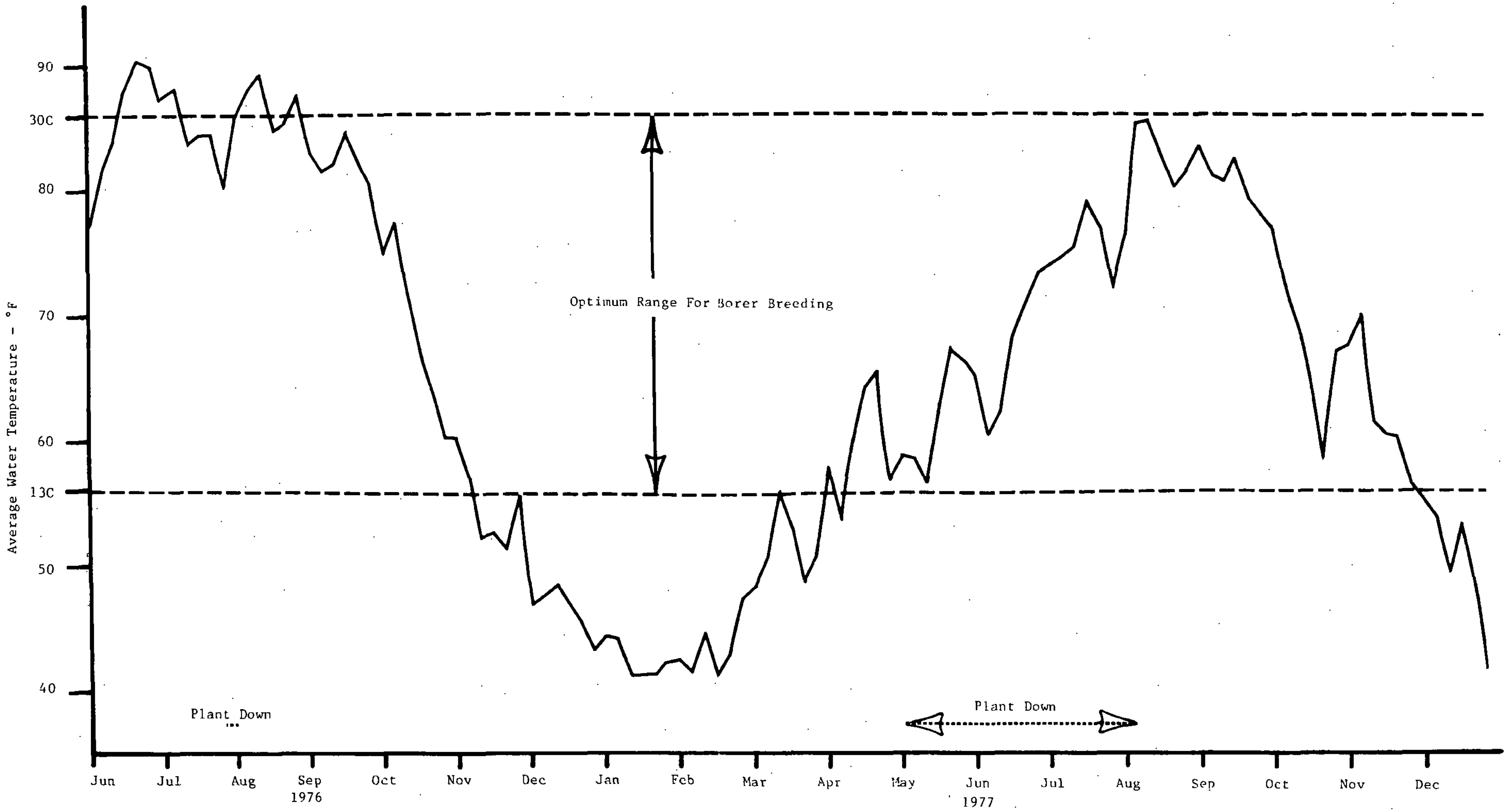


FIGURE D-2. AVERAGE WATER TEMPERATURE °F AT OYSTER CREEK RAILROAD BRIDGE JUNE, 1976, THROUGH DECEMBER, 1977 however. The *Teredo* that were not identified to species were either too small or did not possess a sufficient number of essential taxonomic characters. Specific examples of the extent to which the above-mentioned species of teredinids were able to destroy long-term panels under various salinity conditions are presented later.

The mean salinity, seawater temperature, and the mean percent destruction of the long-term panels at each exposure panel station is presented in Figure D-3. There was no pattern of destruction observed in relation to these parameters. The periodic salinities that were below the limit known to support teredinids were recorded only at exposure panel stations, and they occurred after the breeding season. The low salinities did not persist. The salinities recorded the month before and the month after the low readings were usually within the range to support teredinids. The seawater dilution occurred as a result of freshwater from precipitation and runoff and ice melting.

Most species of teredinids require normal marine conditions for spawning; however, adults may withstand long periods under a variety of extreme conditions by closing the burrow and becoming relatively inactive (Turner, 1966). Available salinity ranges for adult survival and reproduction for the four species of teredinids found in Barnegat Bay are presented in Table D-78.

Bankia gouldi had the largest distribution of any teredinid identified to species. It was present at all stations except Stations 2, 16, and 17. At those stations where *B. gouldi* was present, except for Stations 1 and 7 in November and December, 1977, it was the dominant teredinid in the long-term panels. At Station 7 for the months shown above *Teredo bartschi* was dominant. *Bankia gouldi*, however, was also present in the long-term panels at Station 7 in November and December. *Teredo navalis* was dominant at Station 1.

Bankia gouldi occupied sites where, over the course of the study, salinity and water temperature ranged from less than 1.0 o/oo to 30.6 o/oo, and from 0.0C to 30.3C, respectively.

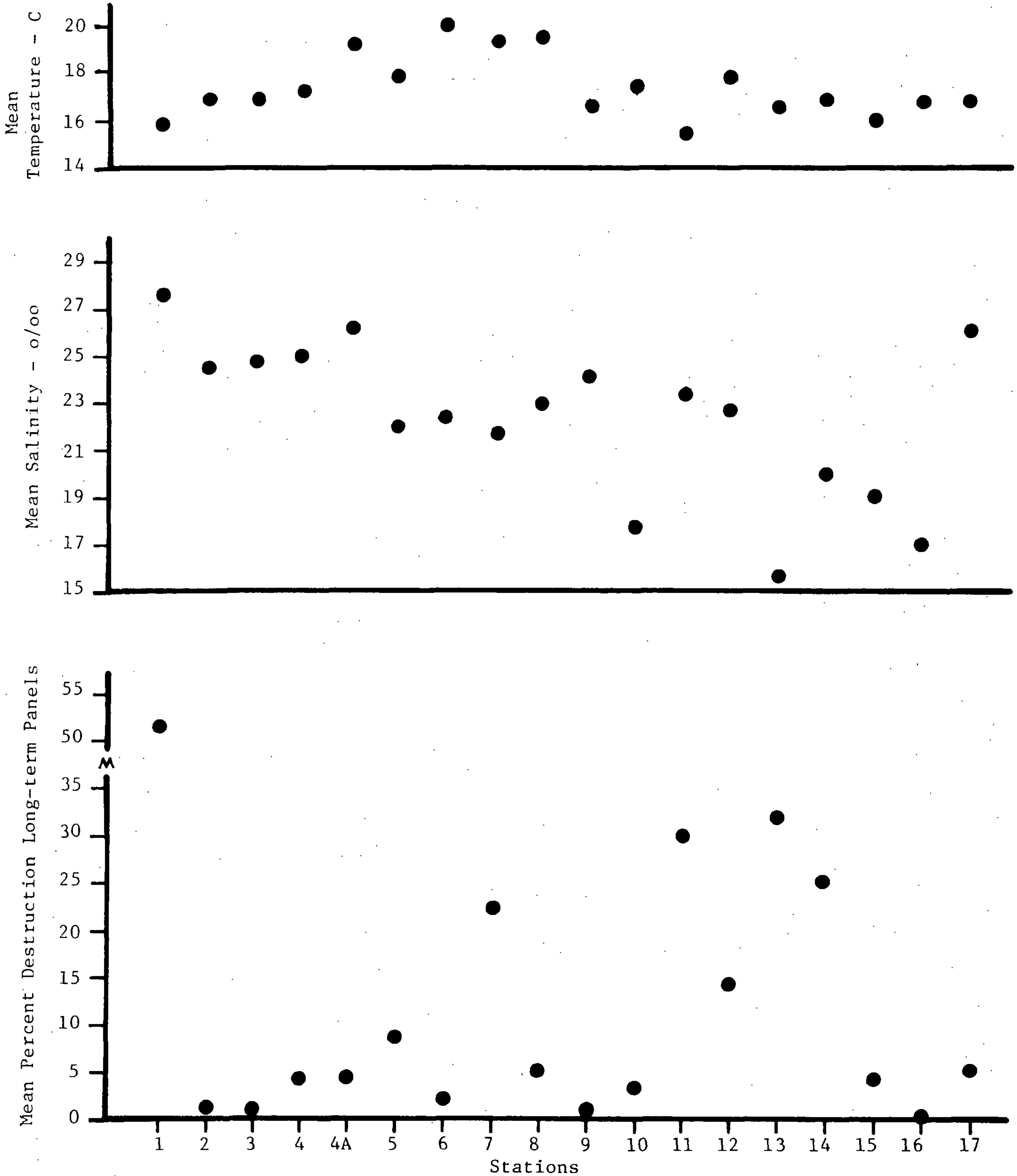


FIGURE D-3. MEAN PERCENT DESTRUCTION OF LONG-TERM PANELS, MEAN SALINITY, AND MEAN TEMPERATURE AT EACH OF THE 18 EXPOSURE PANEL STATIONS, BARNEGAT BAY FOR THE PERIOD JUNE, 1976, THROUGH DECEMBER, 1977

The mean percent destruction of long-term panels at those stations dominated by *B. gouldi* was variable (Table A-25). The highest mean percent destruction of long-term panels occurred at Station 13. It was 40.73 percent and ranged from zero to 90 percent. The mean salinity at this station was 15.5 o/oo, with a range from less than one to 24.8 o/oo. The standard deviation of the mean salinity was 6.9 o/oo.

The long-term panels at Station 11 sustained the second highest mean percent destruction, 39.93 percent. The mean salinity at Station 11 was 23.7 o/oo, with a standard deviation of 3.8 o/oo. The salinity range was from 12.1 o/oo to 28.8 o/oo. The mean temperature was 15.4C, with a standard deviation of 9.1C, and the temperature range was from 0.0C to 28C.

Bankia gouldi was also dominant at Stations 4, 5, 6,7, and 8. All five stations were in the area occupied by the thermal plume. Station 4 is approximately 1.5 miles south of the mouth of Oyster Creek. Stations 5 and 6 are in lagoons that enter Oyster Creek, and Stations 7 and 8 are in Oyster Creek.

At Station 4, the mean percent destruction of long-term panels was 4.2 percent, and ranged from zero to 5 percent. The mean salinity was 25.2 o/oo, with a standard deviation of 2.8 o/oo. Salinities ranged from 19.9 o/oo to 29.9 o/oo. The mean temperature was 16.9C, with a standard deviation of 7.1C. Temperatures ranged from 3.5C to 27.0C.

The mean percent destruction of long-term panels at Station 5 was 10.87 percent, and ranged from zero to 35 percent. The mean salinity was 22.1 o/oo, with a standard deviation of 3.5 o/oo. Salinities ranged from 15.2 o/oo to 26.3 o/oo. The mean temperature was 17.6C, with a standard deviation of 9.3C. Temperatures ranged from 15.2C to 26.3C.

At Station 6 the mean percent destruction of long-term panels was 2.53 percent and ranged from zero to 10 percent. The mean salinity was 22.6 o/oo, with a standard deviation of 4.1 o/oo. Salinities ranged from 14.5 o/oo to 27.7 o/oo. The mean temperature was 19.5C, with a standard deviation of 7.1C. Temperatures ranged from 7.0C to 29.5C.

The mean percent destruction of long-term panels at Station 7 was 28.0 percent, with a range from zero to 95 percent. However, in November and December, 1977, *Teredo bartschi* was the dominant teredinid. The mean salinity at this station was 21.7 o/oo with a standard deviation of 5.0 o/oo. Salinities ranged from 11.8 o/oo to 28.5 o/oo. The mean temperature was 18.5C, with a standard deviation of 8.3C. Temperatures ranged from 3.0C to 30.3C.

At Station 8 the mean percent destruction of long-term panels was 5.67 percent, with a range from zero to 35 percent. The mean salinity was 23.0 o/oo, with a standard deviation of 3.6 o/oo. Salinities ranged from 15.2 o/oo to 28.4 o/oo. The mean temperature was 18.5C, with a standard deviation of 9.2C. Temperatures ranged from 0.0C to 32.0C.

The mean percent destruction of short-term panels removed from the 18 exposure panels stations from June, 1976, through December, 1977 was very low (Table A-24).

At those stations dominated by *Bankia gouldi* the mean percent destruction of short-term panels was variable and rather low. The highest mean percent destruction of short-term panels occurred at Station 7, and it was only 1.8 percent, and ranged from zero to 10 percent. Of the 18 short-term exposure panels removed from Station 7 from July, 1976, through December, 1977, only 7 (39 percent) contained teredinids. The mean percent destruction of short-term panels at the remaining stations where *B. gouldi* was dominant ranged from zero at Stations 3, 4A, and 15 to a high of 0.7 percent at Stations 11 and 14. Data for the remaining stations is presented in Table A-24.

Salinity and temperature data for Station 7 were given in the section on long-term panel destruction. At Station 3 the mean salinity was 24.7 o/oo, and ranged from 18.5 o/oo to 29.5 o/oo. The mean water temperature was 16.5C, with a standard deviation of 7.7C; temperatures ranged from 2.5C to 27C.

Water quality data for Station 4A is based on only eight measurements, because the station was established in April, 1977, and water quality was first recorded in May, 1977. The mean salinity was 26.1 o/oo with a standard deviation of 2.6 o/oo. Salinities ranged from 21.4 o/oo to 29.9 o/oo. The mean temperature was 18.8C, with a standard deviation of 6.3C; temperatures ranged from 7.7C to 28.0C.

At Station 14 the mean salinity was 19.8 o/oo with a standard deviation of 5.9 o/oo. Salinities ranged from less than 1 o/oo to 25.6 o/oo. The mean seawater temperature was 16.9C with a standard deviation of 8.6C. Temperatures ranged from 1.0C to 30.0C.

The mean number of teredinids removed from the short-term panels at those stations dominated by *Bankia gouldi* also fluctuated. Station 7 had the highest number of teredinids which included *Teredo bartschi*. The mean was approximately 40 teredinids per panel. For the remaining stations the mean values ranged from zero at Stations 3, 4A, 15, and 16, to a high of 24.4 at Station 7. Data for the remaining stations are presented in Table A-24.

Teredo navalis was only found at Stations 1, 2, 4, 7, 8, 9, 11, 14, 15, and 17. It was the dominant teredinid at Stations 1, 2, and 17 only.

Station 1 had the highest mean salinity of any of the exposure panel stations, 27.6 o/oo. The standard deviation of the mean was 3.64 o/oo. Salinities ranged from 20.6 o/oo to 30.6 o/oo. The mean temperature at Station 1 was 15.8C, with a standard deviation of 6.5C; temperatures ranged from 4.5 to 25.0C.

At Station 2 the mean salinity was 24.5 o/oo with a standard deviation of 3.4 o/oo, salinities ranged from 19.0 o/oo to 29.9 o/oo. The mean temperature was 16.4C and the standard deviation was 7.8C; temperatures ranged from 1.5C to 27.5C.

The mean salinity at Station 17 was 25.9 o/oo with a standard deviation of 5.1 o/oo, salinities ranged from 9.7 o/oo to 30.6 o/oo. The mean temperature at Station 17 was 16.7C with a standard deviation of 7.4C; temperatures ranged from 4.1C to 28.0C.

Salinity was not a limiting factor at those stations where *Teredo navalis* was found. Salinity reductions in Barnegat Bay during the course of the study were of short duration and did not have a detrimental effect on *T. navalis*. Blum (1922) reported that *T. navalis* can survive for a month at 4.0 o/oo.

Teredo navalis is active and reproduces in salinities from normal seawater to as low as 9.0 o/oo (Miller, 1926). Thus, the salinities recorded at all station where *T. navalis* was present were within the range to allow reproduction to occur.

Seawater temperatures in Barnegat Bay did not limit the distribution of *T. navalis*. Turner (1973) found *T. navalis* over a range of 33C, from 2C to 35C.

Water quality data for the remainder of the stations where *T. navalis* was found are presented in Tables D-53, D-67, and D-68.

The mean percent destruction of long-term panels at Station 1 was 64.93 percent which was the highest mean percent of destruction recorded for any of the exposure panel stations. The percent destruction ranged from zero to 100 percent (Table A-25). At Station 2, the mean percent destruction of long-term panels was 0.33 percent, and ranged from zero to 2 percent. At Station 17, the mean percent destruction of long-term panels was 5.73 percent and ranged from zero to 40 percent (Table A-25).

From July, 1976, through December, 1977, a total of 2,164 teredinids were removed from the short-term exposure panels collected at all stations. Of this total 1,744 teredinids, or 80.59 percent, were removed from the short-term panels at Station 1.

The mean number of teredinids removed from short-term exposure panels was highest at Station 1, 174.4 teredinids per panel, and ranged from zero to 494 teredinids per panel. At Station 2 the mean number of teredinids removed from short-term exposure panels was 0.2 teredinids per panel, with a range from zero to 1 teredinids per panel.

At Station 17, the mean number of teredinids found per exposure panel was 0.3, the range was from zero to two teredinids.

Teredo bartschi was only found at Station 7 in October, November, and December, 1977. However, in November and December it was the dominant teredinid in the long-term panels, it was not dominant in October. The panels removed in November and December were 90 and 95 percent destroyed, respectively. The numbers of shipworms present in each panel were 212 for November and 206 for December.

In November a total of 212 teredinids were found in the long-term panel. *Teredo bartschi* accounted for 87 percent (185 specimens). The remainder were seven *B. gouldi* and 20 Teredinidae. The 20 Teredinidae ranged in size from less than 1 mm to 26 mm; the larger specimens were not identified to species since their pallets were broken or missing.

Teredo bartschi accounted for 63 percent of the teredinids removed from the long-term panel in December (130 specimens). There were seven specimens of *B. gouldi* and 70 specimens of Teredinidae. The Teredinidae ranged in size from 4 mm to 14 mm. The larger specimens were not identified to species since their pallets were broken or missing.

The mean salinity at Station 7 was 21.7 o/oo with a standard deviation of 5.0 o/oo, salinities ranged from 11.8 o/oo to 28.5 o/oo. The mean temperature was 18.5C with a standard deviation of 8.3C; temperatures ranged from 3.0C to 30.3C.

Teredo furcifera was only found at three stations from July, 1976, through December, 1977. The stations were 4, 7, and 11.

At Station 4 one specimen was found in the long-term panel removed in March, 1977. The long-term panel removed in September, 1976 from Station 7 contained one specimen of *T. furcifera*. At Station 11 two specimens of *T. furcifera* were found in the long-term panel removed in February, 1977.

Teredo spp. were specimens that were either too small or in such poor condition that they could not be identified to species. *Teredo* spp. were found in long-term panels removed from Stations 1, 2, 7, 9, 11, 13, 14, and 17; they were only dominant at Station 7 in October, 1977.

The teredinid plankton data (salinity, temperature, and mean number of teredinids per cubic meter) were subjected to analysis using the Kendall Correlation (Sokal and Rohlf, 1967) and Spearman Correlation (Hollander and Wolfe, 1973). The results of the analysis showed that there was no significant correlation between the number of larvae captured per cubic meter with salinity and water temperature at any station or with all stations combined at an alpha of 0.05. The data set only included those periods when teredinid larvae were captured from June, 1975, through November, 1977.

Literature Cited

Allen, M.S. 1924. Toxicity of certain compounds on marine wood boring organisms together with some physiological considerations. In: W.G. Atwood, et al., Marine Structures, their deterioration and preservation. pp. 181-196. National Research Council, Wash., D.C.

Blum, H.F. 1922. On the effect of low salinity on *Teredo navalis*. Univ. California Publ. Zool., 22(4):349-368.

Hollander, M. and D.A. Wolfe. 1973. Nonparametric statistical methods. John Wiley and Sons, New York. 503 pp.

Karande, A.A. and S.S. Pendsey. 1968. Field and Laboratory Observations on *Teredo furcifera* M., A Test Organism for the Bioassessment of Toxic Compounds. Proc. Md. Acad. Sci. B. Vol. LXX, pp. 223-237.

Mawatari, S. 1950. Biological and industrial study of marine borer problem in Japan. Studies on the aquatic animals. Tokyo 1(1):45-124.

Miller, R.C. 1926. Ecological relations of marine wood-boring organisms in San Francisco Bay. Ecology 7(3):247-254.

Roch, F. 1932. Einige Beobachtungen zur Okologie und Physiologie von *Teredo navalis* L. Ark. for Zool., 24(A,2), paper No. 5, 18 p.

Scheltema, R.S. and R.V. Truitt. 1954. Ecological factors related to the distribution of *Bankia gouldi* Bartsch in Chesapeake Bay. Chesapeake Biol. Lab., SolomonId., Maryland, Publ. 100.

Sokal, R.R. and F.J. Rohlf. 1969. Biometry: The principles and practice of statistics in biological research. W.H. Freeman and Company, San Francisco. 776 p.

Turner, R. 1966. A Survey and Illustrated Catalogue of the Teredinidae (Mollusca:Bivalvia). Mus. Comp. Zool., Harvard University, Cambridge, Massachusetts. 265 pp.

Turner, R.D. 1973. Report on Marine Borers (Teredinidae) in Oyster Creek, Waretown, N.J. Mus. Comp. Zool., Harvard University, Cambridge, Massachusetts. First Report April 3, 1973. 30 pp.

APPENDIX C6

APPENDIX C6

A SEASONAL PLANKTON CYCLE IN BARNEGAT BAY, NEW JERSEY

By

KENT MOUNTFORD

A thesis submitted to
The Graduate School
of
Rutgers University
in partial fulfillment of the requirements
for the degree of
Master of Science

Written under the direction of
Professor Edwin T. Moul
of the Department of Botany

New Brunswick, New Jersey
June, 1969

ABSTRACT OF THE THESIS

A Seasonal Plankton Cycle In

Barnegat Bay, New Jersey

By KENT MOUNTFORD

Thesis director: Professor Edwin T. Moul

Phytoplankton and zooplankton samples were taken at approximately bi-weekly intervals through an annual cycle at several stations in lower Barnegat Bay, a temperature barrier built lagoon type estuary about 39° 48' N 74° 06' W. Live examinations were made at each sampling location during this period and continued for qualitative purposes through January, 1969. [Half liter phytoplankton samples were immediately fixed with an I_2 -Kl regent and the organisms concentrated by sedimentation for counting.] Fifty liter zooplankton samples were poured through replacable ASTM 230 mesh stainless steel filter discs and the material back-flushed and preserved with formalin. The sampling methods are evaluated and quantitative results are compared with those from other estuaries.

A spring diatom "flowering" occurred flowing the breakup of ice cover from the bay and was followed by a tremendous abundance of zooplankton dominated by Acartia spp. Grazing by the ctenophore, Mnemiopsis leldyl, severely depleted zooplankton during the summer and only limited recovery was observed during the autumn and early winter. The larvae of benthic invertebrates were periodically abundant from March through October.

Microflagellates often numerically dominated the phytoplankton and produced a summer maximum cell count in excess of the spring peak. Dinoflagellates were abundant during the summer and early autumn but were overshadowed by Skeletonema costatum in August following the period of maximum temperature.

APPENDIX C6

TABLE OF CONTENTS

Estuaries play a central role in sustaining the productivity of our coastal shell and fin-fisheries but, because of their convenience for industrial and recreational purposes, many aspects of this role have been disrupted. With the hope of understanding interactions within these environments, there has been considerable work during the last two decades on the plankton of temperate estuaries along the mid-Atlantic coast of the United States. These estuaries form a geographical continuum from Cape Cod to Cape Hatteras along which a variety of environmental gradients may be studied. This survey examines occurrence and seasonal succession in the plankton community of Barnegat Bay, N.J.

Hulburt (1956 , 1957) has examined the microflora of Great Pond and other embayments in the Cape Code region. Ferrara (unpublished, 1953) studied upper Narragansett Bay and later Smayda (1957) discussed the phytoplankton of lower Narragansett Bay. Marshall and Wheeler (1965) examined the exchange of plankton populations among portions of the Niantic estuary. Long Island Sound, forming an extension of these New England estuaries, was thoroughly investigated from 1952-1954 by Shirley Conover (1956), R. J. Conover (1956), Georgiana Deevey (1956) and others. Deevey (1952) also studied the zooplankton of Block Island Sound and Delaware Bay collections made during the early 1930's (Deevey, 1960). Jeffries (1964) compared component zooplankton populations from Narragansett Bay, Raritan Bay, and the York River in Virginia. Others have worked in the Chesapeake system, among them Marshall (1967) and Patten (1961) with the phytoplankton, and Heinle (1966) with the zooplankton. Williams, Murdoch and Thomas (1968) studied quantitative aspects in the zooplankton of shallow empayments near Beaufort, N.C.

From the New York bight south, long barrier beaches enclose a series of shallow lagoons with limited tidal exchange (Redfield 1950; Carpenter, 1963; and Pritchard, 1960). The plankton of these estuaries has not been extensively studied. Nelson (1925) made some preliminary observations on the Ctenophora of Barnegat Bay and other New Jersey estuaries. Nelson kept routine records on plankton composition in Barnegat Bay while a small oyster laboratory was maintained there (1920-1930 unpublished). Martin (1929) published a small monograph on dinoflagellates recorded from Barnegat and other New Jersey embayments.

DESCRIPTION OF THE REGION INVESTIGATED

Barnegat Bay, the area of this investigation, lies about 39° 48' N, 74° 06' W. (Figure 1). It appears to be somewhat transitional between the cooler estuaries of New England and warmer embayments of the Chesapeake and North Carolina regions. The entire estuary has an approximate surface area of 120 km^2 and a mean depth between 1.3 m in the upper bay and 2.0 m in the lower bay. Chief tidal exchanges are through Barnegat Inlet, which opens into neritic waters of the Atlantic, and a small navigational canal at the bay's northern extremity. A mean tidal range of 0.95 m at Barnegat Inlet is damped so that an average range for five bay stations is only 17 cm (U.S. Coast Guard, 1966). Exchange rates were estimated by Carpenter (1963) at about 7% per tide, so a complete turnover occurs each ninety-six tidal cycles. The bay is fed along its western perimeter by a number of low gradient streams which drain considerable areas of New Jersey's "Pine Barrens". Anderson of the U.S. Geological Survey (personal communication) feels there is a great contribution by ground water, a condition seen by Redfield (1950) in Great South Bay.

The west shore was almost entirely occupied by salt marsh until after World War II when extensive areas were filled for the construction of summer residential communities. Much of the barrier island system offshore has been similarly developed but, a 15 km portion of the Island Beach peninsula east of the study area has remained relatively intact as a state park.

With a recent shift in population composition to include large numbers of retirees and year-round commuters working in northern New Jersey's metropolitan industrial complex, many community and residential sewer systems have begun to prove inadequate. Residential pollution, coupled with locally reduced circulation is a serious threat to the biological system. The taking of shell fish is already prohibited in certain areas.

A thermonuclear electrical generating station at Oyster Creek will use large quantities of water from the estuary to cool its condensers. The discharge of this heated effluent to the system, a possible source of ecological change, has provided the major impetus for this investigation, which is part of a broader biological survey.

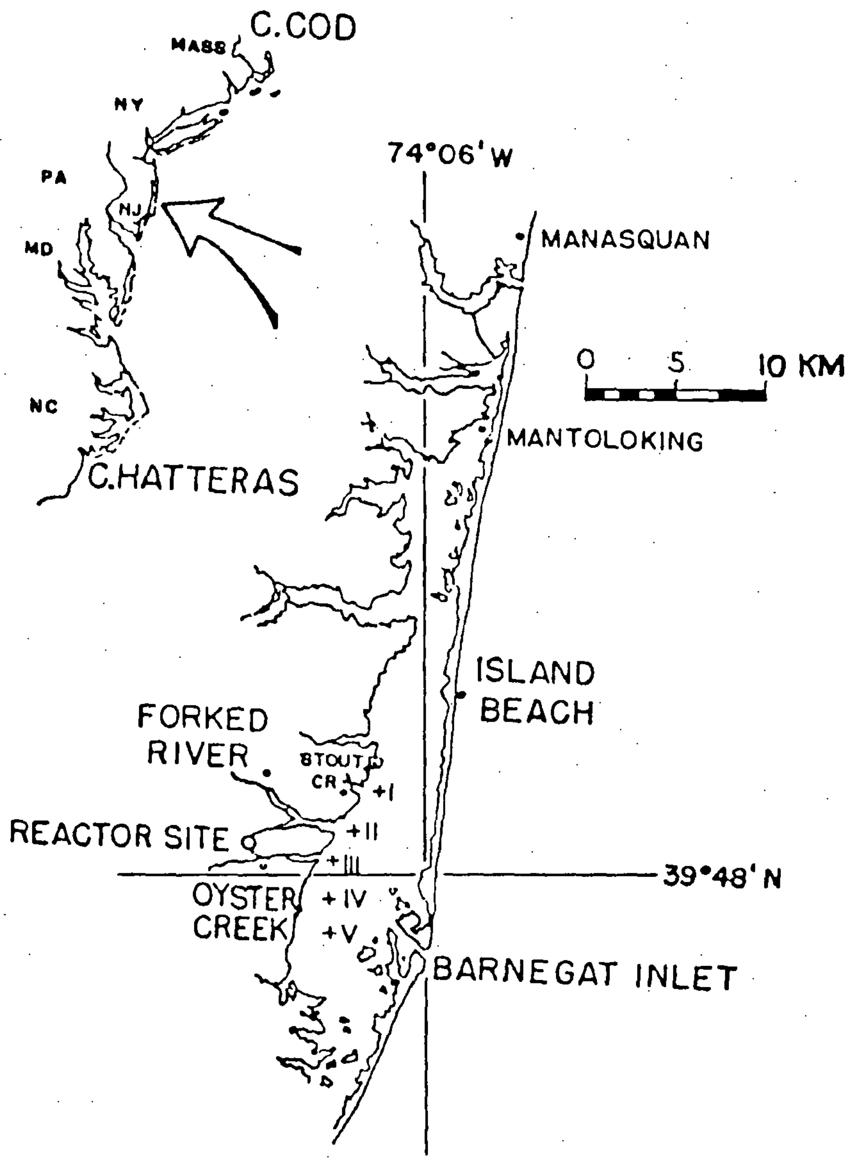
The study area centers around the discharge channel at Oyster Creek and Barnegat Inlet, but some comparisons can be made with preliminary monitoring of the plankton carried out at the northern extremity of Barnegat Bay during 1964 and 1965 (Mountford, 1969 a), and 1966 (Mountford, 1967).

Salinities taken with the material in lower and middle Barnegat Bay ranged from 16.2 o/oo in association with terrestrial runoff at the surface to 31.1 o/oo at 3 mm near the inlet channel. Salinities in the test area generally fell between 21 and 28 o/oo. Temperatures ranged from an August surface maximum of 28.0 C to -0.4 C in January. Periods of ice cover extending over several weeks are usually observed between late December and early March. Stratifications of temperatures and salinity are dependent upon wind conditions. Stiff southerlies usually prevail after midday during the summer and there are frequent prolonged northwesterlies from late winter through spring. Thermoclines as strong as 5 C in half a meter and salinity differences of 5.9 o/oo in 3.0 m were observed.

FIGURE 1

BARNEGAT BAY

An arrow indicates the relationship of this lagoon to other middle Atlantic coast estuaries between Cape Cod and Cape Hatteras.



C.COD
MASS
NY
PA
NJ
MD
NC
C.HATTERAS
74°06'W
MANASQUAN
0
5
10 KM
MANTOLOKING
ISLAND
BEACH
FORKED
RIVER
STOUT
CR
+I
+II
+III
REACTOR SITE
39°48'N
OYSTER
CREEK
+IV
+V
BARNEGAT INLET

FIGURE 1

Surface waters were usually saturated or supersaturated with oxygen. Mid-winter maxima of 14-16 mg O_2/liter were observed. Undersaturation at the bottom is seen, particularly in summer. Locally, in stagnant holes or in association with organic debris and high bacterial concentrations, oxygen has fallen below 4 or 5 mg/liter.

Secchi disc visibility was minimal during the summer (0.6 to 1.1 m) and increased beyond 3.0 m from autumn through spring. Light penetration was often temporarily influenced by wind stirred sediments, organic detritus, and high plankton densities.

METHODS

In mounting this investigation, it was not considered reasonable to ignore either the phytoplankton or the zooplankton in favor of more adequately characterizing the other. Consequently, in all but a few specialized cases, both were sampled at each data point.

From April through September, 1967 both surface and bottom samples were taken to estimate any consistent stratifications. Surface samples were taken with a calibrated 10 liter polyethylene pail. Bottom samples were generally drawn with a hand-operated non-metallic diaphragm pump through vinyl hose, with a weighted intake covered by a 5 mm screen cage to prevent the entrainment of ctenophores.

A live sample of 225 ml was retained from each sampling location and aliquots were examined individually ashore after hand centrifugation at 1000RPM for 60 seconds.

Preserved phytoplankton samples were collected in half-liter screw-cap plastic containers. A concentrated I_2-KI fixative was added immediately in the field. At the laboratory these samples were left undisturbed at least two days before the supernatant was siphoned off and the residue brought down to uniform volume for storage and subsequent enumeration.

From a known volume of thoroughly mixed plankton concentrate, diluted to provide a reasonable counting density, an aliquot of 0.05m $\pm$ 0.005 ml was drawn with a tuberculin syringe and expelled on the counting slide. After dispersal with a stirring needle, the drop was covered with a circular coverslip. Ten random fields were counted at X 100 for the rare and larger phytoplankters and, ten more at X 400 for the abundant forms and nannoplankton, permitting enumeration of previously identified organisms greater than 3 μ diameter.

Analyses of the zooplankton are based on fifty-liter samples drawn at the same time as the phytoplankton material. During the summer of 1967, equivalent samples were pumped from the bottom at each station. The samples were filtered through removable stainless steel 230 mesh discs, which initially were back-flushed into a container between samples. As additional discs became available, the entire filter was changed after each sample. Aliquots from the zooplankton samples were enumerated in a standard Sedgewick-Rafter counting cell, enumerating ten random fields with the scanning lens at X 32. For large and infrequently occurring specimens, the entire cell was occasionally counted.

The regular sampling interval was about fourteen days, winter and summer, with a number of supplementary investigations made to monitor various aspects of the shifting pattern. The quantitative data for 1967-68 represent about 260 subsamples taken at stations on thirty dates while the qualitative data, extending through a partial second year, (Fig. 10) represent primarily live examinations on another 22 sampling dates. Stations were established on an arbitrary grid over about 50 km^2 in lower and middle Barnegat. Within each cruise, subject to the limitations imposed by other investigations, storm, and ice-cover, an effort was made to balance collection of material estimating the effects of inlet tides, transport over broad shallow *Zostera* flats, and terrestrial runoff from creeks entering the bay. Only limited analysis on spatial aspects of the sampling is possible in this paper.

Hydrographic data were collected with each plankton sample. Temperature profiles were constructed using a thermistor, transparency was estimated using a Secchi disc, and dissolved oxygen was determined using the Winkler method on water samples drawn with a Kemmerer or Van Dorn bottle. Salinity was determined by hydrometer with the assistance of Hydrographic Office tables.

INTEGRATED RESULTS AND DISCUSSION

Phytoplankton

In Fig. 2, occurrence histograms for genera and species which exhibited some degree of seasonally have been arranged to depicit relatively distinct seasonal flora. A vertical line drawn through a given date gives the recorded species and constitutes a prediction for other years. Qualitative data for a partial replicate year extend beyond April, 1968 and show the observed repetition in this pattern.

Table 1, is an index of phytoplankton taxa recorded thus far during the survey.

Spring

The spring flowering began in February, 1968 (Fig. 3). The bay may be inoculated with seed stock of *Thalassiosira nordenskioldl* and *Detonula confervacea* (Fig. 4) by tidal action through the inlet. Sufficient *Skeletonema costatum* was always residual in the bay to justify its potential role as a dominant. The presence of heavy and persistent ice-cover may attenuate available isolation, or limit circulation enough to prevent full development of the bloom until melting occurs. A light-dark bottle experiment in January 1969 showed surface gross production was 28.7 mg C m^{-3} hr^{-1}. Beneath 15 cm of ice this was reduced to 14.0 mg C m^{-3} hr^{-1}. Corresponding net values were 9.4 and 4.1 mg C m^{-3} hr^{-1}.

Apparently very slight temperature shifts during the flowering period are sufficient to alter the community composition. In 1968 the water column was generally below 3 C and *T. nordenskioldi* was immensely successful. As water temperatures increased, *S. costatum* became more important. In 1969 water temperatures in mid-March were above 3 C through most of the water column and *S. costatum* appeared to be more abundant than *Thalassiosira*. Conover (1956) has observed a similar balance in the phytoplankton of Long Island Sound. Riley (1958) discussing Long Island waters, puts the critical temperature at about 2C and Smayda (1957) in Naragansett Bay observed a *T. nordenskioldi* maximum when the mean temperature was 2.5 C. Marshall (1967) in the James River estuary, indicates a winter-spring bloom of *Skeletonema* rather than *Thalassiosira*. Haskin (personal communication) found *S. costatum* a spring dominant in Delaware Bay. These estuaries may represent transitional areas where *Thalassiosira nordenskioldi* is losing its ability to compete regularly as a dominant. Higher light in Long Island experimental trials by Conover (1956) seemed to reduce the competitive advantage of *T. nordenskioldi*.

Detonula confervacea was an important winter sub-dominant in Barnegat Bay, reaching 67.6 x 10^3 cells/l during the 1968 flowering. It was not recorded by Marshall (1967) in the James River, nor by Conover (1956) in Long Island Sound. Smayda (1957) merely noted its occurrence

TABLE 1. REGISTER OF PHYTOPLANKTON ORGANISMS IDENTIFIED FROM BARNEGAT BAY, N. J. APRIL, 1967 to APRIL 1969.

DIATOMS

Achnanthes longipes Agardh
Actinoptychus undulatus (Bailey)
Amphiprora incompta Hohn and Hellerman
A. surirelloides Hendey
Amphora sp.
Asterionella japonica Cleve and Möller
Biddulphia spp.
B. arctica (Brightw.)
B. biddulphiana (Smith) Boyer
B. favus (Ehrehberg)
B. granulata Roper
B. vesiculosa Agardh
Campylodiscus sp.
C. fastuosus Ehr.
Cerataulina bergoni H. Peragallo
Chaetoceros spp.
C. approximatus Gran and Angst
C. borealis Bailey
C. curvisetum Cleve.
C. debilis Cleve.
C. decipiens Cleve.
C. dichaeta Ehr.
C. didymus Ehr.
C. fragilis Meunier
C. secundus Cleve.
C. similis Cleve.
C. simplex Ostemfeld
C. subtills Cleve.
Cocconels spp.
Cochlodinium helix (Pouch.) Lemm. ex Lebour
Coscinodiscus spp.
C. angstil Gran
C. centralls Ehr.
C. excentricus Ehr.
C. radiatus Ehr.
Cyclotella of meneghiniana Kützing
Cymbella spp.
Detonula spp.
D. confervacea Cleve.
D. cystifera Gran
Diploneis sp.
D. crabro Ehr.
Ditylium brightwellii (West.)
Eucampia groenlandica Cleve.

TABLE 1. (Continued)

T. nitzschiodes Grun.
Thalassiosira spp.
T. condensata (Cleve)
T. gravida Cleve.
T. hyalina (Grun)
T. nordenskioldi Cleve.
T. rotula Meunier
Thallassiothrix longissima Cleve and Grun.

DINOFLAGELLATES

Amphidinium spp.
A. carteri Hulburt
A. fusiforme Martin
A. sphenoides Wulff
Ceratium bucephalum ? Cleve
C. fusus (Ehr.) Clap. and Lach.
C. macroceros Ehr.
C. minutum Jorgensen
Ceratium tripos Ehr.
Dinophysis sp.
D. acuminata Clap. and Lach.
D. acuta Ehr.
D. ovum Schutt
Dipolopsalis lenticula Bergh
Glenodinium sp.
G. danicum Paulsen
G. foliaceum Stein
Goniodoma sp.
Gonyaulax sp.
G. digitale (Fouchet)
G. polygramma Stein
G. scrippsae Kofoid
G. spinifera (Clap and Lach).
G. tricantha Jorgensen
Gymnodinium spp.
G. incoloratum Conrad
G. nelsoni Martin
G. punctatum Pouchet
G. splendens Lebour
Gydrodinium spp.
G. dominans Hulburt
G. pellucidum (Wulff)
G. pingue (Schutt) Kofold and Swezy
Gyrodinium resplendens Hulburt
Hemidinium sp.
Massartia sp.
Nematodium sp.
N. armatum (Dogiel) Lebour
Noctiluca scintillans Macartney
Ostreopsis monotis J. Schmidt
Peridinium spp.

TABLE 1. (Continued)

E. zodiacus Ehr.
Fragillaria sp.
F. crotonensis Kitton
F. cylindrus Grunow
Grammatophora spp.
Guidardia flaccida (Castr.)
Gyrosigma spp.
Lauderia glacialis (Crum.)
Leptocylindrus sp.
L. danicus Cleve.
L. minimus Gran
Lichmophora sp.
Lithodesmium undulatum Ehr.
Melosira sp.
M. borreri Greville
M. granulata Ehr.
M. juergensii Agardh
M. nummuloides (Dillw.) Agardh.
Navicula spp.
N. cruciculoides Brockman
N. distans W. Smith
N. (Schizonema) gravelei Agardh
N. monilifera Cleve.
Nitzschia sp.
N. closterium Ehr.
N. paradoxa Gmelig and van Heurck.
N. seriata Cleve.
Paralia (melosira)sulcata Ehr.
Pinnularia sp.
P. ambigua Cleve.
Pleurosigma sp.
P. fasciola W. Smith
P. formosum W. Smith
P. marinum Donkin
Rhabdonema adriaticum Kützing
Rhizosolenia sp.
R. alata Brightwell
R. cylindrus Cleve.
R. delicatula Cleve.
R. fragillima ? Bergon
R. semispina Hensen
R. setigera Brightw.
R. stolterfothii H. Perag.
Skeletonema costatum (Greville)
Striatella unipunctata Agardh.
Surirella sp.
S. smithii Ralfs
Synedra sp.
S. hennedyana (Greg.)
Tabellaria sp.
Thalassionema frauenfeldii (Grun.)

TABLE 1. (Continued)

P. brevipes Paulsen
P. claudicans Paulsen
P. depressum Bailey
P. excavatum Martin
P. granii Ostenfeld
P. leonis Pavillard
P. pallidum Ostenfeld
P. roseum Paulsen
P. triquetra (Stein)
P. trochoideum (Stein) Lemm.
Peridinopsis rotunda Lebour
Polykrikos sp.
P. barnegatensis Martin
P. hartmanni Zimmerman
P. kofoidi Chatton
Prorocentrum micans Ehr.
P. redfieldi Bursa
P. scutellum Schroeder
P. triangulatum Martin
Spirodinium fissum Levander

OTHER FLAGELLATE FORMS

Bipedomonas sp.
Calycomonas gracilis (lohmann) Wulff
Carteria sp.
Chlamydomonas spp.
Chroomonas sp.
Cryptomonas spp.
Distephanus speculum (Ehr.) Haeckel
Ebria tripartita (Schumann) Lemmermann
Euglena spp.
Eutreptia sp.
Ochromonas sp.
Pyramimonas sp.
P. tetrarhynchus Schmarda
P. torta Conrad
Scherefflia dubia Pascher

OTHER FORMS

Merismopedia sp.
Aphanothece sp.
Lyngbya sp.
Nannochloris sp.
Oscillatoria spp.
Pediastrum sp.
Phormidium sp.
Scenedesmus quadricaudata (Turpin) Brebisson
Spirulina sp.

FIGURE 2

SEASONAL PHYTOPLANKTON CYCLING

Breaks in the histograms indicate absence on at least one sampling oate.

Essentially cold and warm water flora can be distinguished by shifts in density of the diagram.

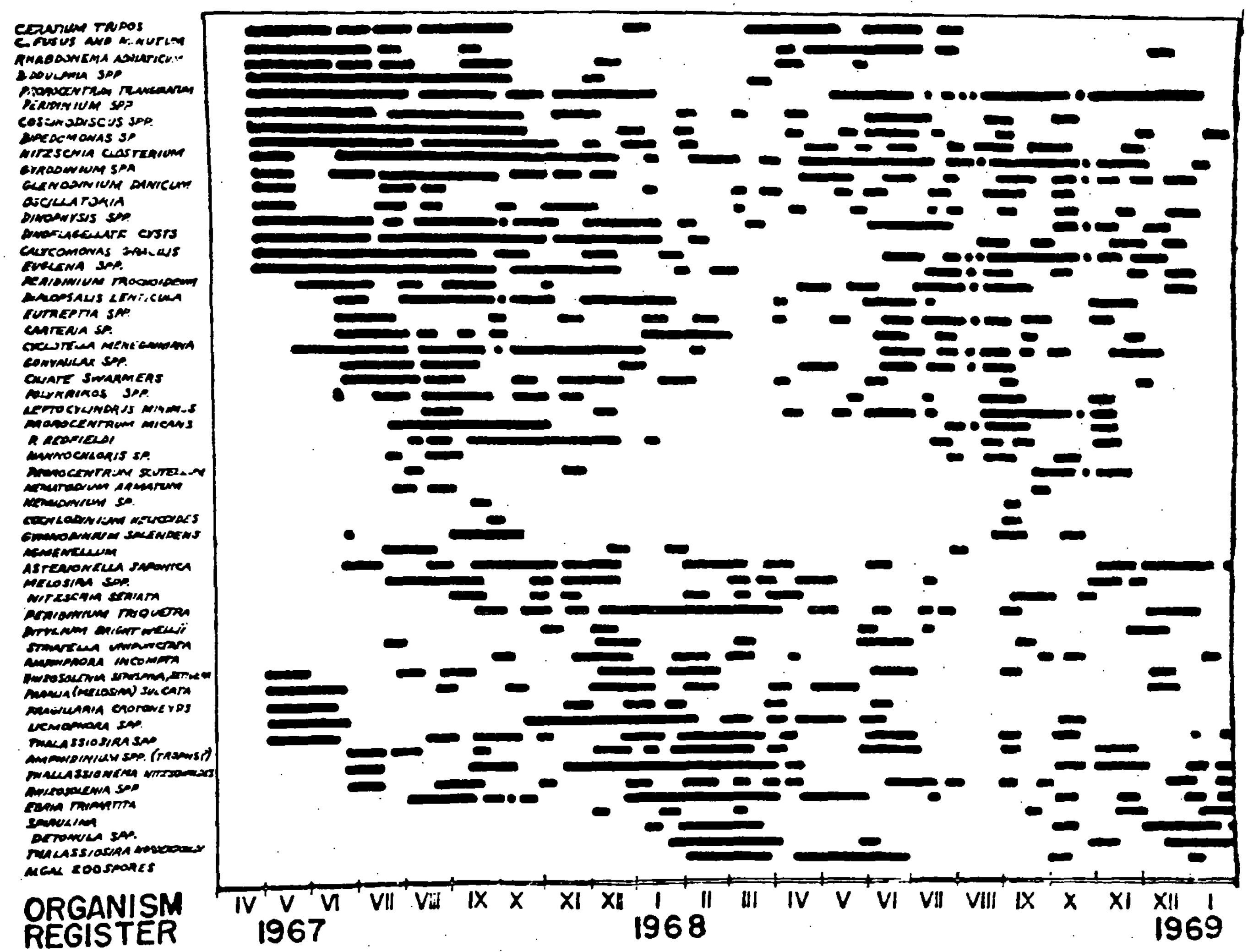

ORGANISM REGISTER
IV V VI VII VIII IX X XI XII I II III IV V VI VII VIII IX X XI XII I
1967
1968
1969

FIGURE 2

FIGURE 3

TOTAL PHYTOPLANKTON AND TOTAL MICROFLAGELLATES

Thousands of cells per liter plotted against date. Note logarthmic and arithmetic ordinates.

Microflagellate density estimates include the four organisms in Figure 5.

The symbol "o" connected by a solid line represents mean surface density for all samples on a given date. The symbol "o" connected by (see Figure 3) a dashed line represents mean bottom density for all samples on a given date. The symbol "o" indicates the start of sample pooling and (see Figure 3) thereafter only a single mean is plotted without a symbol for each date. The number of samples varied from a minimum of two to a maximum of ten within each date.

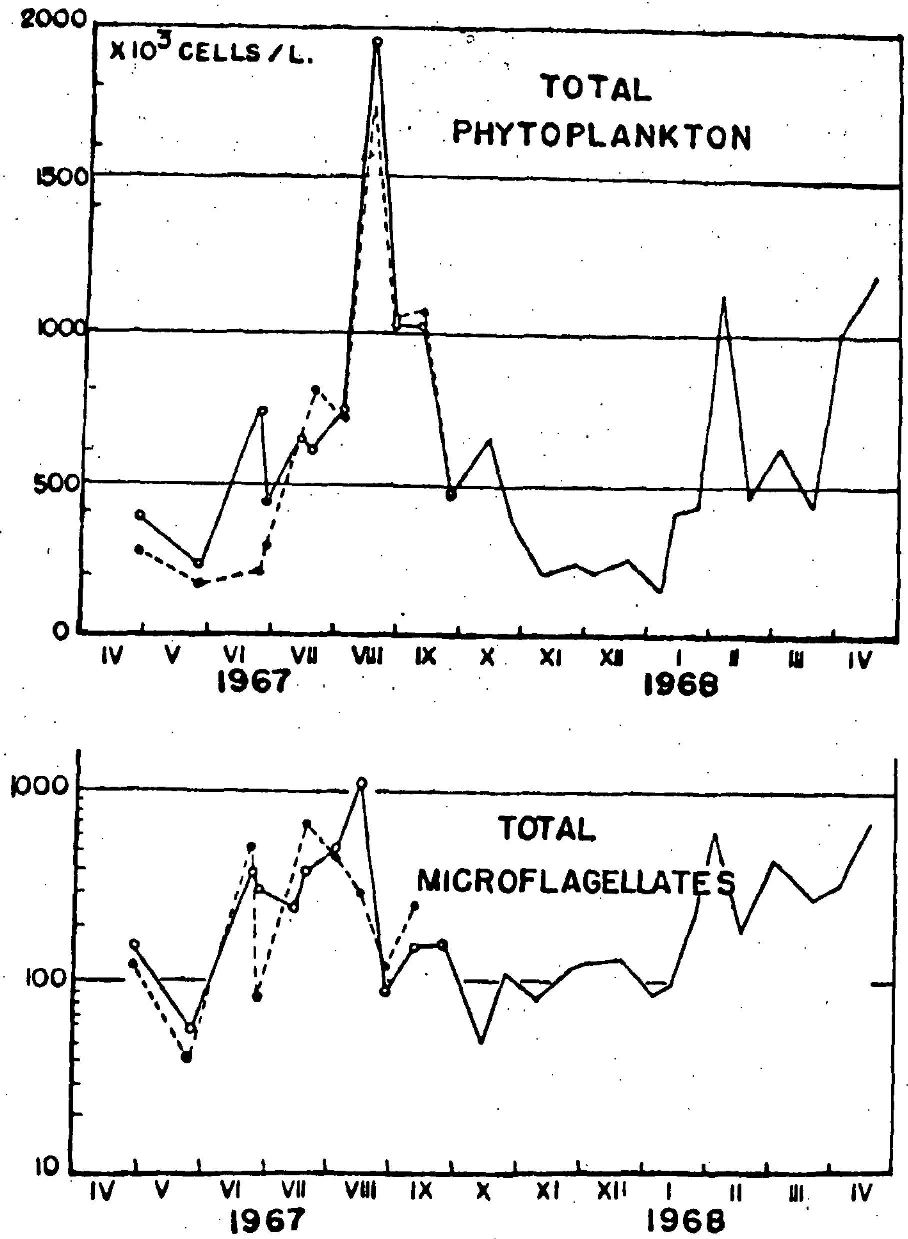

X10³ CELLS / L.
TOTAL
PHYTOPLANKTON
2000
1500
1000
500
0
IV V VI VII VIII IX X XI XII I II III IV
1967
1968
TOTAL
MICROFLAGELLATES
1000
100
10
IV V VI VII VIII IX X XI XII I II III IV
1967
1968

FIGURE 3

FIGURE 4

WINTER-SPRING DIATOMS

Thousands of cells per liter plotted against date. Note logarthmic and arithmetic ordinates.

In the genus The lassiosira, T. nordenskioldi has consistently been the dominant species.

The symbol "o" connected by a solid line represents mean surface density for all samples on a given date. The symbol "o" connected by a dashed line represents mean bottom density for all samples on a given date. The symbol "o" indicates the start of sample pooling and thereafter only a single mean is plotted without a symbol for each date. The number of samples varied from a minimum of two to a maximum of ten within each date.

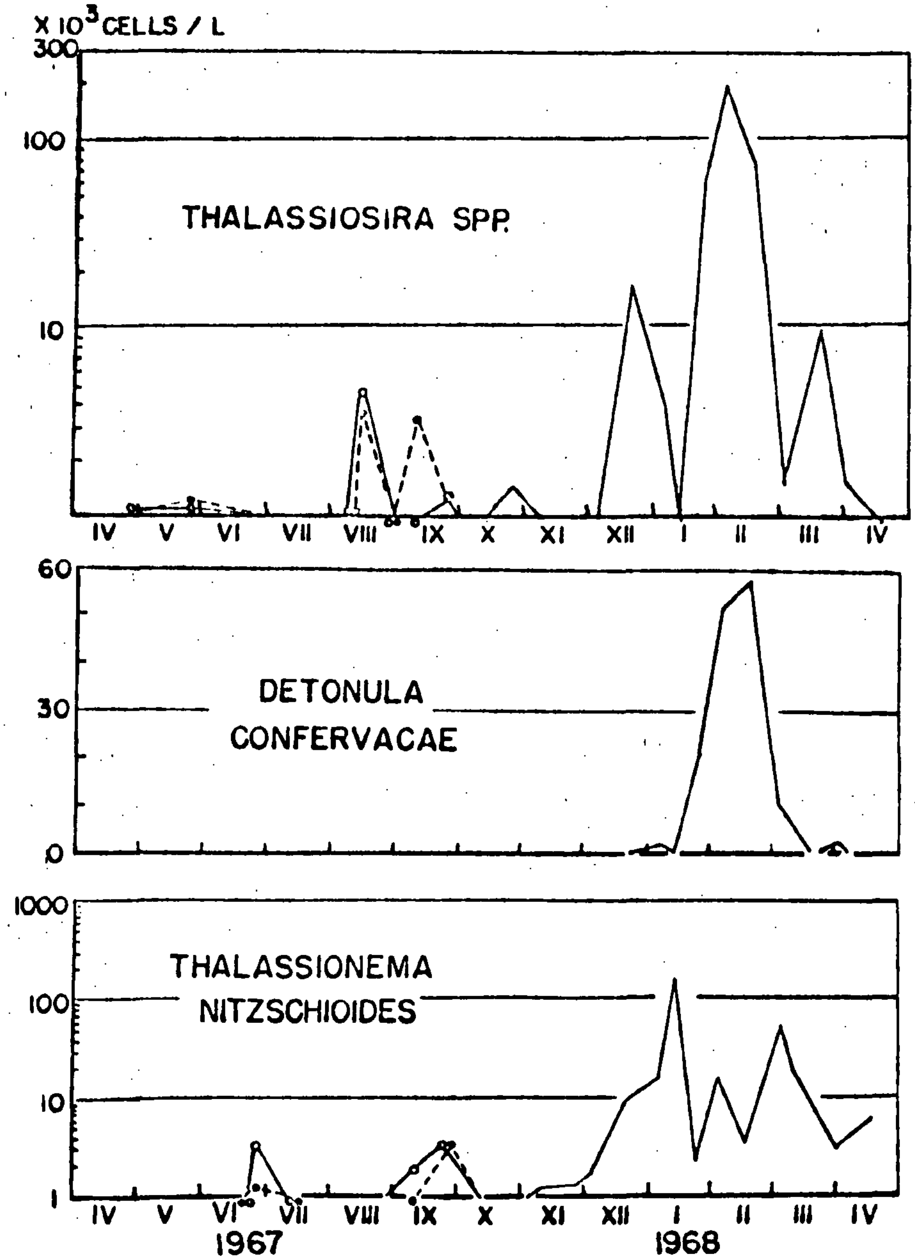

X 10³ CELLS / L
300
100
10
THALASSIOSIRA SPP.
IV V VI VII VIII IX X XI XII I II III IV
60
30
0
DETONULA
CONFERVACAE
1000
100
10
1
THALASSIONEMA
NITZSCHIOIDES
IV V VI VII VIII IX X XI XII I II III IV
1967
1968

FIGURE 4

in Narragansett Bay. The importance of D. confervacea in Barnegat was repeated in preliminary 1969 material. Thalassionema nitzschiodes (Fig. 4) was abundant through the winter-spring period, with clusters of cells frequently appearing in the samples. Only isolated cells were found from late spring through the autumn.

While in the 1968 flowering, Thalassiosira nordenskioldi was the major single species, it is significant to note that the cell count was dominated by microflagellates (Fig. 5), particularly the genera Cryptomonas, Bipedomonas ? and Pyraminonas. Of a total 1119 cells counted, 616 were microflagellates.

As we investigate inshore waters, increasing importance is assumed by this group of minute diverse organisms. While they are among the most delicate with respect to preservation, they seem to tolerate remarkable environmental extremes (Hulburt, 1965). The tiny circular biflagellate species designated here as Bipedomonas sp. has been recovered from a freshwater bog on Island Beach and occurs in the bay year-round.

Zooplankton grazing after March, with a high standing crop of copepods, apparently prevented the intense bloom conditions from continuing. Considering the food requirements of such dense zooplankton populations, however, phytoplankton productivity must continue fairly high. Nutrient depletion ends the flowering in Long Island Sound, with zooplankton increasing only slightly during and after the bloom (Conover, 1956).

In Barnegat Bay, the grazing effect was apparent mostly on larger diatoms, with the microflagellate populations not under visible pressure until May.

FIGURE 5

IMPORTANT MICROFLAGELLATES

Thousands of cells per liter plotted against date. Ordinate is logarthmic.

Dotted lines connect dates between which individual density estimates were not made for a particular organism.

The symbol "o" connected by a solid line represents mean surface density for all samples on a given date. The symbol "o" connected by a dashed line represents mean bottom density for all samples on a given date. The symbol "o" indicates the start of sample pooling and thereafter only a single mean is plotted without a symbol for each date. The number of samples varied from a minimum of two to a maximum of ten within each date.

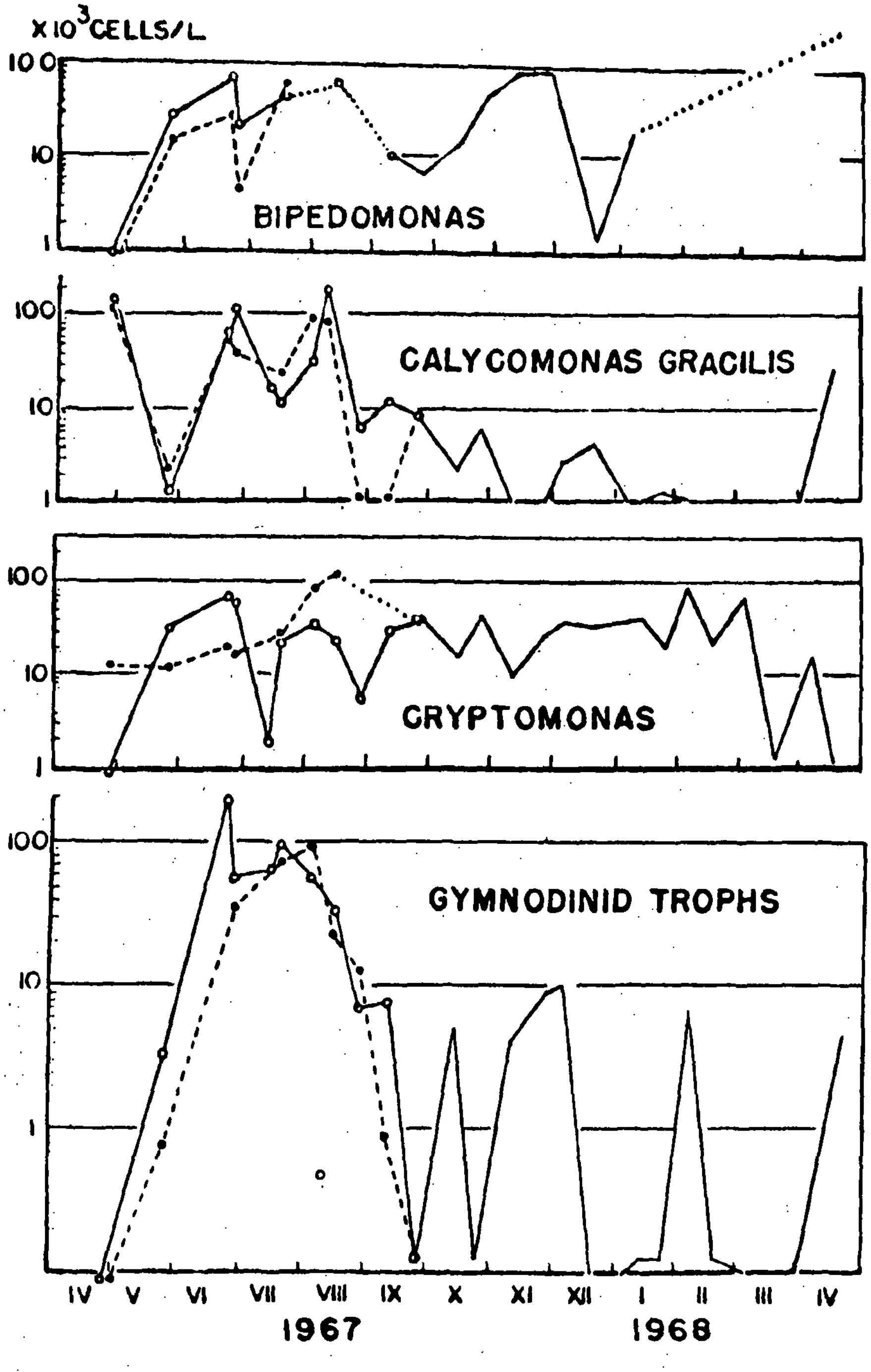

X 10³ CELLS/L
100
10
1
BIPEDOMONAS
100
10
1
CALYCOMONAS GRACILIS
100
10
1
CRYPTOMONAS
100
10
1
GYMNODINID TROPHS
IV V VI VII VIII IX X XI XII I II III IV
1967
1968

FIGURE 5

Summer

By June, water temperatures rose beyond the optima of cold water diatoms and sudden decimation of the copepod stock by predatory ctenophores brought about radical changes in community composition.

Curl and McLeod (1961) in elegant experimental work with Skeletonema suggest, for this diatom at least, that as temperatures rise beyond 20 the tolerance to light intensity decreases. Light is, of course, maximal at this latitude about 21 June, at solar perihellon. The experimental range of tolerance demonstrated is so narrow that light should become inhibitory, and indeed there was an almost total disappearance of S. costatum by the end of June.

With more rapid warming, there was a distinct shift in the flora to a series of dinoflagellates (Figs. 6,7), which are generally dominant throughout much of the peak temperature season. Most pronounced was the upsurge of small, faintly green gymodinids (see Fig. 5) which, at various times resembled the Gymnodinium Incoloratum shown by Conrad and Kufferath (1954) and the G. punctatum reported by Martin (1929) in Barnegat Bay, and Mackie (1969a) in Delaware Bay. In close monitoring of plankton populations, one is led to suspect that these organisms represent one or more developmental stages of other dinoflagellate species. Some appear to intergrade with Peridinium trocholdeum, (Fig. 6) and others with species of Gonyaulax, (Fig. 6) particularly G. digitale. G. digitale appeared to be more important in the lower bay than G. spinifera which was common during 1966 studies on the Pyrrhophyta of a northern Barnegat cove (Mountford, 1967) and dominant at the same location in mid-August 1968. Hulburt (1965) discusses intergradation among various forms of mature dinoflagellate (the genera Prorocentrum and Exuviaella).

Gymnodinium splendens occurred in Barnegat Bay for brief periods in September and October of both 1967 and 1968 forming a localized bloom of 0.4×10^6 cells per liter in 1967. A flask containing nearly unialgal Gymnodinium splendens was permitted to stand in natural illumination. Months later, after no life had been observed in the flask for many weeks, large numbers of gymnodinid swarmers appeared in the flask. They did not respond to subculturing and never matured if, indeed, that was to be expected.

The naked dinoflagellate genus Gyrodinium (Fig. 6) chiefly G. pellucidum was a frequent plankter from June through mid-November. It is doubtful that more than a few calls of this organism would have been identified without live observation. In fixative, most cells collapsed leaving only the pellicle which, without prior observation would have been judged detritus.

Prorocentrum spp. (Fig. 7) are conspicuous in most samples from late May through December. P. triangulatum was described as a new species for Barnegat Bay by Martin (1929). It was then often the most abundant form in the stomachs of oysters.

FIGURE 6

COMMON DINOFLAGETTATES

Thousands of cells per liter plotted against date. Ordinate is logarthmic.

Peridinopsis rotunda showed the widest period of occurrence. Reading downward the observed range narrows with Gonyaulax spp. having a much shorter span.

The symbol "o" connected by a solid line represents mean surface density for all samples on a given date. The symbol "o" connected by a dashed line presents mean bottom density for all samples on a given date. The symbol "o" indicates the start of sample pooling and thereafter only a single mean is plotted without a symbol for each date. The number of samples varied from a minimum of two to a maximum of ten within each date.

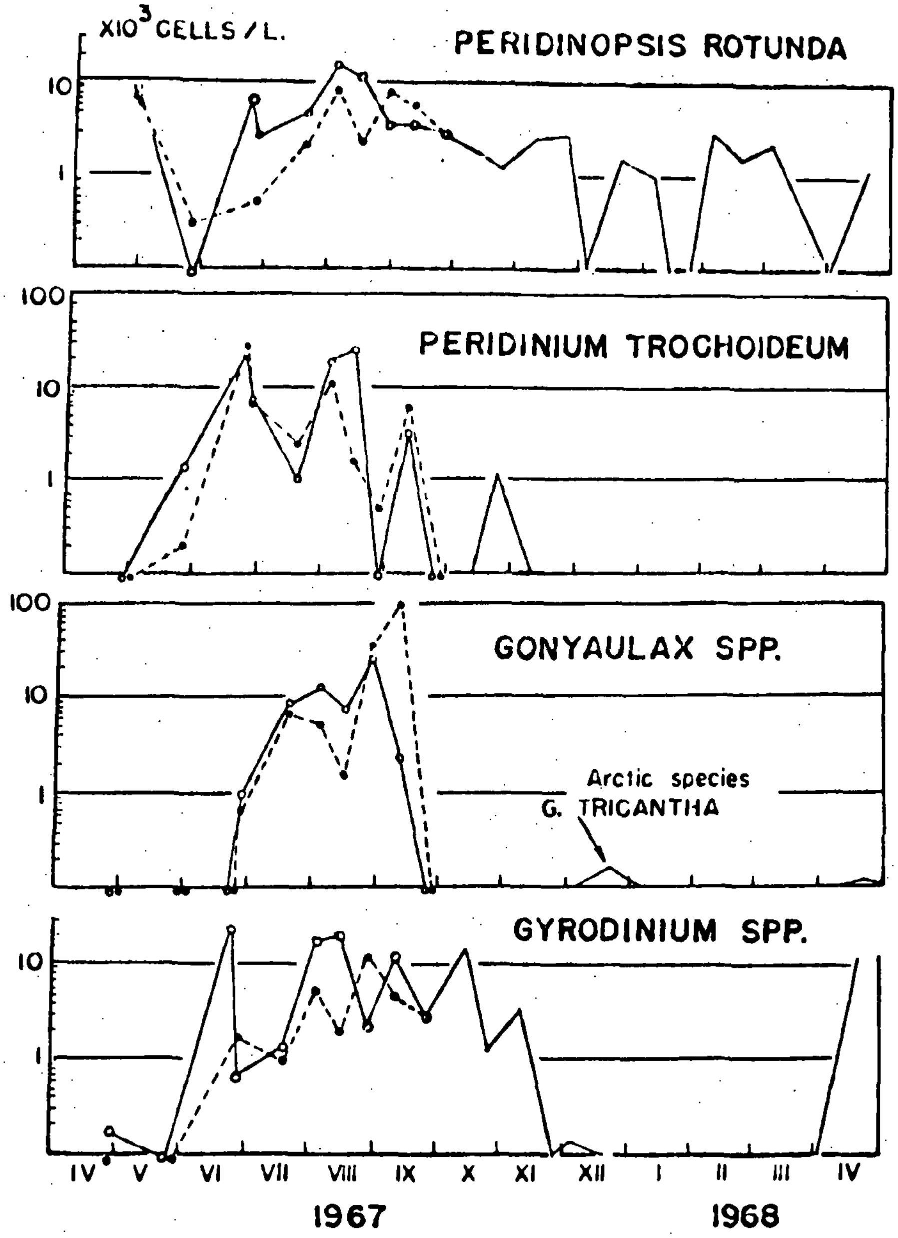

X10³ CELLS / L.
PERIDINOPSIS ROTUNDA
10
1
100
PERIDINIUM TROCHOIDEUM
10
1
100
GONYAULAX SPP.
10
1
Arctic species
G. TRICANTHA
GYRODINIUM SPP.
10
1
IV V VI VII VIII IX X XI XII I II III IV
1967
1968

FIGURE 6

FIGURE 7

THE GENUS PROROCENTRUM

Thousands of cells per liter plotted against date. Ordinate is arithmetic.

Four recorded species showed a succession through the summer.

The symbol "o" connected to a solid line represents mean surface density for all samples on a given date. The symbol "o" connected by a dashed line represents mean bottom density for all samples on a given date. The symbol "o" indicates the start of sample pooling and thereafter only a single mean is plotted without a symbol for each date. The number of samples varied from a minimum of two to a maximum of ten within each date.

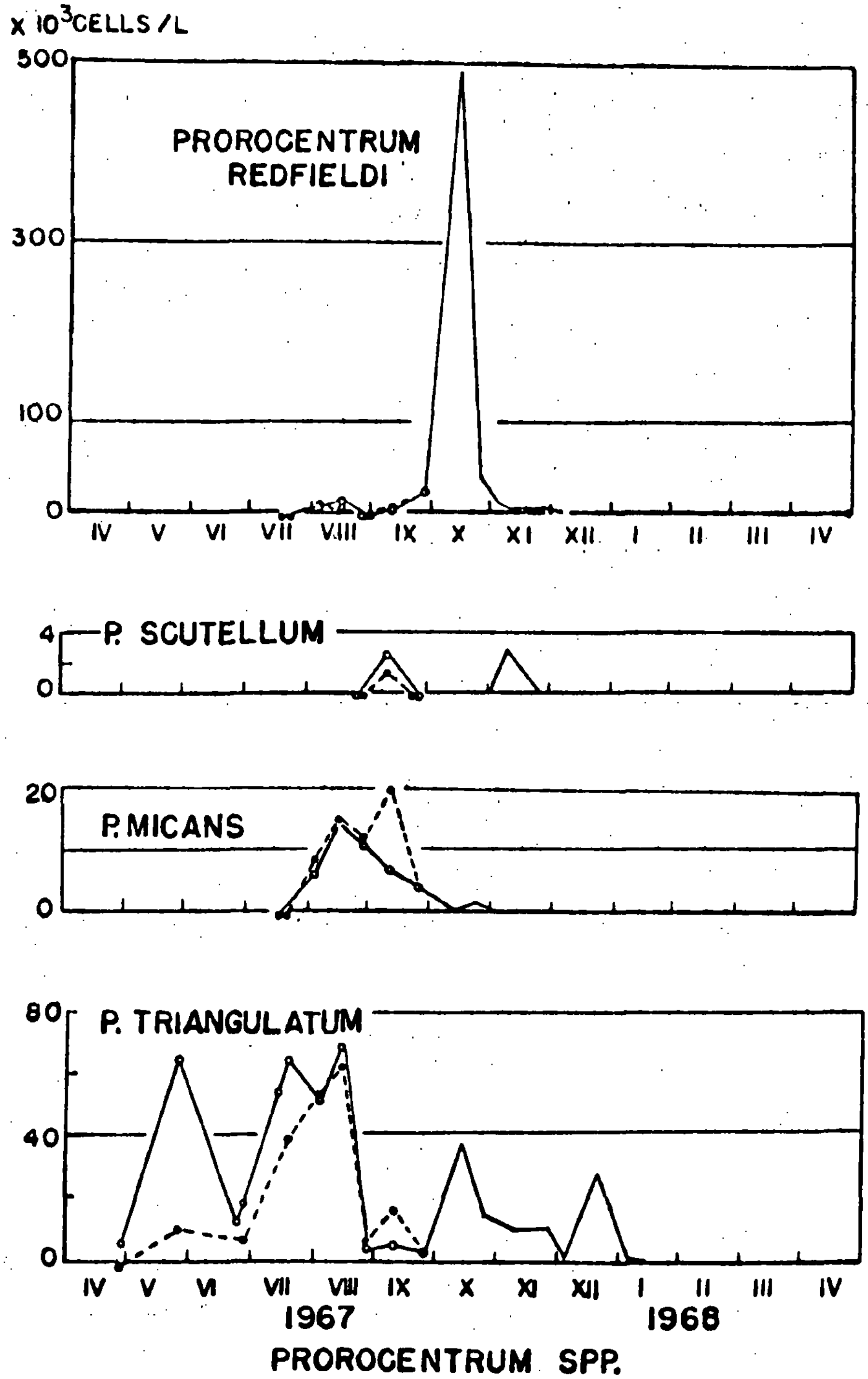

X 10³CELLS /L
500
300
100
0
PROROCENTRUM
REDFIELDI
IV V VI VII VIII IX X XI XII I II III IV
4
0
P. SCUTELLUM
20
0
P. MICANS
80
40
0
P. TRIANGULATUM
IV V VI VII VIII IX X XI XII I II III IV
1967
1968
PROROCENTRUM SPP.

FIGURE 7

Martin said it was obviously one of the thirteen organisms listed by Grave (1912) as forming the bulk of food for Chesapeake Bay oysters. Barnegat Bay, in 1899, had 296 acres of producing oyster beds (Wilson, 1953). Today, as far as can be determined, the oyster is locally extinct; the food supply is still there.

There appeared to be a fairly regular sequence of four species from this genus, all of which seem relatively distinct morphologically. P. triangulatum appeared first, and was fairly common throughout the summer. In 1966 it was implicated with local patches of red water at the upper end of the bay (Mountford, 1967). P. micans was seen in abundance only from the end of July through August, 1967, a relatively short period. This species is also reported from the James River by H. G. Marshall (1967) and by Marshall and Wheeler (1965) from the Niantic estuary in Connecticut. P. scutellum follows briefly between August and October.

Wood and Lutes (1967) show Prorocentrum redfieldi as a separate species, but Martin (1929) described what might have been the same organism as an "ocean form" of P. micans. It reached nearly half a million cells per liter in Barnegat during October, 1967, and in 1968 was one organism responsible for extensive red-tides off the New Jersey coast. Samples taken off Manasquan in neritic waters during these blooms contained 1.9×10^6 cells/liter of P. redfieldi, with a dry-weight biomass of 13.25 mg/liter compared to 5.03 mg/liter in waters outside the bloom. Gross photosynthesis of this population estimated with a single light-dark bottle pair was 557 mg Cm^{-3} hr^{-1}. Waters surrounding the bloom were about 95% saturated at 6.50 mg O_2/liter and inside with strong sunlight about 156% saturated with 10.70 mg O_2/liter. The experimental sample showed these organisms were distinctly photonegative at August surface light intensities.

Polykrikos kofolid and scattered cells of P. martmani, which are non-photosynthetic dinoflagellates appeared a number of times during both 1967 and 1968. Prager (personal communication) identified P. kofoldi as dominant in a serious red-tide which occurred in September 1964 throughout Barnegat Bay. Densities were estimated at over 9×10^6 cells/ liter, and a fish kill among less mobile species with some loss in the benthos was documented (Mountford, 1965). Flemer (personal communication) reports Polykrikos a frequent and relatively abundant constituent of blooms in the Patuxent River, Md.

A number of diatoms are trace plankters through the summer. They include Navicula spp., Pleurosigma spp., and as an intruder from neritic waters, Coscinodiscus spp.

Only three diatoms were important during the warmer months, a Cyclotella sp., Nitzschia closterium and Skeletonema costatum (Fig. 8). The Cyclotella, cf. meneghiniana was encountered particularly near the creek mouths, and may be a fresh water intruder. It appeared abruptly in May and was quite common until December when, quite as abruptly, it disappeared until the following April. The cells are usually solitary but occasionally appear jointed in groups of two to four by a submicroscopic muclaginous connection. No Cyclotella was reported by Conover (1956) in her Long Island Sound material but Marshall and Wheeler (1965) report Cyclotella cf. caspia for the Niantic River.

Nitzschia closterium (Fig. 8) is a benthic form but its relatively small size and prominent spines make it easily suspended by turbulence. When conditions are favorable, it becomes important in the plankton. During 1967 this diatom was most common in the warmer months but, the very high April, 1968 peak suggests a response to optimal temperature which Ryther (1964) experimentally determined at 15 C.

Smayda (1957) reports Skeletonema costatum dominant all year in Narragansett Bay, while Marshall and Wheeler indicate a July-October flowering in the Niantic River. H. G. Marshall (1967) shows S. costatum dominant in most of his samples. Hulburt (1956) shows a mid-August peak within Great Pond but not outside in adjacent Vinyard Sound.

In Barnegat Bay traces of S. costatum (Fig. 8) were seen from April through July, chiefly at the bottom in deeper channels along the west shore of the bay. On 11 August small numbers appeared at all four stations, and four days later, on 15 August, high densities of Skeletonema were encountered at each of these points. This diatom was again important during the spring of 1968.

Conover (1956) noted a discrepancy between chlorophyll and cell counts during her summer determinations. She postulated inadequate preservation, particularly of the small naked flagellates, accentuated by an inverse relationship of chlorophyll content to cell size as a cause.

In Barnegat Bay, the highest cell numbers observed all year were during the August coincidence of abundant micro flagellates (1.02×10^6cell/ liter) and the later summer Skeletonema flowering (Figs. 3, 5, 8). Hulburt (1956) recorded a similar July-August peak within Great Pond, but not in adjacent Vinyard Sound. Marshall (1967) reported a summer fall phytoflagellate maximum for the James River estuary.

Smayda (1957), and earlier, Ferrara (1953), postulated respectively three and two week cycles in the microflagellate populations of Narragansett Bay, with maximal densities between $1.7 - 2.0 \times 10^6$ cells/liter. A similar pattern of cycling, although partially masked by the sampling frequency of 14 days, can be seen in (Fig. 3). Maximal densities are also comparable.

Conrad and Kufferath (1954) show several morphological variations in the microflagellate Calycomonas gracilis. Several forms of this organism became abruptly common in Barnegat Bay during the period between April and October (Fig. 5). Marshall and Wheeler found C. gracilis and C. ovalis dominant through much of the period from March or April through November, constituting up to 99% of total cell counts in the Niantic estuary. Hulburt (1965) speaks of a June peak around Woods Hole for one unidentified Chrysophycean and Marshall (1956), speaks of two unidentified "cryptophyceans" in the James River estuary. It is possible they were referring to the same or similar organisms.

FIGURE 8

SUMMER-FALL DIATOMS

Thousands of cells per liter plotted against date. Note logarthmic and arithmetic ordinates.

Cyclotella sp. appeared and disappeared quite abruptly. *Skeletonema costatum* was virtually absent during early and mid-summer.

The symbol "o" connected by a solid line represents mean density for all samples on a given date. The symbol "o" connected by a dashed line represents mean bottom density for all samples on a given date. The symbol "o" indicates that start of sample pooling and thereafter only a single mean is plotted without a symbol for each date. The number of samples varied from a minimum of two to a maximum of ten within each date.

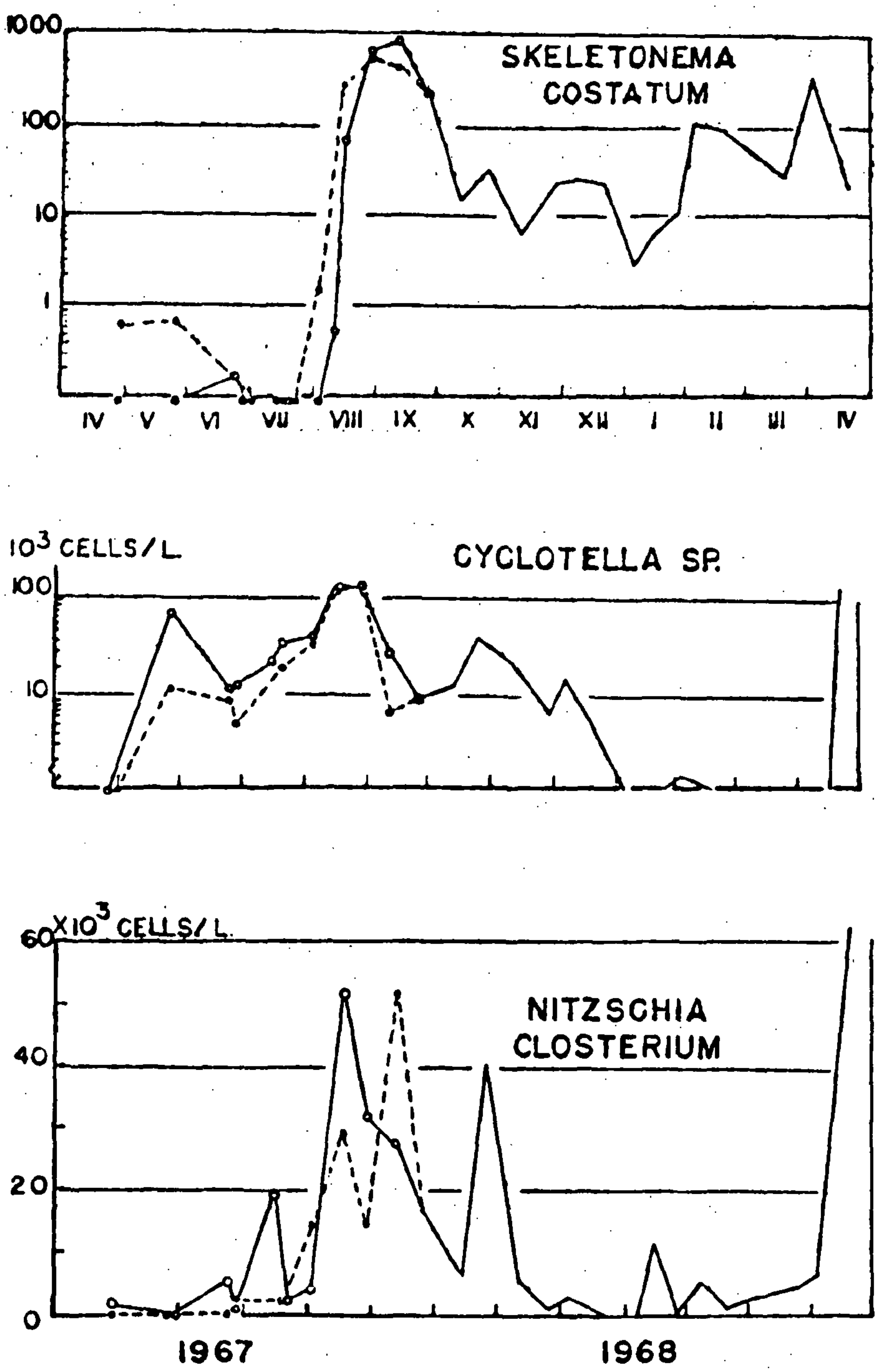

1000
100
10
1
SKELETONEMA COSTATUM
IV V VI VII VIII IX X XI XII I II III IV
10³ CELLS/L.
CYCLOTELLA SP.
100
10
60 X10³ CELLS/L.
40
20
0
NITZSCHIA CLOSTERIUM
1967
1968

FIGURE 8

Nannochloris atomus in Moriches Bay (Ryther 1964) was an indicator pollution. Similarly, the distinctly polluted Raritan estuary is periodically dominated by a minute Chlorophycean similar to Nanno chloris sp. (Prager, personal communication). This, or a kindred form, appeared both summers in Barnegat (Fig. 1) reaching estimated densities from 1.1 to 10.3 x 10^6 cells/liter, superimposed upon the rest of the phytoplankton community. Because of infrequent and unsatisfactory enumerations of this minute cell, it has been omitted from the total phytoplankton data (see discussion of method). The importance of this organism to the estuary is incompletely known. Droop (1958) stated that Monochrysis will grow in vitamin free culture only if Nannochloris is present. Nannochloris itself has not vitamin requirement but presumably produces some useable extracellular metabolite. A small dinoflagellate Amphidinium cf. carteri was isolated in crude culture from Barnegat Bay during November 1967. It remained in lag phase until a contaminant population of Nannochloris became established, and then began exponential growth.

Autumn

Changing weather patterns usually subject New Jersey to periods of lowered temperature and clear radiation nights after mid-October. The bay responds with rather rapidly falling water temperatures, and despite frequent calm mild days, insolation is insufficient to allow significant rewarming of the water column.

Much of the autumnal flora represented an extension of summer populations, particularly the eurythermal forms such as Prorocentrum triangulatum among the Pyrrophyta, Skeletonema costatum; in the Chrysophyta and certain euglenoid flagellates. Total phytoplankton decreased in abundance. The blue-green general, Anabaena, Oscillatoria and Spirulina, primarily detatched epiphytes from scenescent benthic macro-algae, were observed in the plankton.

Distinctly coldwater species begin to reestablish populations. Licmophora sp., all but absent since June, appeared in October, followed by Thallassionema nitzchiodes and Amphiprora spp.. A small Amphidinium, apparently A. fusiforme was quite common. It may sometimes be confused, in fixed material, with Gymnodinium incoloratum (Fig. 5). Both, as we have said, may represent trophic stages of other dinoflagellates. This Amphidinium has been observed by MacKiernan at the Virginia Institute of Marine Science (personal communication), Mackie (personal communication) and myself, to swim "hypocone" forward, contrary to the description by Martin.

Zoospores similar to those of Ectocarpus spp. but probably those of some other alga, occurred with Cryptomonas (Fig. 5) and several unidentified forms to make up a microflagellate community which, during the season of minimum temperature was dominant.

Poridinium triquetra, reported for Barnegat under its former generic designation Heterocapsa (Mountford, 1967) appeared periodically in both summers but showed the greatest development during the colder months.

Seed stocks of Thalassiosira nordenskioldi, and Detonula confervacea appeared about a month before the spring flowering.

Zooplankton

Taxonomy of the zooplankton collected during this survey is incomplete. Particularly among the copepods, identification to species frequently requires dissection of the specimen or at least examination of portions of the anatomy frequently concealed by chance orientation in the closed counting cell. The harpacticoids, periodically of abundance in Barnegat Bay, are especially difficult.

Spring

The spring flowering provided abundant forage for a tremendous upsurge in zooplankton (Fig. 9) dominated by calanoid copepods, chiefly Acartia spp. A lag of 27 days was observed in the apparent maximum of phytoplankton and the subsequent zooplankton peak in Barnegat Bay. At peak density the zooplankton filter clogged after only 25 liters of tie sample had been poured. Centrifuged volume estimates reached 60 ml/m^3. Survey data for the north end of Barnegat (Mountford, 1969a) showed peaks in settled net plankton volume of 20 ml/m^3 in April, 1964 and 14 ml/m^3 for March 1965 with a peak of 22 ml/m^3 in early May, 1965. The 1968 material represented a total census of 2.1 x 10^6 organisms/m^3, compared to a maximum of 0.26 x 10^6 recorded by Deevey (1956) in Long Island Sound, almost an order of magnitude less. The timing of sampling runs, the stations chosen, and the number of samples taken all contribute to the variability seen from year to year in Barnegat Bay. All three peak values reported were based on a single sample with date, and an interval of at least seven days separated consecutive estimates. Centrifuged volumes include that portion of the phytoplankton retained by a filter pore size of 106 μ.

The available standing crop of phytoplankton decreases during spring, but, the increase and maintenance of high zooplankton populations implies continued high phytoplankton productivity. The Barnegat Bay results imply much better utilization of the spring phytoplankton crop than estimated by Williams, Murdoch and Thomas (1968) in a shallow embayment near Beaufort, N. C., where maximum zooplankton volume reached only 0.149 ml/m^3 and only a small fraction of the phytoplankton was grazed.

The genus Acartia strongly influenced patterns in the zooplankton of Barnegat Bay (Fig. 3), a condition reflected in almost every other estuary studied along the Atlantic Coast. (Jeffries, 1964; Conover 1956). There appeared to be a seasonal shift in late winter permitting Acartia clausi Glesbrecht to establish populations alongside A. tonsa Dana. This shift is apparently not as radical as that described for Long Island Sound (Conover, 1956) but, resembles more that seen by Heinle (1966) in the Chesapeake region. As in Heinle's material the shift seems coupled with heavy infestation of A. tonsa (and apparently members of other copepod genera), by the epizooid Zoothamnium. Although older A. Tonsa are more heavily infested, the epizooid was seen even on late naupliar stages and thus would not suggest exclusive colonization of a scenescent adult population.

Deevey (1960) reported that A. tonsa was much decreased by January or February in Delaware Bay, but had a resurgence in June or July. She found A. clausi between February and May or June in Block Island Sound (Deevey, 1952).

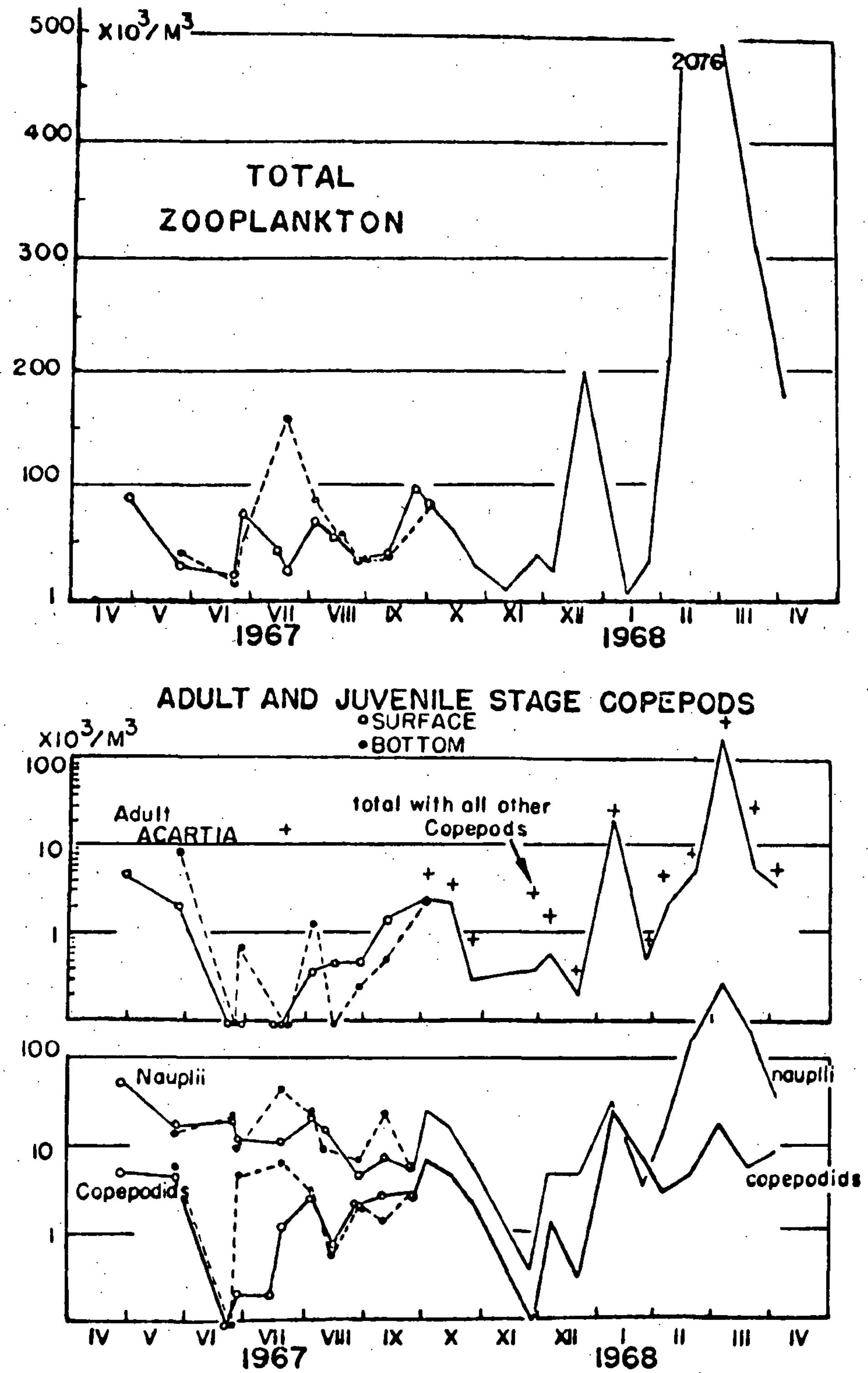
FIGURE 9

TOTAL ZOOPLANKTON AND ADULT AND JUVENILE STAGE COPEPODS

Thousands of organisms per cubic meter plotted against date. Note logarthmic and arithmetic ordinates.

Much of the seasonal cycle reflect changes in populations of Acartia spp.

The symbol "o" connected by a solid line represents mean surface density for all samples on a given date. The symbol "o" connected by a dashed line represents mean bottom density for all samples on a given date. The symbol "o" indicates the start of sample pooling and thereafter only a single mean is plotted without a symbol for each date. The number of samples varied from a minimum of two to a maximum of ten within each date.



500 X10³/M³
400
300
200
100
1
TOTAL ZOOPLANKTON
2076
IV V VI VII VIII IX X XI XII I II III IV
1967
1968
ADULT AND JUVENILE STAGE COPEPODS
○SURFACE
●BOTTOM
X10³/M³
100
10
1
Adult ACARTIA
total with all other Copepods
100
10
1
Nauplii
Copepodids
nauplii
copepodids
IV V VI VII VIII IX X XI XII I II III IV
1967
1968

FIGURE 9

Several other copepod genera, Eurytemora, Temora and Centropages increase during the bloom period. According to Deevey (1960) C. hamatus Lilljeborg and C. typicus Kroyer are major continental shelf species. C. hamatus occurred from winter through spring in Delaware Bay while C. typicus was the fall-winter species. This agrees with tentative identifications made of Centropages spp. found in Barnegat Bay

A pronounced spring peak of polychaete setigers (Fig. 10) recorded in 1968, represented, unfortunately, the data from only a single station. Many setigers later appeared at other stations through March and April although never in such great abundance. Setigers from the peak sample were held in a small tank and allowed to develop while being fed with crude plankton cultures. The young worms which ultimately metamorphosed and built tubes on the bottom appeared to be Polydora sp., which is not an important benthic form in Barnegat Bay. Polydora, however, has an active planktonic setiger which Jeffries (1964) listed first among polychaete larvae for his Raritan Bay plankton collections. He also reported spring peaks of polychaete larvae for April and May in Narragansett Bay, May through June in Raritan Bay and April through May for the York River.

The occurrence of the delicate Chaetognath Sagitta elegans Zahony from late fall through spring in Barnegat Bay is consistent with Deevey's (1956) finding that S. elegans is the only species in Long Island Sound waters.

TABLE 2

The Occurrence of Sagitta elegans in Barnegat Bay
1967-1968

5-minute net tow Abundance	Data	Temperature	Salinity
1 individual In 3 stations	20 XII	4.5°	27.5%
Hundreds In a single sample	3 III	2.2°	30.6%
Dozens in a single sample	10 III	4.7°	25.6%
2 individuals in 4 stations	7 IV	9.2°	24.0%

Sagitta is apparently quite sensitive to higher temperatures. Taken from the field into the laboratory they have not survived holding at 16-20°C for more than a few hours.

In March and April of 1965 (Mountford, 1969a), 1968 and 1969 the mature and immature medusae of Syncorne (Sarsia) mirabilis L. Agassiz became very abundant. Their spatial distribution is variable, with tidal effects the determining factor (Marshall and Hicks, 1962). Miner (1950) reports the occurrence of this medusa from Narragansett Bay northward between February and May. Numbers recovered on 7 April, 1968 during five minute drifts at four stations with an 0.1 m^2 net ranged from 3 to 59 Syncorne. Comparable numbers were taken in 1969.

In 1968, S. mirabilis was succeeded by the coelenterate Aequora forskalea Peron and Lesueur which appeared again during the autumn. Deevey (1952) reported unclassified hydromedusae mostly during March and April for Block Island Sound. In 1944, they constituted 65% of the zooplankton volume there.

When water temperatures exceeded 14°C, the large Coelenterate Cyanea capillata Eschscholtz became abundant. It feeds on small fishes and was observed capturing live Menidia menidia Linn. and digesting small sticklebacks (Gasterosteus sp.) and the metamorphosed juveniles of Anguilla rostrata (LeSueur) Cyanea disappeared abruptly from the bay in June when large numbers were seen lying scenescent in warmer shallows along the lee shore of Island Beach. None were encountered until the following spring. Deevey reported Cyanea for May, 1944 and May, 1945 in Block Island Sound. Marshall and Hicks (1962) documented a spring to early summer occurrence in the Niantic River, Conn.

Summer

Bivalve (Pelecypod) and gastropod veligers (Fig. 10) were present from early April through December. Gastropod veligers first became abundant in July and August, 1967 and were scarce after September. Mean densities did not exceed $8 \times 10^3/m^3$ but a peak of $24 \times 10^3/m^3$ was observed at the bottom near the mouth of Forked River. In Raritan Bay Jeffries (1964) found veligers of Nassarius to be the most abundant. He also reported that gastropod veligers never matched the density of bivalve veligers. In Barnegat, bivalve veligers, at peak density, exceeded gastropod veligers by a factor greater than two.

Bivalve veligers were most abundant from the end of August through mid-October. In light of Jeffries (1964) data, timing of the peaks suggests that Mercenaria (Venus) mercenaria Linn. is responsible, but reproduction is then occurring later in Barnegat Bay than in Raritan Bay, where an August maximum is observed.

Most other estuaries show summer peaks for these meroplanktonic larvae, although the months of importance vary with the thermal pattern and composition of the benthic community. Both these groups are considerably more abundant and more strongly cyclic within the estuary than reported for less enclosed regions like Delaware Bay, Long Island, and Block Island Sounds, where scattered individuals have been recorded in most months of the year.

FIGURE 10

OTHER ZOOPLANKTERS

Thousands of organisms per cubic meter plotted against date. Note logarithmic and arithmetic ordinates.

Rotifers were important during the colder months. Note the successive contribution of several larval benthic invertebrates.

The symbol "0" connected by a solid line represents mean surface density for all samples on a given date. The symbol "0" connected by a dashed line represents mean bottom density for all samples on a given date. The symbol "0" indicates the start of sample pooling and thereafter only a single mean is plotted without a symbol for each date. The number of samples varied from a minimum of two to a maximum of ten within each date.

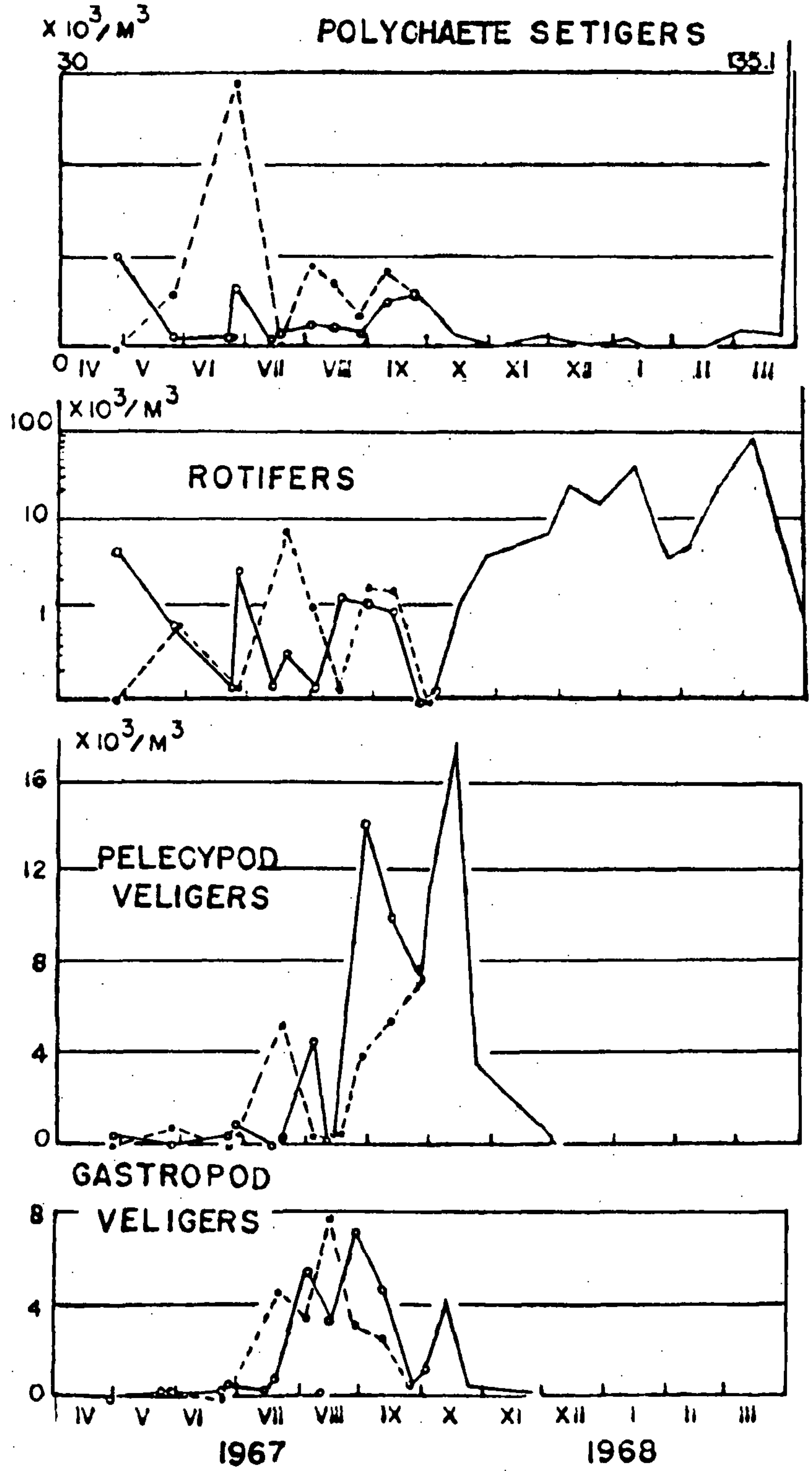

X 10^3/M^3
POLYCHAETE SETIGERS
30
135.1
0
IV V VI VII VIII IX X XI XII I II III
100
X 10^3/M^3
ROTIFERS
10
1
X 10^3/M^3
16
12
PELECYPOD
VELIGERS
8
4
0
GASTROPOD
VELIGERS
8
4
0
IV V VI VII VIII IX X XI XII I II III
1967
1968

FIGURE 10

The appearance of the ctenophore Mnemiopsis leidyi A. Agassiz at the beginning of summer in Barnegat Bay is a remarkable occurrence, which has proven predictable within 1 week for five years in upper Barnegat Bay. At Mantoloking, the date of appearance has been between 31 May and 14 June since 1964. A temperature of 23°C may be the key factor. With more conservative temperatures, in particularly near the bottom, lower and middle Barnegat Bay, it is hardly surprising that this onset was not observed until late June or the first week of July.

The densities generated in a few days are remarkable, with counts as high as fifty organisms in fifty liters (estimated therefore, at $1000/m^3$). Mnemiopsis is an efficient predator on the zooplankton, feeding with particular capacity on calanoid copepods. Zooplankton volumes in the bay were immediately and drastically reduced. Deevey (1960) did not show such a depletion for Delaware Bay or adjacent neritic waters but, Williams, Murdoch and Thomas (1968) report extremely low zooplankton volumes where ctenophores and medusae make up the bulk of material in 16% of their samples. Their average zooplankton volume for the year, excluding ctenophores, was only $0.114\ ml/m^3$.

During periods of maximum ctenophore predation, harpacticoid copepods, which are primarily bottom dwellers, assume a position of relative importance. Presumably because of their benthic habits, they are spared the heavy predation inflicted upon pelagic genera. In addition, many harpacticoids carry their eggs through hatching, which aids survival by eliminating a non-motile pelagic stage.

Allowing for the tremendous grazing which must occur to support a large Mnemiopsis population, Acartia tonsa must maintain high fecundity (Heinle, 1966). While the standing crop of adult Acartia is low, the Barnegat Bay material suggests that naupliar stages are one or more orders of magnitude more abundant than adults (Fig. 8), during the period of maximum grazing.

Autumn

The experimental work of Mayer (1912) and Nelson (1925) indicated that Mnemiopsis is more sensitive to damage from increases in temperature than decreases. Autumn specimens, acclimated to colder water, disintegrated at 20°C in our laboratory after a matter of hours. They have been refrigerated for several days without apparent damage and Nelson (1925) froze them in a salt-ice slurry without mortality.

In Barnegat Bay Mnemiopsis has been found viable during December 1965 and 1967. They were recovered by dredge while resting on the bottom or seen in the shallows, particularly among blades of Zostera. To some extent, Mnemiopsis was replaced by a second species, Beroe ovata Chamisso and Eysenhardt in autumn. Both species apparently cease to be important predators by November.

Despite the removal of heavy predation, an autumnal increase was not observed in the Barnegat zooplankton. It took Acartia until December to establish a token adult population. Heinle (1966) found, in summer, that at 26°C Acartia's generation time, egg to egg, was only four days. At 15°C this time increased to 13 days.

Exclusive of nauplii, the rotifers _Asplanchna spp_. and _Synchaeta spp_. reaching densities of 70 x $10^3/m^3$ along with several tintinnid protozoa, became important during the autumn. The tintinnid, _Cymatocyclis sp_. has shown a rather predictable occurrence each fall since 1964. In 1967 it reached a mean density for all stations of 8.4 x $10^3/m^3$ on 14 October.

Winter

The Rotifera continued to occupy a position of importance in the zooplankton through spring, with a March maximum of 90 x $10^3/m^3$ indicating better development in Barnegat Bay at lower temperatures. Jeffries (1964) reported two rotifer species in the Raritan estuary which reached 130 x $10^3/m^3$ but the peaks were in May and June.

Only minute zooplankton populations were observed during the January period of ice cover. Low temperatures may cause still viable organisms to sink in the water column where, with ice cover, they are not resuspended by wind action. Bottom samples are unfortunately not available to test this hypothesis Heinle (1966) did not show this winter minimum for the Patuxent River. With increased phytoplankton, the zooplankton began responding in early February.

DISCUSSION OF METHOD

A truly quantitative examination of estaurine plankton is incredibly complex. With any single sampling or preservation technique, we rule out adequately characterizing certain segments of the plankton. Many of the small penate diatoms require special cleaning and mounting operations before sufficient detail can be discerned to assure proper identification. Portions of each sample have been preserved so that this can be done in the future.

The use of relatively small volume phytoplankton samples resulted in unsatisfactory density estimates for the larger and less abundant genera such as Coscinodiscus, Biddulphia, and Rhizosolenia among the diatoms, and the diatoms, and the large armored dinoflagellates Ceratium and Peridinium. In the binary phytoplankton-zooplankton emphasis of this program, it was found that these larger forms were adequately recovered by the zooplankton filter, but when densities were put on a per-liter basis, the numbers were virtually insignificant. These small populations appear to result from innocula through Barnegat Inlet with the tidal stream, and are not indigenous to the bay.

The species list for each collection date is based primarily upon live examination, largely eliminating the loss of recognizable organisms through fixation. Various conditions of temperature and seration were studied to determine holding conditions which would minimize changes in the live material before examination. In examinations made 3.0, 29.8 and 44.0 hours after collection, total cell count and species composition were most stable, and percent mortality was lowest, when the sample was maintained near ambient environmental temperature and gently aerated with the finest possible stream of bubbles. Refrigeration for 44 hours at approximately 4° 0 increased mortality 40% over duplicate samples held 44 hours at the ambient. Note that in winter, refrigeration at 4° represents an elevation by as much as 5° above ambient environmental temperature, probably an undesirable condition.

Losses in the preserved phytoplankton concentration process were estimated with a set of representative samples by collecting all the supernatants, concentrating them by centrifugation for two hours at 2000 RPM, and enumerating the recovered organisms. For the larger phytoplankters, loss was estimated at 5.29 cells/ml an amount considered negligible compared to the total density estimated in the original material (329 cells/ml $\pm$ 59 cells/ml 95% confidence interval). Losses in the nannoplankton (3–10 μ) were about seven times as high (33.3 cells/ml.) or 1.01% of the estimated total number in these samples).

Conover (1956), using neutral formalin, found discrepancies in her data which she ascribed to the inadequate preservation of many naked forms. In the James River, Marshall (1967) used a Lugol-Rodhe solution. His total cell counts were lower than those observed in Barnegat Bay, particularly during the summer. On the other hand, Hulburt (1956) reports bloom intensities more than forty times the maximum Barnegat Bay determinations. He counted live material and there is no doubt that a certain proportion of the cells in a fixed sample become unrecognizable. Bainbridge (1957) however, suggests that natural densities do not exceed 50- cells/ml for diatoms, and 2500 cells/ml for flagellates. The flagellate figure approximates the maximum observed density in Barnegat, 2900 cells/ml and agrees well with Smayda (1957) and Ferrara (1953) for Narragansett Bay. Most workers in the estuary, however, have encountered diatom blooms, particularly of Skeletonema, which exceed 1000 cells/ml. The Barnegat maximum for this diatom in 1967-68 was 1250 cells/ml.

Minute forms such as Nannochloris which Ryther (1964) found so phenomenally abundant in Moriches Bay, were not noticed until they reached fairly high density in Barnegat Bay. Enumeration could only be satisfactorily accomplished under oil immersion and, therefore, was attempted in only a few exploratory cases, which suggest that an additional 10,000 cells/ml may occasionally be present in the water column. Certainly these discrepancies in enumeration deserve continued investigation.

The effects of four fixatives were evaluated both from the standpoint of total cells recovered and ease of recognition for the more delicate species. Formalin, acetic acid and Lugol's solution were rejected. The addition of a saturated l_2-Kl solution to each 500 ml sample, resulting in a final concentration of 0.2% was found acceptable. This reagent is prepared by saturating 100 ml distilled water with KI and then saturating it with I_2.

After eighteen months storage some samples preserved with the reagent developed filaments of fungus. Williams (1962) reported the addition of Thimerosal (sodium ethylmercurithiosalicylate) 0.16% plus an equal weight of sodium borate improved the preservative qualities of I_2-KI fixatives after volatilization of the free iodine. A reagent modification was accordingly examined.

The resulting body of data provided a convenient assessment with six replicates, on the accuracy of density determinations and stability of species composition among samples drawn from a homogeneous source. The modified preservation appeared slightly better but the differences were not statistically significant. The 95% confidence interval on mean total cell number was 16.9 cells/ml or, for these samples, 4.2%.

The purpose of disc filtration in Zooplankton sampling was to eliminate between-sample contamination which had been suspected in the use of conventional plankton nets. To assess the importance of this factor, a standard 0.1 m^2 plankton net used for sampling in the Barnegat estuary was carefully washed with one liter of distilled water. The rinsings were collected and centrifuged to remove suspended matter, which was then examined under the microscope. Similarly, a filter disc, in use at that point for nine months and back-flushed after each sample, was vigorously scrubbed in distilled water and the washings centrifuged for examination.

Thirty-one species were identified in the net washings, among which many would have been judged as viable cells in enumeration, despite 17 days drying since the last use. Eleven species were identified from the filter, of which only two cells would have been judged viable. The filter cannot be towed like a net. This logistically limits sample size, but the method appears to reduce contamination from previous samples. With the filters changed completely after each use and returned to the laboratory for thorough cleaning, contamination can be ruled out.

TABLE 3. REPEATABILITY OF DENSITY ESTIMATES AND SPECIES COMPOSITION IN PHYTOPLANKTON SAMPLES INDEPENDENTLY DRAWN FROM A CARBOY OF HOMOGENEOUS MATERIAL.

	I_2 KI			Plus Thimerosal		
Replicates	A	B	C	D	E	F
Total Number of Species:	19	18	18	18	19	18
DIATOMS						
Skeletonema costatum	164.8	164.8	123.2	187.8	138.3	134.0
Cocconeis spp.	17.6	17.6	24.0	26.2	36.4	30.6
FLAGELLATES						
Cryptomonas sp.	36.0	28.0	12.0	18.2	25.5	36.4
Euglenoid flagellate	1.6	1.6	0	1.5	1.5	3.6
Gyrodinium pellucidum	1.6	6.4	11.2	12.8	18.9	29.1
Bipedomonas ? sp.	72.0	40.0	76.0	61.9	40.0	94.6
Carteria sp.	0	0	0	0	0	3.6
Unident. Micro-flagellate	40.0	28.0	36.0	40.0	40.0	51.0
Gymnodinium incoloratum	0	0	4.0	1.5	1.5	4.4
TOTAL INCL. ALL OTHER SPECIES	426	402	406	404	397	438

All figures cells per ml. A B C = 401.3 D E F = 403.0

To examine the effect of net pore size on the efficiency with which organisms were removed from the water, random samples of the stainless steel mesh and nylon bolting cloth were compared. Mean pore size for the bolting cloth was $84\mu \pm 23\mu$ (S.E.) and for the stainless mesh $106\mu \pm 16\mu$ (S.E.). Although pore size is greater in the stainless mesh, it is more uniform, despite long hard use, than in new bolting cloth.

The density reported for early naupliar stages and small tintinnids in this study is probably significantly less than actual. Heinle (1966) found he was losing most of the early nauplii even through his 74μ bolting cloth nets. Since such classes of organisms are periodically of great abundance in every estuary, a means to circumvent these losses is required. In work subsequent to that summarized here, we anticipate enumerating these organisms in the fixed phytoplankton samples, for which no filtering is required.

To examine the relative amounts of material retained by each method, samples were drawn at four stations on the same date with both the plankton net and filter. The volume of material retained by both systems was compared after centrifugation and no statistically significant differences were found. On the average, the filter surprisingly retained a slightly higher volume. Enumeration of the samples revealed no consistent trend toward loss in any of the major zooplankton groups, although variability was great enough that further investigation is warranted.

Loss estimates in concentration of the zooplankton (as opposed to filtration) indicate that essentially all the organisms removed from the filter are retained in the final concentrate. Between 1.8 and 2.3% of Zoothamnium, an epizoid on Acartia spp. are lost in concentration. Because of its phenomenal seasonal abundance and lack of uniformity of infestation on host copepods, reliable quantification is nearly impossible. Zoothamnium is not included in the numerical abundance data.

During periods of minimum zooplankton abundance when densities were in the 1-2000 organisms/m^3 range, the reliability of the fifty-liter sample was decreased. So few organisms were present that virtually the entire sample had to be counted. During periods of maximum abundance when densities approached 2×10^6 organisms/m^3, the filter, having a relatively small mesh area, clogged after passing barely 25 liters.

LITERATURE CITED

Bainbridge, R. 1957. The size, shape and density of marine phytoplankton concentrations, Biol. Rev. 32: 91-115.

Brandt, K. and C. Apstein. 1908. In Nordisches Plankton, Botanischer Tell. XVIII.

Bursa, A. 1959. The Genus Prorocentrum Ehrenberg. Morphodynamics Protoplasmatic Structures, and Taxonomy. Can. J. Bot. 37: 1-31.

Carpenter, J. H. and D. W. Pritchard. 1963. Concentration Distribution for Material Discharged into Barnegat Bay. Pritchard-Carpenter, Consultants. The John Hopkins University, Baltimore 18, Md. 13 p.

Conover, R. J. 1956. Oceanography of Long Island Sound. VI. Biology of Acartia clausi and A. tonsa. Bull Bingham Oceanogr. Collect. 15: 156-233.

Conover, Shirley A. 1956. Oceanography of Long Island Sound. IV. Phytoplankton. Bull. Bingham Oceanogr. Collect 15: 62-111.

Conrad, W. and H. Kufferath. 1954. Recerches sur les Eaux Saumatres des Environs de Lilloo. II. Inst. Roy. Sci. Nat. Belg. 127: 1-346.

Curl, H. C. and G. C. McLeod. 1961. The Physiological Ecology of a Marine Diatom Skeletonema costatum (Grev.) Cleve. J. Mar. Res. 19: 70-88.

Deevey, G. B. 1952. A survey of the Zooplankton of Block Island Sound, 1943-1946. Bull. Bingham Oceanogr. Collect. 13: 65-119.

Deevey, G. B. 1956. Oceanography of Long Island Sound, 1952-1954. V. Zooplankton. Bull. Bingham. Oceanogr. Collect. 15: 113-155.

Deevey, G. B. 1960. Plankton Studies. I. The Zooplankton of the Surface waters of the Delaware Bay Region. Bull. Bingham. Oceanogr. Collect. 17: 5-53.

Droop, M. R. 1966. Summation. I. C. H. Oppenheimer (ed.) Marine Biology, N. Y. Acad. Sci. Interdisciplinary Communications Program. N.Y. 369 p.

Ferrara, R. 1953. Phytoplankton studies in upper Narragansett Bay. Unpub. M. S. Thesis. Library, Univ. of Rhode Island.

Grave, C. 1912. Fourth report of the shell-fish commission of Maryland. 324-348. Baltimore.

Heinle, D. R. 1966. Production of a calanoid copepod <u>Acartia tonsa</u> In the Patuxent River Estuary. Ches. Sci. 7: 59-74.

Hendey, N. Ingram. 1964. An introductory account of the smaller Algae of British Coastal Waters. Part V. Bacillariophyceae (Diatoms) Her Majesty's Stationary Office, London, 317 p.

Hulburt, E. M. 1956. The Phytoplankton of Great Pond, Massachusetts. Biol. Bull. Woods Hole 110: 157-168.

Hulburt, E. M. 1957. The Taxonomy of Unarmored Dinophycease of Shallow Enbayments on Cape Cod, Massachusetts. Biol. Bull. 112: 196-219.

Hulburt, E. M. 1965. Flagellates from Brackish Waters in the vicinity of Woods Hole, Massachusetts, J. Phycol. 1: 87-95.

Hulburt, E. M. 1965. Three Closely Allied Dinoflagellates. J. Phycol. 1: 95-96.

Jeffries, H. P. 1964. Comparative Studies on Estuarine Zooplankton. Limnol. and Oceanogr. 9: 348-358.

Ketchum, B. H. 1954. Relation between circulation and planktoni populations. in estuaries. Ecology 35: 191-200.

Lebour, M. V. 1925. The Dinoflagellates of Northern Seas. Marine Biol. Assoc. U. K. 250 p.

Lebour, M. V. 1930. The Planktonic Diatoms of Northern Seas. Adlard and Son, Ltd., London, 244 p.

Mackie, Gloria T. 1969a. Quantitative studies of feeding in <u>Crassostrea virginica</u>. Bull. N.J. Acad. Sci. 14: in press (Abstr.).

Marshall, Harold G. 1967. Plankton in James River Estuary, Virginia. I. Phytoplankton in Willoughby Bay and Hampton Roads. Ches. Sci. 8: 90-101.

Marshall, N. and S. D. Hicks. 1962. Drift of Medusae and their distribution in relation to the hydrography of the Niantic River Conn. Limnol. and Oceanogr. 7: 268-269.

Marshall, N. and B. Wheeler. 1965. Role of the coastal and upper Estuarine waters contributed phytoplankton to the shoals of the Niantic Estuary. Ecology 46: 665-672.

Martin, G. W. 1929. Three new dinoflagellates from New Jersey. Bot. Gazette 87: 556-558.

Martin, G. W. 1929. Dinoflagellates from Marine and Brackish Waters in New Jersey. Univ. Iowa Studies in Natural History 12: 3-32.

Mayer, A. G. 1912. Ctenophores of the Atlantic Coast of North America. Publ. No. 162. Carnegie Institute, Washington.

Miner, R. W. 1950. Field Book of Seashore Life. G. P. Putnam, New York, 888 p.

Mountford, K. 1965. A late Summer Red Tide in Barnegat Bay, N. J. Underwater Naturalist 3: 32-34.

Mountford, K. 1967. The Occurrence of Pyrrhophyta In a Brackish Cove Barnegat Bay, New Jersey at Mantoloking, May through December, 1966. Bull. N.J. Acad. Sci. 12:9-12.

Mountford, K. 1969a. Plankton Survey Data for Barnegat Bay N. J. 1964-1965. Bull. N. J. Acad. Sci. 14: In press (Abstr.).

Nelson, T. C. 1925. On the occurrence and food habits of Ctenophores in New Jersey Inland Coastal Waters, Biol. Bull. 48: 92-111.

Patten, B. C. 1961. Nannoplankton Records obtained from Chesapeake Bay Cruises of R/V. Pathfinder and R/V Observer, January 1960 - January 1961. Virginia Institute of Mar. Sci. Special Scientific Report No. 21.

Pritchard, D. W. 1960. Salt balance and exchange rate for Chincoteague Bay. Ches. Sci. 1: 48-57.

Redfield, A. C. 1951. Report on a survey of the hydrography of Great South Bay made during the summer of 1950 for the town of Islip, N. J. Woods Hole Oceanographic Institution. Ref. No. 50-48.

Riley, G. A. 1966. Seasonal cycles and succession of societies. In C. H. Oppenheimer (ed.). Marine Biol. N.Y. Acad. Sci. Interdisciplinary Communications Program. N.Y. 369 p.

Ryther, J. 1954. Ecology of phytoplankton Blooms in Moriches and Great South Bay. Biol. Bull. 106: 198-209.

Smayda, T. J. 1957. Phytoplankton studies in Lower Narragansett Bay. Limnol, and Oceanogr. 2: 342-359.

Spooner, G. M. 1933. Observations on the reaction of marine plankton to light. J. Mar. Biol. Ass. U. K. 19: 385-438.

United States Coast and Geodetic Survey. 1966. Navigational Chart 825-SC. U.S. Govt. Printing Office, Washington, D. C.

Williams and Murdoch. 1966. Phytoplankton Production and Chlorophyll concentration in the Beaufort Channel, N. C. Limnol and Oceanogr. 11: 73-82.

Williams, R. B., Marianne Murdoch, L. K. Thomas. 1968. Standing Crop and Importance of zooplankton in a system of shallow Estuaries. Ches. Sci. 9: 42-51.

Williams, L. G. 1962. Plankton population dynamics. Public Health Service publication No. 663. Supplement 2. 90 p.

Wilson, H. F. 1953. The New Jersey Shore. Vol. I. New York 2 vol.

Wood, R. D. and J. Lutes. 1967. A guide to the Phytoplankton of Narragansett Bay, R. I. Stellas Printing, W. Kingston, R. I. 65 p.