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William F. Clapp Laboratories, Inc.
Duxbury, Massachusetts

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For the Period December 1, 1977 to November 30, 1978

on

WOODBORER STUDY ASSOCIATED WITH THE OYSTER CREEK GENERATING STATION

to

JERSEY CENTRAL POWER & LIGHT COMPANY

February 28, 1979

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

Report No. 14893

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MANAGEMENT SUMMARY

Through Contract #EA-77-1, Jersey Central Power & Light Company requested Battelle's William F. Clapp Laboratories 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 study period from December, 1977, through November, 1978, and the discussion includes trends observed since the inception of the program in June, 1975.

Four species of teredinids, two endemic and two non-native subtropical species were found in the Barnegat Bay system during the course of the study, although only three were observed in 1977 and 1978. *Teredo navalis* was dominant on the east side of the bay and *Bankia gouldi* dominated the west side of the bay. The subtropical species, *Teredo bartschi*, was found only in Oyster Creek. The subtropical species, *Teredo furcifera*, was not found at any exposure panel station during the 1977 or 1978 season.

The two subtropical species are used as "tracer" species to assess the effects of the thermal discharge. *Teredo furcifera* was found at seven locations throughout the bay in 1975, but declined in density to the extent that no specimens were found during the 1977 season or in the first half of the 1978 season, suggesting that this species has not become firmly established in Barnegat Bay and was apparently not influenced by the thermal discharge.

During 1978 the exposure panel data show that there was an increase in abundance of *Teredo bartschi* in Oyster Creek, reflecting a positive thermal effect but there is no present indication of dispersal effects into Barnegat Bay.

The generating plant does not effect the *Teredo navalis* population at Station 1, the Inlet, and no effect on the distribution of *Bankia gouldi* north or south of Oyster Creek could be discerned.

There has been an overall decline in the teredinid atta[illegible] in Barnegat Bay since 1975. The decline is particularly apparent at Station 4, Waretown, which is in the plume area south of Oyster Creek, and north at

Station 12, Stouts Creek, which is not in the thermal plume, which suggest that the thermal plume does not affect the marine borer population at these locations.

The average values of the water parameters were calculated for the six-month exposure or the long-term panels at all the stations and no relationship with the percent destruction could be seen.

The amount of destruction to the panels at the mouth of Forked River (Station 11) was not significantly different ($\alpha = 0.05$) from Oyster Creek (Stations 5 and 6) which are in the thermal discharge and at Cedar Creek and Holly Park (Stations 13 and 14) which are beyond the thermal discharge. The circulation of water between Oyster Creek and Forked River, and Barnegat Bay in general suggests that locations north of Forked River may be a source of teredinid infestation at Station 11. There is no evidence that *Bankia gouldi* are transported from Oyster Creek.

Teredinid gonadal development at stations around Barnegat Bay followed normal patterns and there is no evidence that prolonged breeding seasons occurred at any site except in the discharge area where a ripe gonad was observed in May, and late active to partially spent specimens were observed in November and December.

Histological studies showed the presence in the shipworms of two protozoan parasites. The haplosporidian *Minchinia* was present in *Teredo* specimens and cysts formed by the encapsulation of *Boveria teredinidi* were observed in *Bankia gouldi*. It is theorized that the presence of the parasites may contribute to keeping *Teredo* abundance down, and to causing a weakening in *Bankia*.

Comparisons of water temperatures and seasonal teredinid attack indicates that no extended teredinid breeding season exists in the bay. The minimal amount of settlement in November in the thermal discharge indicates that the extended breeding season in Oyster Creek is not extensive.

There was no apparent thermal effect on *Limnoria* populations which were 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, C.I. Belmore, and R.E. Hillman

INTRODUCTION

With the demand for increased amounts of electric power there has been increasing concern over the effects of heated effluents on the environment. It is well known that temperature is a major factor influencing the activities and reproductive behavior of marine invertedrates (Odum, 1959).

The molluscan marine borer or shipworm has caused extensive and devastating damage to man-made wooden structures for centuries (Clapp and Kenk, 1963), and natural cycles of attack are known to occur. A heavy infestation of shipworms occurred in Barnegat Bay in 1975 causing concern as to their continued abundance and distribution, particularly in relation to the effects of the Oyster Creek Nuclear Generating Plant.

Barnegat Bay is a large shallow bay, approximately 30 miles long, with fresh water entering from numerous tributaries and with a tidal exchange primarily from Barnegat Inlet. The thermal effluent from the Oyster Creek Generating Plant is discharged into Oyster Creek, a saltwater creek. Because of this, marine organisms inhabiting the creek are, at times, exposed to temperatures that are higher than at other areas in the Barnegat Bay system.

Jersey Central Power & Light Company requested Battelle's William F. Clapp Laboratories to conduct an investigation to determine whether resident marine borer populations in the Oyster Creek discharge are contributing significant additional damage in Barnegat Bay, over what would be caused to the same wood by marine borers occurring "naturally" in the Barnegat Bay system.

To achieve this goal there is a need to know the species of marine borers present in Barnegat Bay, their distribution and abundance, their destructiveness and seasons of reproductive activity. Three integrated tasks were conducted: 1) wood exposure panels were installed at 20 locations (stations) in Barnegat Bay and adjacent areas (Figure 1), 2) the gonads of teredinids collected throughout the study area were examined to determine if the shipworms in the area of the thermal plume were experiencing an extended breeding season, and 3) 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 marine borers.

This report presents data and results for the period December, 1977, through November, 1978, and in the discussion includes trends observed since the inception of the program in June, 1975.

The materials and methods and detailed results for each portion of this study, exposure panels, water quality, and marine borer development status, are presented in Appendices A, B, and C, respectively.

RESULTS AND DISCUSSION

Due to severe marine borer attack in Barnegat Bay in 1975, the panel exposures were designed for six-month exposure periods. Data obtained since then established that no borers settled on any six-month panels submerged after November and removed by June. Consequently the data reflect each teredinid breeding season. There have been three and one-half breeding seasons to date, and wherever applicable, these results will be used in the following discussion.

Four species of teredinids, two endemic, two non-native subtropical species, were found in the Barnegat Bay system during the course of the study, although only three were observed in 1977 and 1978.

The two species endemic to Barnegat Bay are *Bankia gouldi* which is dominant on the west shore of the bay, and *Teredo navalis* which is dominant on the east side of the bay. The two subtropical species, *Teredo furcifera* and *Teredo bartschi*, are considered non-native species because they were not observed in Barnegat Bay prior to 1974 (Firth et al., 1976).

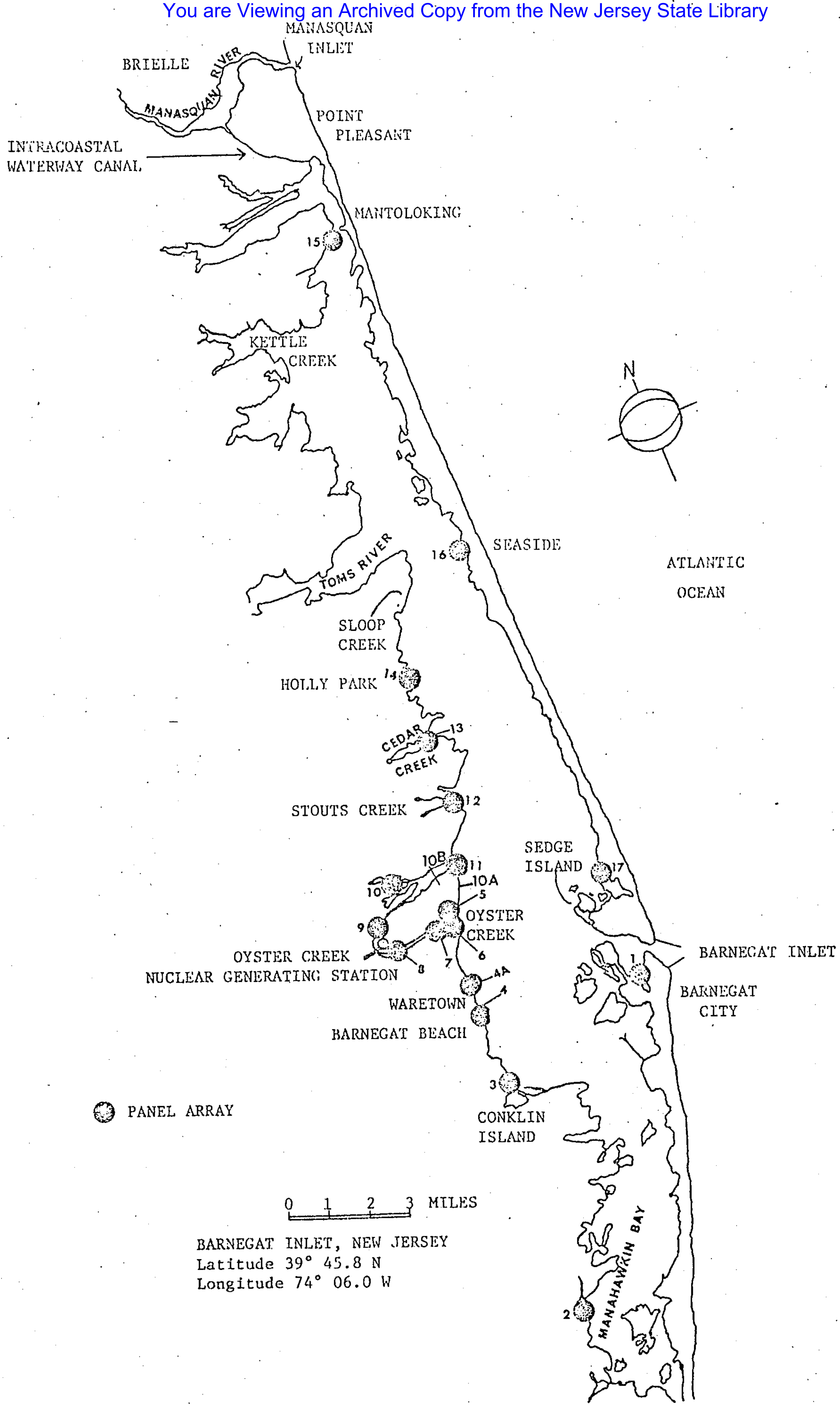

FIGURE 1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHICAL LOCATIONS OF EXPOSURE PANELS

The presence of *Bankia gouldi* in Barnegat Bay has been recorded by investigators for more than 75 years (Atwood and Johnson, 1924; Nelson, 1923). Its distribution is cosmopolitan as the species has been found at each of the exposure locations sometime during this study. However, *B. gouldi* is most abundant on the west side of the bay, particularly north of Oyster Creek at locations in Stouts Creek and Holly Park which are beyond the influence of the thermal plume (Woodward-Envicon, 1974).

Other than the great abundance of *Teredo navalis* near Holly Park reported by Nelson (1923) in the early 1920's, this species is found primarily on the east and southern areas of the bay. As in previous years (Wallour, 1960), it continues to be abundant at the Inlet where there is no effect from the generating plant. In 1975 *Teredo navalis* was present at ten locations on the west side of the bay, at six locations in 1976 and 1977, and at only two locations during the first half of the 1978 season. For the period July through November, 1978 it was the only species present at Station 2, Manahawkin, with a total of ten specimens found in panels for that time. Seven specimens from Station 11, Forked River, were the only other *Teredo navalis* found on the west side of the bay during this period. The paucity of specimens indicated no positive effect from the thermal discharge.

How the two subtropical species were introduced into Barnegat Bay is unknown, although they were brought possibly by boats that had come from subtropical areas as suggested by Turner (1973), or perhaps the species was endemic in so few numbers that they were not recorded previously. However their introduction, it is hypothesized that the importance of these two species lies in the supposition that if they continue to be present and their numbers increase, it would show that environmental parameters, particularly water temperatures and salinity, are favorable for their survival and proliferation. Consequently the two species are used in this study as "tracer" species to assess the effects of the thermal discharge.

Even though it is considered a subtropical species, *Teredo furcifera* has a wide temperature and salinity tolerance (Karande, 1968).

Teredo furcifera was found at seven locations throughout the bay in 1975, but declined in density to the extent that no specimens were found during the 1977 season or in the first half of the 1978 season. This decline may be due in part to the severity of the winter of 1976, since summer water temperatures and salinities in 1977 and 1978 were within the breeding range (24 C - 33 C, 6 o/oo - 34 o/oo) at the seven locations where *T. furcifera* was first found in 1975. Karande (1968) observed that settlement of *Teredo furcifera* larvae is independent of both salinity and temperature variation, and is dependent on high fecundity. The decline in both numbers and locations suggests that this species has not become firmly established in Barnegat Bay and has not proliferated because of the thermal discharge.

Teredo bartschi, the second "tracer" species has been found only in Oyster Creek. The water temperatures in Oyster Creek are in the optimal range for teredinid breeding from April through October-November irrespective of plant downtimes. Specimens containing umbonate larvae were removed from Station 7 in January, 1978, and Hoagland (1978) reported that larvae developed to-the straight hinge stage in specimens removed in February, 1978 at an adjacent location. Umbonate larvae were present each month during the first half of the 1978 season. The abundance of *Teredo bartschi* has increased in Oyster Creek, and the species is dominant at all Oyster Creek stations except at the railroad bridge. It is theorized that the severe winter of 1976 may have caused some winter kill but that environmental conditions in Oyster Creek were favorable for the few survivors. *Teredo bartschi* are opportunistic and gregarious, so that the removal of the trashwood from Oyster Creek in 1976 not only diminished the *Bankia gouldi* population but increased opportunities for localized *T. bartschi* settlement. Figure A-5 shows the amount of teredinid destruction to long-term exposure panels from July, 1975, through November, 1978. The heavy attack in 1975 was caused by *Bankia gouldi*. *Teredo bartschi* was the dominant species after 1975 and the amount of attack increased each season at Stations 5, 6, and 7, reflecting a positive thermal effect within Oyster Creek. We have not found *T. bartschi* beyond Oyster Creek, and the attack by other teredinids continues to decrease at Station 4 which is south of Oyster Creek but in the influence of the thermal plume. Thus it appears that the Oyster Creek Generating Station is not affecting the dispersal of *Teredo bartschi*.

Short-term (one-month exposure) panels provide data concerning the season of year that attack is initiated. Data from short-term panels exposed monthly from June, 1975 through November, 1977 showed that successful settlement did not take place in Barnegat Bay from December to June (Richards et al., 1978). Table A-21 shows this to be true in 1978. Similar observations were made by Hoagland et al. (1978).

Settlement patterns for the teredinid species in Barnegat Bay in 1978 were similar to those of the preceding seasons. The heaviest settlement for *Teredo navalis* occurred September through November, and in August and September for *Bankia gouldi*. The 1978 settlement pattern for *T. bartschi* is of particular interest. In 1976 and 1977, most *T. bartschi* settlement occurred during September and October after that of *Bankia gouldi*. In 1978, *T. bartschi* settlement occurred from July through October with the greatest number settling in August and September. This is further indication that *Teredo bartschi* are preferential settlers, and it is suggested that the absence of large numbers of *Bankia gouldi* in Oyster Creek makes a longer settling season possible for *Teredo bartschi*. No *Teredo furcifera* were observed so that no settlement pattern could be established.

There has been a significant ($\alpha = 0.05$) drop in settlement in short-term panels since 1975 which is reflected by the corresponding decline in attack in the long-term panels. Settlement at Station 1 is well beyond any plant influence so that the settlement was not due to any thermal effects of the power plant. Since the attack at Station 1 is almost exclusively *Teredo navalis*, it is assumed that the teredinid settlement on the short-term panels also is *T. navalis*.

The settlement on short-term panels in the rest of Barnegat Bay in 1978 (total of 19 teredinids) was restricted to Stations 10A and 11 through 14, and occurred in August and September. All but two teredinids were identified as *Bankia gouldi*. The remaining two, too small for identification, were found in August at Stations 12 and 14 and probably also were *B. gouldi*, as subsequent settlement in September at Stations 13 and 14 were *Bankia*. The largest settlement (7) took place in September at Station 14 which is beyond the influence of the generating plant. Thus it would appear that the generating plant did not affect the distribution of *Bankia gouldi*.

The amount of settlement in short-term panels from Oyster Creek Stations 5, 6, and 7 showed an increase in numbers in 1978 due to the abundance of *Teredo bartschi*. Richards et al. (1978) observed that *T. bartschi* successfully settled at water temperatures of 18.6 C so that continued restriction of this species in Oyster Creek is an indication of no dispersal into the bay. Settlement was present in short-term panels removed in October but the generating plant was not operating from September 16 to December 8 so that there were no plant effects on settlement for that period.

Over one hundred years ago Quatrefages (1849) proposed the theory that most shipworms in the wood die during the winter, and the few surviving specimens reproduce the following summer. Since larviperous shipworms may produce more than 20,000 to 50,000 larvae per individual (Nair and Saraswathy, 1971), only a few survivors are needed to repopulate or reinfest a given area. Few *Teredo bartschi* were found in panels from Oyster Creek in 1976 but the numbers greatly increased in 1977 and 1978. However, there is no evidence of *Teredo bartschi* dispersal beyond Oyster Creek. 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. *Teredo bartschi* are ready to settle within 72 hours (Lane et al., 1954) so that any suitable, available wood is susceptible. Since all long-term panels are exposed only six months, and the settlement data show no overlap of breeding seasons, the source of *T. bartschi* must be from infested wood near the panel locations.

The minimum salinity range for *Teredo bartschi* is unknown, but since the salinity in Oyster Creek was less than at stations south of Oyster Creek and in Forked River, but significantly greater ($\alpha = 0.05$) than at Stations 13 through 16, also north of Oyster Creek, salinity does not appear to affect its distribution. As previously mentioned, Richards et al. (1978) reported that *Teredo bartschi* settle and successfully penetrate wood at water temperatures as low as 18.6 C. Settlement of *T. bartschi* in Oyster Creek was heavy in August and September, 1978 when water temperatures ranged from 25.8 - 30.5 C. During that same period water temperatures were 24 - 26 C at Station 4, and 22 - 28 C at the other Barnegat Bay stations but there was no evidence of *Teredo bartschi* settlement, indicating that the water temperatures in Oyster Creek did not affect the dispersal of this species. However, since it has been established that *T. bartschi* can settle at temperatures as low as 18.6 C, and that the local population has increased in the creek, the possibility of future dispersal beyond the mouth of Oyster Creek should be considered.

The settlement data for 1978 indicate that *Teredo bartschi* began to reproduce and settle in June and continued through October, with the greatest settlement occurring in the August and September short-term panels. *Bankia gouldi* settle from June through August with the greatest amount occurring in July. The largest settlement of *Teredo navalis* is during September to November.

The results obtained from exposure panels submerged during three and one-half teredinid seasons show an overall decline in marine borer attack in Barnegat Bay (Figure A-5). The decline is particularly apparent at Station 4, Waretown, which is in the plume area south of Oyster Creek, and north at Station 12, Stouts Creek, which is not in the thermal plume. The percent destruction at Station 4 was less than ten percent in long-term panels from 1977 and in the first part of the 1978 season in contrast to 90 percent in 1975 and 20 percent in 1976. At Station 12 the percent destruction declined from 95 percent in 1975 to five percent in 1978. This suggests that the thermal plume has no affect on the marine borer population at these locations.

In 1975 very heavy attack occurred at the other panel locations outside the plume. It is believed that this attack resulted from natural events (Richards and Belmore, 1975) and much of the decline in the following seasons is attributed to the winters of 1976 and 1977, slow recovery of survivors, and possible parasitic effects. Reference to Figures A-7 through A-11 show that there was no relationship between the percent destruction to the long-term panels and any of the water quality parameters. The marine borer attack increased at locations in the northwestern part of the bay in 1977 but was not as severe as in 1975.

The attack pattern was somewhat different in Oyster Creek. The demolition of the marinas and removal of trash wood in 1976 effectively diminished the possibility of Oyster Creek becoming a breeding area for *Bankia gouldi*. However, the attack in the panels from Stations 5, 6, and 7 increased in 1977 and 1978 due to the abundance of *Teredo bartschi*.

It is not possible at this time to determine if the thermal discharge affects Station 10A, immediately north of the mouth of Oyster Creek since this station was not established until Spring of 1978.

Figure A-6 shows that the amount of destruction to the panels was significantly ($\alpha = 0.05$) greater at Station 1. The destruction of the panels at Station 11 was less than at Station 1 but not significantly different from Stations 5 and 6 which are in the thermal discharge, and Stations 13 and 14 which are beyond the influence of the thermal discharge. Since the attack at Stations 5 and 6 is caused by *Teredo bartschi* and that at Station 11 by *Bankia gouldi*, it is suggested that the infrequent recirculation of water from Oyster Creek to Forked River (Woodward-Envicon, 1974) is not transporting *Bankia gouldi* from Oyster Creek. Richards et al. (1978) theorized that since the seawater drawn into Forked River comes from Barnegat Bay and the normal water flow in upper Barnegat Bay is from north to south, locations north of Forked River may be a source of teredinid infestation at Station 11. The above data for 1978 supports this theory.

There was no significant difference ($\alpha = 0.05$) in the destruction of the panels from Station 12, the control station, and the remaining stations.

The result of a two-factor analysis of variance showed that no station-month interactions were present ($\alpha = 0.903$) so that station means may be directly compared. The results show a consistent decrease in attack since 1975 (Table A-25) at all stations except Station 7.

Using the seasonal mean percent attack for 1975-1977 and the first half of the 1978 season the stations were ranked in descending order (Table A-27). Stations 1, 13, and 14 which are beyond influence of the thermal discharge were ranked in the upper third for all four seasons. Station 1, which had ranked number 1 for 1975-77 was ranked second to Station 7 for the first half of the 1978 season. This change in rank is due to the increase in *Teredo bartschi* population at Station 7.

The average values of the water parameters were calculated for the six-month exposure of the long-term panels at all the stations and no relationship with the percent destruction could be seen (Figures A-7 through A-10).

The species of teredinids, abundance of settlement, availability of substrate, and environmental parameters influence the growth (length) of the individual specimens. Data for the 1978 season (Table A-29) from Stations 1 and 14 show that the growth rate of *Teredo navalis* to be similar to that reported by Clapp (1925) while growth of *Bankia gouldi* was less than that reported by Turner (1973). This growth was not affected by the generating station operation as both locations are beyond influence of the thermal discharge. Nagabushanam (1961) observed that *Teredo furcifera* (*Teredo furcillatus* Miller) grew 29 millimeters during the month of highest temperature, 30.9 C. We could not confirm this as no *T. furcifera* were found. However, data for *Teredo bartschi* indicate a similarity. During the 1977 and 1978 seasons, growth of *Teredo bartschi* in Oyster Creek also was greatest during the period of highest water temperature. Specimens in the thermal discharge grew 40 millimeters in the September, 1977 short-term (one month) panel, and 35 millimeters in the July, 1978 short-term panel at temperatures of 28 C and 29 C.

However, abundance rather than size has caused the greatest amount of destruction to the panels in Oyster Creek.

Gonadal cycles of the teredine borers generally correlated, as expected, with water temperature. Loosanoff (1942) for example, showed that for spawning of some bivalves to take place, a critical water temperature must be reached. This temperature can vary with species and with locale, a given species being adapted to its normal temperature regime depending on where it is located. Thus, it could be expected that gonadal development in shipworms from areas influenced by the thermal plume would be earlier than in those specimens from areas where normal spring and summer warming took place.

At Station 7, in the discharge canal, a specimen of *Bankia gouldi* was found with a partially spent gonad in December, 1975, and a ripe specimen was found in May, 1978 from a special panel (see Appendix C) submerged in May, 1977. All *Bankia* at that station were spawned out by October, however.

Some *B. gouldi* were found at Stations 8 and 9 with partially spent to spent gonads as late as January and February, but the number of *B. gouldi* recovered from panels exposed at those stations after 1976 declined sharply (Appendix A), and it is highly unlikely that many larvae were produced out of season, nor is there any reason to believe that they could survive in the colder ambient waters once they developed.

Gonadal development in *B. gouldi* at other stations around Barnegat Bay followed normal seasonal patterns, and there is no evidence that prolonged breeding seasons occurred at any site except in the discharge area.

Patterns of gonad development in the various species of *Teredo* were not as well-defined seasonally as in *Bankia gouldi*, although there were no indications from gonadal tissues examined that the reproductive cycles of the *Teredo* species were influenced by the thermal plume, except perhaps within the discharge canal.

In general, it appears that gonadal development in *Teredo* takes place during the warmer months, but is quite rapid. A single individual can reach sexual maturity within a month, as has been shown to be the case several times in specimens recovered from the one-month panels. If a larva is released in August and sets in September, and gonad development begins, the specimen can be nearly ripe in October. The water temperature, by that time, might have already cooled down below the critical spawning temperature, and the gonad remains in the nearly ripe phase. Cytolysis of the gametes begins to take place, but may slow down as the water cools in November and December. This would account for the large number of late active stages found in species of *Teredo* recovered in the fall and winter (Appendix C).

At Station 1, in Barnegat Inlet, for example, ripe gonads were found in February of 1976 and 1978, and partially spent gonads were found as early as May. At Station 17, also on the eastern side of the Bay, partially spent gonads were found in January, 1976, and ripe gonads were found in December of 1976 and 1977. These stages could have been reached in late summer and early fall, and the shipworms stayed that way as the water temperatures cooled. There is no evidence from settling patterns (see Appendix A) that larvae were actually released and settling during the colder months, although settling does occur into November in the Inlet area.

During the histological examinations for gonad conditions, a number of specimens were found to contain parasites of one sort or another depending upon the species of shipworm being examined. The three species of *Teredo* collected during the program often contained one or more life cycle stages of the haplosporidian (Protozoa) parasite *Minchinia*, and specimens of *Bankia gouldi* were often found to contain cysts formed by the encapsulation of another protozoan, *Boveria teredinidi*, which had invaded the shipworm's tissues. Descriptions of the parasites and details of their incidence are provided in Appendix C.

Because of the amount of tissue damage apparently caused by the parasites, the question of whether the parasites could be affecting the abundance and distribution of the shipworms arose. For example, could the parasites be responsible for wide-scale mortalities of shipworms, especially at those sites where the parasites were most prevalent?

Because of the percentages of infection shown in Appendix C refer only to those specimens examined for gonad analysis, it was not possible to correlate them with the numbers of shipworms removed from panels at the various stations as shown in Appendix A. Also, some of the infection figures were derived from special panels placed on exposure only to monitor gonad development and the incidence of disease (see Appendix C for a discussion of the special panels), and specimens were received from them during periods when there were no shipworms in the regular panels. However, general comparisons of these data can be made, and Table 1 gives the numbers of *Teredo navalis* removed from panels at the three stations where that species is most prevalent, Stations 1, 11, and 17, and compares those figures with the *Minchinia* infection ratios in the specimens removed for gonad analysis at the same stations.

At Station 1, the number of *Teredo* removed was relatively light during the 1975-1976 season but increased during the 1976-1977 and 1977-1978 seasons. So far in 1978, it does not appear as if there will be a significant decline in the abundance of *Teredo* at Station 1. During the study, infections were heaviest in late 1976. They increased sharply, however, during October and November, 1978. It would not appear, therefore, that *Minchinia* infections at Station 1 have influenced the abundance of *Teredo* at that station.

Teredo abundance has declined considerably at Stations 11 and 17 since 1975, and *Minchinia* incidence was high in 1976 and, on a percentage basis, 1977. It is possible, therefore, that while *Minchinia* infection is probably not the sole reason for the decline, it could be contributing substantially to keeping *Teredo* abundance down at those stations.

Table 2 shows similar comparisons with the abundance of *Bankia gouldi* at Stations 6, 11, 13, and 14 and the presence of cysts of the ciliated protozoan, *Boveria teredinidi*. It can be seen that the abundance of *B. gouldi* has generally declined since 1975 at the four stations used in the comparison, and throughout the area in general (Appendix A). The incidence of encystment has also declined over that same period. From the available data, it cannot be said that there is a direct cause and effect. The encystment of *Boveria* is unique thus far to Barnegat Bay (see Appendix C), and the reasons for the phenomenon are not clear. It is possible that a general decline in water quality has occurred through-

TABLE 1 . COMPARISON OF NUMBERS OF *Teredo navalis* FOUND IN EXPOSURE PANELS WITH THE INCIDENCE OF *Minchinia* INFECTIONS IN SPECIMENS EXAMINED FOR GONAD ANALYSIS AT THREE STATIONS IN BARNEGAT BAY

		Station 1		Station 11		Station 17	
		Number In Panel	Infection Ratio	Number In Panel	Infection Ratio	Number In Panel	Infection Ratio
1975	Aug						
	Sep						1/3
	Oct					87	3/3
	Nov	3				90	2/2
	Dec	17		100			4/4
1976	Jan			156	1/2	103	3/3
	Feb	60	0/2	3		33	1/4
	Mar	400	0/2				
	Apr						
	May						
	Jun						
	Jul						
	Aug	37	0/3				
	Sep	423	2/8	23	0/8		
	Oct	230	3/7	13	6/6	8	3/4
	Nov	400	5/5	22	3/5	17	2/5
	Dec	400	2/6	11	3/5	22	4/5
1977	Jan	300		11		4	
	Feb	400		4	1/7	2	
	Mar	1	1/11			4	1/2
	Apr						
	May		0/19				
	Jun		1/6				
	Jul						
	Aug						
	Sep	160	0/21				
	Oct	300	0/13	1	1/1		
	Nov	390	4/6	6	1/1		
	Dec	380	0/6	1	1/1		2/2
1978	Jan	400		2		4	3/3
	Feb	375	3/10			1	2/2
	Mar	220	0/8				0/1
	Apr						
	May		11/20				
	Jun		2/9				2/2
	Jul			1			
	Aug	1	0/1				
	Sep	115	0/3	1		1	0/2
	Oct	329	9/10				0/1
	Nov	430	13/15	2		4	4/5

TABLE 2 . COMPARISON OF NUMBERS OF *Bankia gouldi* FOUND IN EXPOSURE PANELS WITH THE INCIDENCE OF *Boveria* ENCYSTMENT IN SPECIMENS EXAMINED FOR GONAD ANALYSIS AT FOUR STATIONS IN BARNEGAT BAY

		Station 6		Station 11		Station 13		Station 14	
		Number In Panel	Infection Ratio	Number In Panel	Infection Ratio	Number In Panel	Infection Ratio	Number In Panel	Infection Ratio
1975	Aug	42	0/6	387	2/3	100	0/5	335	0/10
	Sep	268	0/1	323	2/4	340	0/6	400	1/1
	Oct	135		374	3/4	399	3/3	400	
	Nov	100	0/1	251	2/3	400	0/2	400	3/4
	Dec	18	4/6	220	1/2	399	3/3	400	1/2
1976	Jan	160	1/3	240	1/2	64	3/3	400	1/1
	Feb	2	1/1	64	0/4			8	0/3
	Mar								
	Apr								
	May								
	Jun								
	Jul			4				2	
	Aug			6		24	0/5	7	0/3
	Sep	2	0/1	23		31	4/6	11	2/5
	Oct	1		11	0/3	26	5/6	19	
	Nov			33	0/2	20	6/6	17	1/6
	Dec	1		31	0/3	21	5/6	10	2/6
1977	Jan	1		42		5		2	
	Feb	1		31	0/8	2	3/4		
	Mar		0/1						1/2
	Apr								
	May								
	Jun								
	Jul								
	Aug			15	0/6	5		1	0/2
	Sep			82	0/8	13	0/7	5	0/6
	Oct			59	2/6	10	0/6	9	0/6
	Nov			38	0/13	8		5	1/5
	Dec	1	0/1	25	0/6	18	0/6	9	0/6

TABLE 2 . Continued

		Station 6		Station 11		Station 13		Station 14	
		Number In Panel	Infection Ratio	Number In Panel	Infection Ratio	Number In Panel	Infection Ratio	Number In Panel	Infection Ratio
1978	Jan			34	0/6	4	2/4	6	0/4
	Feb			1				1	0/1
	Mar								
	Apr								
	May						0/4		0/1
	Jun				1/2		0/1		
	Jul					2			
	Aug			2	0/5	1	0/3		
	Sep			14		7		9	0/2
	Oct			30	0/10	6		9	
	Nov			10	0/8	8	0/7	13	0/11

out Barnegat Bay, although that is not evident from the water quality parameters collected as part of this study (Appendix B). The inability of *B. gouldi* to resist invasion by *Boveria* could be the result of a weakening of the shipworm by the poor quality of the water, which could also be a contributing factor in the decline in abundance of the shipworm. At any rate, the incidence of encystment has become very low, and has been evident only at Stations 10A, 10B, 12, 13, and 14 during 1978, but at a low level.

Temperatures recorded at each panel removal period show the water temperature in Oyster Creek was within the teredinid breeding limits (13 C - 30 C) in March, 1977 and by April, 1976 and 1978. This is a month earlier than at most of the other locations in Barnegat Bay. However, no seasonal teredinid attack has been present at any location until the July removal period indicating that an early teredinid breeding season has not been established anywhere in the bay.

The water temperatures were below breeding limits after October, 1976 and November, 1977 at all locations except in Oyster Creek. In 1978 water temperatures were still within breeding limits by November at Stations 1, 4, and 10 through 17, and in Oyster Creek. Settlement has occurred each year in short-term panels removed in November from the Inlet which is not affected by the generating plant. Historically, teredinid settlement has been recorded at this time from this location (Richards and Belmore, 1975), and apparently this is normal at the Inlet. The only other settlement occurring in November short-term panels was in the thermal discharge at Oyster Creek Station 6 (1975, 9 specimens) and Station 7 (1977, 3 specimens). This amount of settlement in the short-term panels indicates that the extended breeding season in Oyster Creek is minimal and no extended breeding season has been observed in other areas of Barnegat Bay.

During periods of time when the generating plant is not operating, water temperatures in Oyster Creek are ambient and comparable to the rest of Barnegat Bay. Figure B-2 shows that the overall water temperature patterns for Oyster Creek in 1975-1978 are similar for each season but the plant down-times vary. Each season the water temperature in the Creek was below the teredinid breeding range from December through March during which time winter-kills could occur.

In 1976 and 1977 the plant down-times were during the summer months when ambient temperatures were in the optimum breeding range so that there was no effect from the generating plant. The water temperatures were not as high from June through August, 1977 and 1978 as during the same period in 1975 and 1976 although settlement of *Teredo bartschi* was greater. The generating plant was not operating after September 16, 1978 and the water temperature dropped to ambient. That this had a thermal effect on *Teredo bartschi* was apparent by the decline in settlement from >1000 in September to a total of 21 in October. A similar decline in temperature and *Teredo bartschi* population occurred in 1977 when the plant was in operation. Similar water temperature patterns occurred at Stations 1, 12, and 14 which had heavy attack by *Teredo navalis* (Station 1) and *Bankia gouldi* (Stations 12 and 14). These stations are beyond influence of the heated discharge so that they were not affected by the operation of the generating plant.

The distribution of *Limnoria* in Barnegat Bay is restricted to the Inlet and locations in the bay south of Oyster Creek. *Limnoria tripunctata* was the only species identified. April was the only month in the year when all panels were free of *Limnoria* and very little migration takes place from October to May. There has been a light but steady increase in attack at Station 1, and a noticeable increase at Station 2. The heaviest attack occurred at Holiday Harbor 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 for support of 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 found in the Barnegat Bay system during the study period of 1975 through 1978, although only three were observed in 1977 and 1978. *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 species *Teredo bartschi* was found only in Oyster Creek. The subtropical species *Teredo furcifera* was not found at any exposure panel station during the 1977 or 1978 seasons, and this species does not appear to be established in Barnegat Bay.

Studies to date indicate an increase in abundance of *Teredo bartschi* reflecting a positive thermal effect in Oyster Creek but do not indicate any dispersal effects into Barnegat Bay.

Settlement patterns for the teredinid species in Barnegat Bay in 1978 were similar to those of the preceding seasons. The greatest amount of settlement of *Bankia gouldi* occurs in July, of *Teredo bartschi* in August and September, and *Teredo navalis* in September to November.

Data from exposure panels submerged during three and one-half teredinid seasons show an overall decline in marine borer attack in Barnegat Bay. The decline is particularly apparent at Station 4, Waretown, which is in the plume area south of Oyster Creek, and north at Station 12, Stouts Creek, which is not in the thermal plume. The thermal plume does not affect the marine borer population at these locations.

The limited amount of recirculation of water from Oyster Creek to Forked River suggests that locations north of Forked River may be a source of teredinid infestation at Station 11. There is no evidence that *Bankia gouldi* are transported from Oyster Creek.

Gonadal development in *Bankia gouldi* at stations around Barnegat Bay followed normal seasonal patterns and there is no evidence that prolonged breeding seasons occurred at any site except in the discharge area.

Patterns of gonad development in the various species of *Teredo* were not as well-defined seasonally, although there were no indications from gonadal tissues examined that the reproductive cycles of the *Teredo* species were influenced by the thermal plume except within the discharge canal.

Two protozoan parasites have been found in the teredinids in Barnegat Bay. Incidence of the haplosporidian *Minchinia* was high in 1976 as the *Teredo* abundance declined. It is possible that the protozoan is contributing substantially to keeping *Teredo* abundance down. Cysts of the protozoan *Boveria teredinidi* have been found in *Bankia gouldi* which may have been weakened enough by unknown factors to allow invasion by the protozoan.

Comparisons of water temperatures and seasonal teredinid attack indicate that no extended teredinid breeding season exists in the bay. The minimal amount of November settlement in the thermal discharge indicates that the extended breeding season in Oyster Creek is not extensive.

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.

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APPENDIX A

APPENDIX A

EXPOSURE PANELS

Introduction

Untreated wood exposure panels traditionally have been used for marine borer studies since the National Research Council's marine borer investigation in 1922 (Atwood, 1924). Continuous operation of long-term and short-term panels provides data on the incidence and distribution of individual species, their survival and growth, breeding seasons, amount of destruction to the substrate, and demonstrates seasonal variations.

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 12-month period December, 1977 through November, 1978 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 twenty 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.

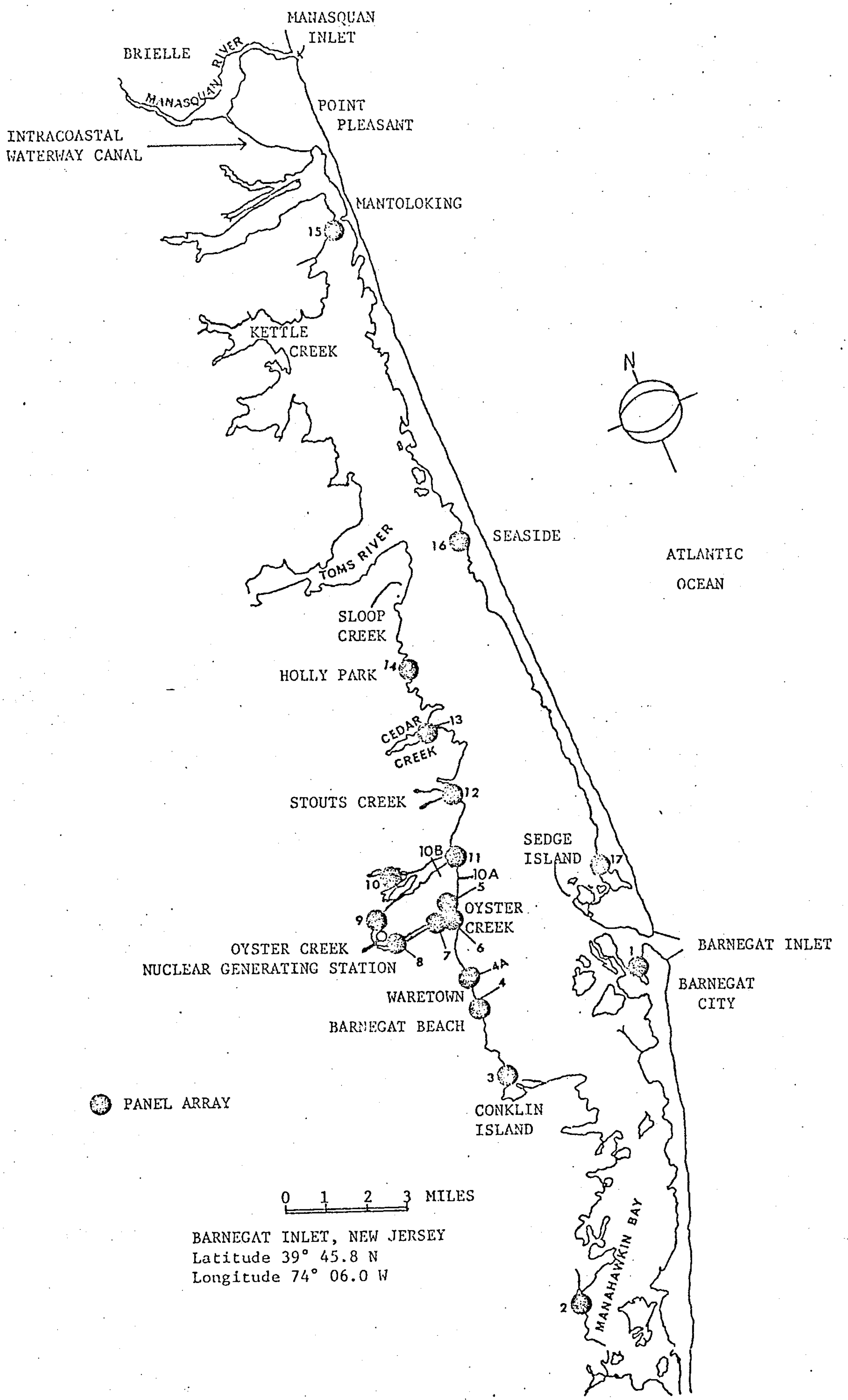


FIGURE A-1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHICAL LOCATIONS OF EXPOSURE PANELS

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	Bulkhead	WC 13,14	Lat. 39° 40'N Long. 74° 13'W
3.	Iggie's Marina East Bay Ave. Barnegat (Conklin Island)	Bulkhead	WC 16,17,18,19	Lat. 39° 45'N Long. 74° 12.5'W
4.	Liberty Harbor Marina Washington Ave. Waretown	Bulkhead	WC 21 R. Turner Rutgers U.	Lat. 39° 47'N Long. 74° 11'W
4-A*.	Holiday Harbor Marina Lighthouse Drive Waretown	Bulkhead	WC 21 R. Turner Rutgers U.	Lat. 39° 48'N Long. 74° 11'N
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	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
10A*.	Private Dock 1-16 Aquarius Ct. Forked River	Under Dock		Lat. 39° 49'N Long. 74° 10'W
10B*.	Private Dock 1307 Beach Blvd. Forked River	Under Dock		Lat. 39° 49.4'N Long. 74° 10.1'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	End of Pier	WC 46	Lat. 39° 52'N Long. 74° 09'W

TABLE A-1. (continued)

Site No.	Site	Structure to be used for Suspension of Rack	Nearest Previous Data Stations	Approximate Latitude and Longitude
14.	Dicks Landing Island Drive Bayville (Holly Park)	Pier	WC 49 R. Turner Nelson	Lat. 39° 54'W Long. 74° 08.1'W
15.	Winter Yacht Basin Inc. Rt. 528 Mantoloking Bridge W. Mantoloking	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

*Site 4-A installed April, 1977
Sites 10 A, 10 B installed April, 1978.

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 panels 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 and number of marine borers 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; Bartsch, 1908; Purushotham, et al., 1971; Clapp, 1923, 1925; 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.

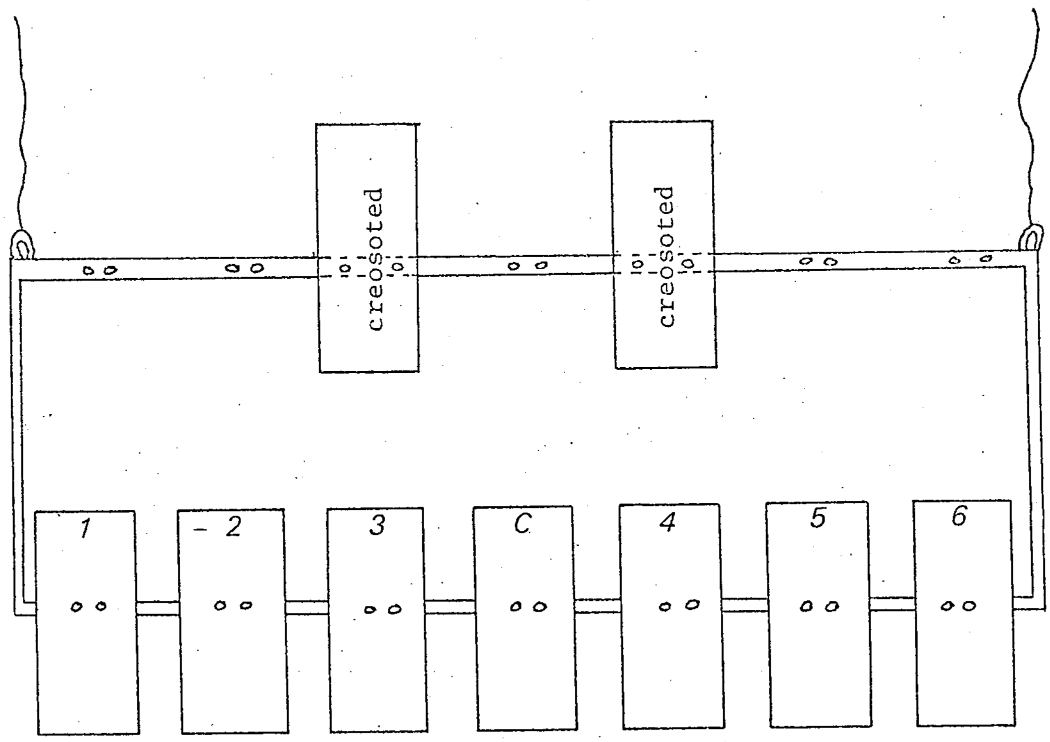


FIGURE A-2. EXPOSURE PANEL ARRAY

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

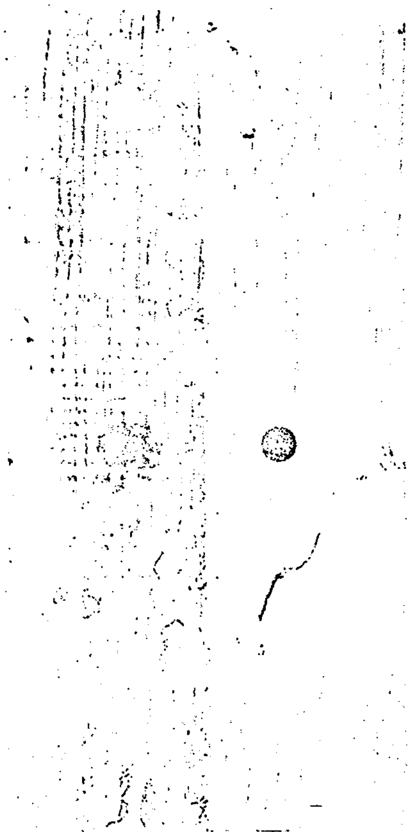
* Percent filled depends upon size of specimens present in panels
** Arbitrary number assigned to panels 76-100 percent filled.

Limnoria

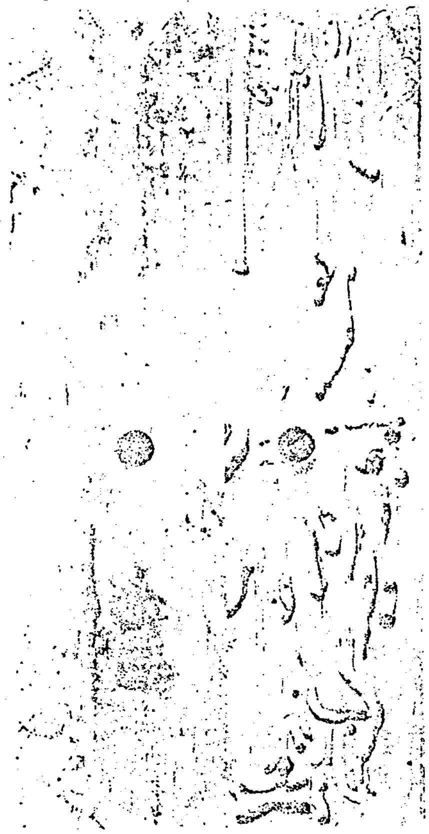
No. of tunnels per sq. inch	Total no. of tunnels	Attack Rating
1	1-85	Trace
10	86-850	Slight
25	851-2125	Moderate
50	2126-4250	Medium heavy
75	4251-6375	Heavy
100*	6375-8500	Very heavy

* Ratings of approximately 100 per square inches indicate the maximum density beyond which it is impossible to count

TEREDINIDAE

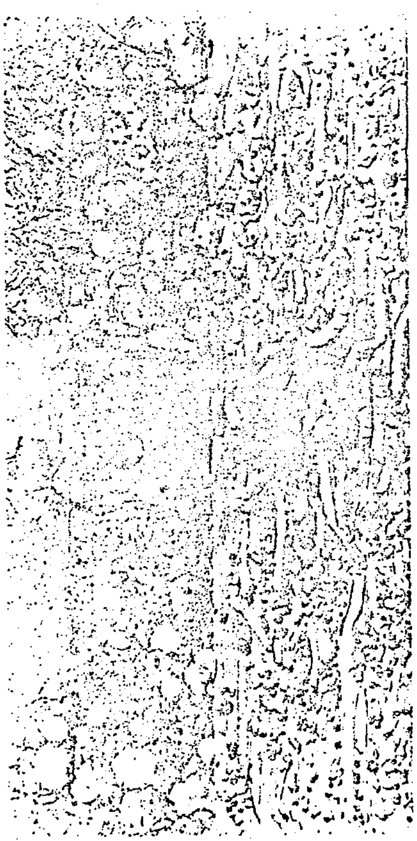


Trace



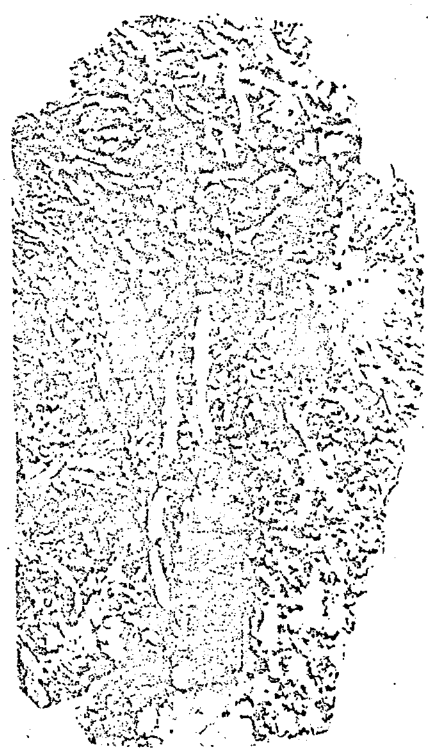
Slight

Moderate



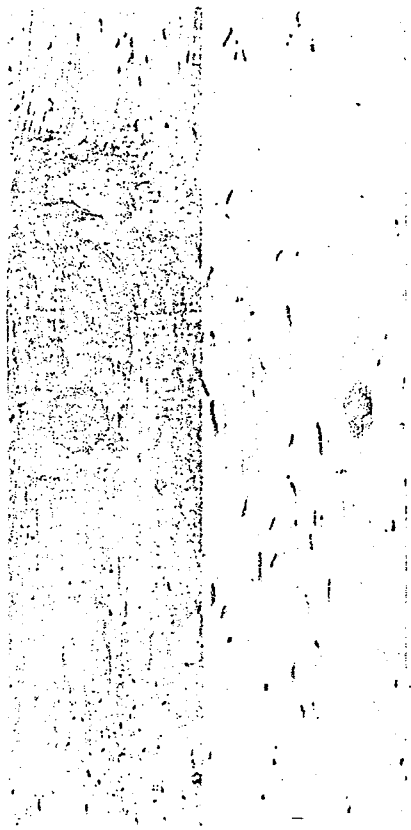
Moderately Heavy

Heavy

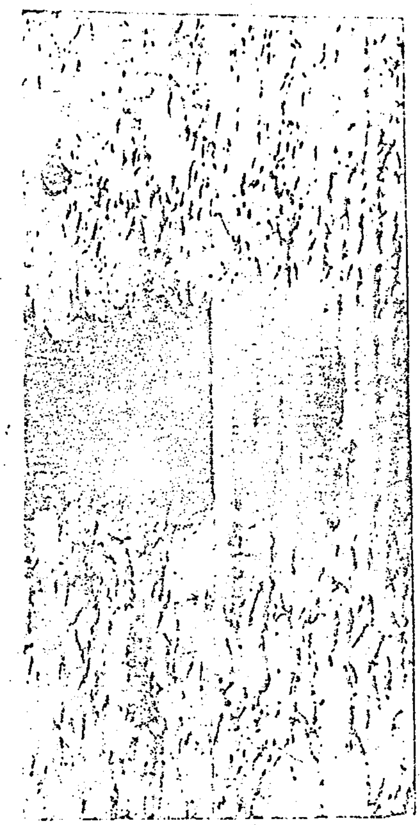


Very Heavy

LIMNORIDAE



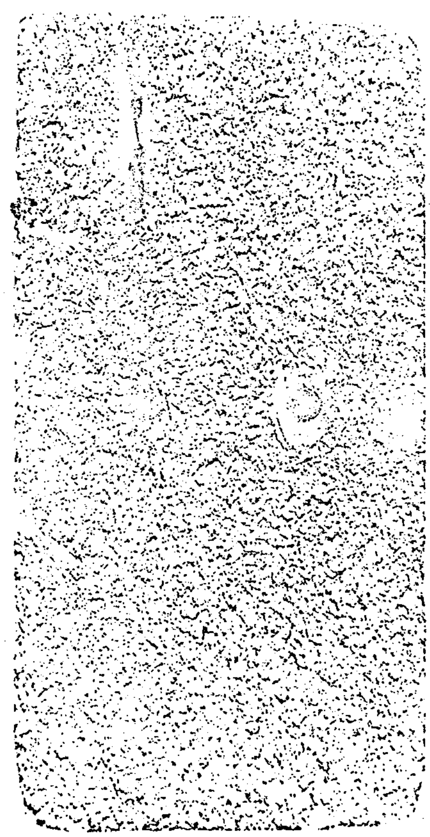
Trace



Slight

Moderate

Moderately Heavy



Heavy

Very Heavy

One instance of vandalism occurred in the summer of 1978. The lines had been cut and the entire panel array at Station 13, Cedar Creek was found on the shore at the June panel exchange period. The array was rehung from the same dock at a different location. It was estimated that the panels were out of the water for 2-3 days, but there was no apparent loss of specimens.

Ice conditions were severe in January, February and March but all exposure panels were successfully retrieved and replaced.

Additional exposure panel arrays were submerged April 5, 1978 at two new locations between Oyster Creek and Forked River: Station 10A near the mouth of the Christmas Tree Lagoons; Station 10B near the Beach Boulevard Bridge (Table A-1 , Figure A-1).

The long-term panel scheduled for removal in January, 1978 from Station 1 had been removed 3 months previously due to severe *Teredo navalis* attack. The replacement panel was submerged in January, 1978, thus maintaining the six-month cycle.

A total of four creosoted panels were lost due to ice or mechanical failure and replaced as follows:

Station 16	-	one panel, March 1, 1978
Station 3	-	one panel, April 4, 1978
Station 7	-	one panel, May 31, 1978
Station 2	-	one panel, July 12, 1978

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 (Neter et al., 1974). 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 the difference between the means of two levels of factor A, we use

$$D = \bar{X}_{i.} - \bar{X}_{i.}$$

$$s^2(D) - \frac{2\ MSE}{bn} = \text{variance of } D$$

and

$$T = \frac{1}{2}\ q\ (1 - \alpha;\ a,\ (n-1)\ ab) = \text{Tukey statistic}$$

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 levels of factors A and B, and

α is the significance level for the test.

This leads to the confidence intervals

$$D\text{-}Ts(D) \leq \mu_{i.} - \mu_{i.} \leq D + Ts\ (D)$$

with an 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 (Hollander, et. al., 1973). The statistic is given

by $< \; = \dfrac{12 \sum_{i=1}^{n} [R_i - (n+1)/2]\ [S_i - (n+1)/2]}{n\ (n^2 - 1)}$

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

$$r \cdot \frac{n-2}{1-r^2} \quad 1/2$$

with the Student's t distribution with n-2 degrees of freedom.

Kendall Rank Correlation Coefficient. Kendall's coefficient is similar to the Spearman coefficient except in the application (Hollander, et. al., 1973). If the data to be analyzed have 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 = number of pairs (X_i, Y_i)

$$\xi(X_i, X_j, Y_i, Y_j) = \{ \begin{matrix} 1 \text{ if} \\ -1 \text{ if} \end{matrix} \ (X_i - X_j)\ (Y_i - Y_j) \begin{matrix} >0 \\ <0 \end{matrix}$$

The significance of tau is determined by comparison with a normal distribution with a standard deviation of $[\ (4n=10)/(9n^2-9n)].^{1/2}$

Results

Teredinid summary data for the 12-month period December, 1977 through November, 1978 are presented in Tables A-3 through A-14 . Since the inception of the program in 1975, the data show the absence of teredinids at all stations in panels removed in May and June. Due to the use of a 6-month panel rotation cycle, it is possible to establish July through April as the months in which each season's borer activity occurs.

Teredinid Distribution and Dominance

Three species of teredinids, *Bankia gouldi, Teredo navalis,* and *Teredo bartschi* were present in wood exposure panels removed from 20 locations during the period December, 1977 through November, 1978. A fourth species, *Teredo furcifera,* present in panels removed in 1975 and 1976 (Richards et al., 1976) was not found in 1977-78 (Tables A-15 through A-18).

TABLE A-3. SUMMARY DATA FOR INCIDENCE OF TEREDINIDAE IN PANELS REMOVED DECEMBER 6-7, 1977

Site	Panel	No. of Specimens±	Percent Filled	Size Range in mm	Species Identification
1	p	380	98	40-140	*T. navalis*
	c	0			
3	p	1	<1	1	
	c	0			
4A	p	1	8	260	1 *B. gouldi*
	c	0			
5	p	4	35	105-430	4 *B. gouldi*
	c	0			
6	p	1	7	230	1 *B. gouldi*
	c	0			
7	p	207	95	4-280	130 *T. bartschi*, 1 *B. gouldi*
	c	0			
8	p	1	8	270	1 *B. gouldi*
	c	0			
9	p	1	2	95	1 *T. navalis*
	c	0			
10	p	2	15	240-250	2 *B. gouldi*
	c	0			
11	p	26	80	75-195	1 *T. navalis*, 25 *B. gouldi*
	c	0			
12	p	7	40	140-230	7 *B. gouldi*
	c	0			
13	p	18	90	120-260	18 *B. gouldi*
	c	0			
14	p	11	60	2-300	9 *B. gouldi*
	c	0			

Sites 2, 4, 15, 16, 17, no Teredinidae present.
p = long-term panel submerged June 6-7, 1977.
c = short-term panel submerged November 8-9, 1977.
± Species not identified - too small; pallets missing or broken.

TABLE A-4. SUMMARY DATA FOR INCIDENCE OF TEREDINIDAE IN PANELS REMOVED JANUARY 4, 1978

Site	Panel	No. of Specs.±	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	p*	400	100	<1-55	*T. navalis*	1 with larvae
	c	0				
2	p	3	10	110-155	3 *T. navalis*	
	c	0				
3	p	2	6	105-110	2 *B. gouldi*	
	c	0				
4	p	1	2	95	1 *B. gouldi*	
	c	0				
4A	p	1	4	170	1 *B. gouldi*	
	c	0				
5	p	1	7	260	1 *B. gouldi*	
	c	0				
7	p	192	75	7-210	160 *T. bartschi*, 2 *B gouldi*	umbonate larvae
	c	0				
8	p	2	10	160-240	2 *B. gouldi*	
	c	0				
9	p	2	12	190-270	2 *B. gouldi*	
	c	0				
10	p	1	2	90	1 *B. gouldi*	dead
	c	0				
11	p	36	75	70-190	34 *B. gouldi*, 2 *T. navalis*	
	c	0				
12	p	5	25	110-225	5 *B. gouldi*	
	c	0				
13	p	4	20	150-220	4 *B. gouldi*	
	c	0				

TABLE A-4. Continued.

Site	Panel	No. of Specs.$^{\pm}$	Percent Filled	Size Range in mm.	Species Identification	Remarks
14	p	6	25	150-200	6 *B. gouldi*	
	c	0				
17	p	5	5	20-100	4 *T. navalis*	
	c	0				

Sites 6, 15, 16, no Teredinidae present.
p = long-term panels submerged July 12-13, 1977.
c = short-term panels submerged December 6-7, 1977.
* = panel removed October 12, 1977 due to severe teredinid attack.
Species not identified - too small; pallets missing or broken.

TABLE A-5. SUMMARY DATA FOR INCIDENCE OF TEREDINIDAE IN PANELS REMOVED FEBRUARY 1, 1978

Site	Panel	No. of Specimens±	Percent Filled	Size Range in mm	Species Identification
1	p	375	99	12-100	*T. navalis*
	c	0			
7	p	240	30	5-75	200 *T. bartschi*
	c	0			
11	p	4	<1	1-9	1 *B. gouldi*
	c	0			
14	p	1	2	100	1 *B. gouldi*
	c	0			
16	p	1	1	63	1 *B. gouldi*
	c	0			
17	p	1	2	80	1 *T. navalis*
	c	0			

Sites 2-6, 8-10, 12, 13, 15, no Teredinidae present.
p = long-term panels submerged August 9-11, 1977.
c = short-term panels submerged January 4, 1978.
Species not identified - too small; pallets missing or broken.

TABLE A-6. SUMMARY DATA FOR INCIDENCE OF TEREDINIDAE IN PANELS REMOVED MARCH 1-2, 1978

Site	Panel	No. of Specs.±	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	p	320	25	1-42	220 *T. navalis*, 100 *Teredo* spp.	
	c	0				
5	p	1	<1	24	1 *T. bartschi*	Dead
	c	0				
6	p	2	1	27-45	2 *T. bartschi*	1 dead, 1 live
	c	0				
7	p	94	20	4-39	81 *T. bartschi*	Dead
	c	0				
11	p	2	<1	1-2		
	c	0				

Sites 2-4, 8-10, and 12-17, no Teredinidae present.
p = long-term panels submerged September 13-14, 1977.
c = short-term panels submerged February 1, 1978.
Species not identified - too small; pallets missing or broken.

TABLE A-7. SUMMARY DATA FOR INCIDENCE OF TEREDINIDAE IN PANELS REMOVED APRIL 4-5, 1978

Site	Panel	No. of Specs.±	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	p	165	1	<1-2		
	c	0				
6	p	1	<1	6	1 *Teredo* spp.	
	c	0				
7	p	14	<1	<1-18	2 *T. navalis*	
	c	0				

Sites 2-5 and 8-17, no Teredinidae present.
p = long-term panels submerged October 11-12, 1977.
c = short-term panels submerged March 1-2, 1978.
±Species not identified - too small; pallets missing or broken.

TABLE A-8. SUMMARY DATA FOR INCIDENCE OF TEREDINIDAE IN PANELS REMOVED MAY 1-3, 1978

Site	Panel	No. of Specs.±	Percent Filled	Size Range in mm.	Species Identification	Remarks
1-17					No Teredinidae Present	

Long-term panels submerged November 8-9, 1977.
Short-term panels submerged April 4-5, 1978.

TABLE A-9. SUMMARY DATA FOR INCIDENCE OF TEREDINIDAE IN PANELS REMOVED MAY 31 THROUGH JUNE 1, 1978

Site	Panel	No. of Specs.±	Percent Filled	Size Range in mm.	Species Identification	Remarks
1-17					No Teredinidae Present	

Long-term panels submerged December 6-7, 1977.
Short-term panels submerged May 1-3, 1978.

TABLE A-10. SUMMARY DATA FOR INCIDENCE OF TEREDINIDAE IN PANELS REMOVED JULY 10-12, 1978

Site	Panel	No. of Specs. $\pm$	Percent Filled	Size Range in mm.	Species Identification	Remarks
6	p	0				
	c	1	<1	<1	–	
7	p	93	10	<1-36	71 *T. bartschi*	Dead. Several with larvae.
	c	58	3	<1-35	5 *T. bartschi*	Dead. One with larvae.
10B	p	1	<1	2	1 *B. gouldi*	
	c	0				
11	p	1	<1	13	1 *T. navalis*	
	c	0				

Sites 1-5, 8-10A, 12, 14-17, no Teredinidae present.
Site 13 - rack missing.
p = long-term panels submerged January 11, 1978.
long-term panels 10A and 10B submerged April 6, 1978.
c = short-term panels submerged June, 1978.
Species not identified - too small; pallets missing or broken.

TABLE A-11. SUMMARY DATA FOR INCIDENCE OF TEREDINIDAE IN PANELS REMOVED AUGUST 8-9, 1978

Site	Panel	No. of Specs.±	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	p	9	<1	<1-17	1 *T. navalis*	
	c	4	<1	<1-1		
5	p	12	2	<1-52	2 *T. bartschi*	1 dead. 10 embryonic.
	c	4	<1	<1-1		2 with umbonate larvae.
6	p	1	<1	9	*Teredo* spp.	
	c	1	<1	<1		
7	p	730	20	<1-77	129 *T. bartschi*, 1 *B. gouldi*	Umbonate larvae.
	c	1800	1	<1-11	2 *T. bartschi*	All but 2 embryonic.
10A	p	0				
	c	1	<1	13	1 *B. gouldi*	Submerged April, 1978.
10B	p	1	2	70	1 *B. gouldi*	Submerged April, 1978.
	c	0				
11	p	4	1	<1-48	2 *B. gouldi*	
	c	5	<1	<1-11	4 *B. gouldi*	
12	p	0				
	c	1	<1	1		
13	p	1	<1	28	1 *B. gouldi*	
13*	p	4	1	<1-35	2 *B. gouldi*	Panel submerged 7 mos.
	c	0				
14	p	1	<1	2		
	c	1	<1	1		

Sites 2-4A, 8-10, 15-17, no Teredinidae present.
p = long-term panels submerged February 1, 1978, unless otherwise noted.
c = short-term panels submerged July 10-12, 1978.
Site 13 - rack located. Panels removed for July and August.
Species not identified - too small; pallets missing or broken.
* = Submerged January 4, 1978.

TABLE A-12. SUMMARY DATA FOR INCIDENCE OF TEREDINIDAE IN PANELS REMOVED SEPTEMBER 6-7, 1978

Site	Panel	No. of Specs.±	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	p	130	25	<1-80	115 *T. navalis*	Larvae present, many with ripe gonads.
	c	330	5	<1-14	40 *T. navalis*	
2	p	1	<1	13	*Teredo* spp.	
	c	1	<1	4	*Teredo* spp.	
4	p	1	1	65	*B. gouldi*	
	c	0				
5	p	121	20	<1-100	91 *T. bartschi*	Umbonate larvae present.
	c	18	<1	<1-10	1 *T. bartschi*	
6	p	1	<1	2		
	c	2	<1	<1		
7	p	567	98	1-150	536 *T. bartschi*, 1 *B. gouldi*	Umbonate larvae present.
	c	1104	10	<1-10	4 *T. bartschi*, 150 *Teredo* spp.	
10A	p*	2	8	100-170	2 *B. gouldi*	1 with ripe gonads.
	c	0				
11	p	14	22	17-145	*B. gouldi*	
	c	0				
13	p	7	12	26-88	*B. gouldi*	
	c	4	<1	<1-3	1 *Bankia* spp.	
14	p	9	17	45-120	*B. gouldi*	
	c	7	1	<1-27	6 *B. gouldi*	
17	p	1	<1	24	1 *T. navalis*	
	c	0				

Sites 3, 4A, 8-10, 10B, 13, 12, 15, 16, no Teredinidae present.
p = long-term panel submerged March 1-2, 1978, unless otherwise noted.
c = short-term panel submerged August 8-9, 1978.
* = submerged 5 months.
± Species not identified - too small; pallets missing or broken.

TABLE A-13. SUMMARY DATA FOR INCIDENCE OF TEREDINIDAE IN PANELS REMOVED OCTOBER 2-3, 1978

Site	Panel	No. of Specs.±	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	p	364	80	<1-100	329 *T. navalis*	
	c	31	<1	<1-2		
2	p	3	15	70-185	3 *T. navalis*	
	c	0				
4	p	4	7	30-100	4 *B. gouldi*	
	c	0				
4A	p	1	1	37	1 *B. gouldi*	
	c	0				
5	p	171	25	<1-160	90 *T. bartschi*, 1 *B. gouldi*	Umbonate larvae present.
	c	53	<1	<1-1		
6	p	15	1	<1-57	1 *T. bartschi*	Umbonate larvae present.
	c	11	<1	<1-1		
7	p	360	99	<1-80	*T. bartschi*	
	c	21	<1	<1-3		
10A	p	5	25	140-200	5 *B. gouldi*	
	c	0				
10B	p	2	12	185-260	2 *B. gouldi*	
	c	0				
11	p	33	50	<1-140	30 *B. gouldi*, 1 *T. navalis*	
	c	0				
12	p	2	5	80-110	2 *B. gouldi*	
	c	0				
13	p	6	14	16-150	*B. gouldi*	
	c	0				
14	p	9	25	75-165	*B. gouldi*	
	c	0				

TABLE A-13. Continued.

Site	Panel	No. of Specs.±	Percent Filled	Size Range in mm.	Species Identification	Remarks
15	p	1	2	95	1 *B. gouldi*	
	c	0				
17	p	2	<1	<1-1		
	c	0				

Sites 3, 8-10, 16, no Teredinidae present.
p = long-term panel submerged April 4-5, 1978.
c = short-term panel submerged September 6-7, 1978.
± Species not identified - too small; pallets missing or broken.

TABLE A-14. SUMMARY DATA FOR INCIDENCE OF TEREDINIDAE IN PANELS REMOVED NOVEMBER 8-9, 1978

Site	Panel	No. of Specs.±	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	p	430	98	<1-150	*T. navalis*	
	c	650	1	<1-1		
2	p	5	17	63-175	5 *T. navalis*	1 with ripe gonads.
	c	0				
4	p	1	4	155	1 *B. gouldi*	
	c	0				
5	p	680	50	<1-220	79 *T. bartschi*, 1 *B. gouldi*	Larvae present.
	c	0				
6	p	58	15	<1-52	22 *T. bartschi*	Umbonate larvae present.
	c	0				
7	p	2460	99	<1-115	300± *T. bartschi*, 2 *B. gouldi*	Several releasing larvae.
	c	0				
8	p	1	13	450	1 *B. gouldi*	
	c	0				
10A	p	3	15	130-245	*B. gouldi*	1 dead.
	c	0				
11	p	12	45	11-200	10 *B. gouldi*, 2 *T. navalis*	
	c	0				
13	p	8	45	120-250	8 *B. gouldi*	
	c	0				
14	p	13	70	115-255	13 *B. gouldi*	
	c	0				
17	p	5	15	60-180	4 *T. navalis*, 1 *B. gouldi*	
	c	0				

Sites 3, 4A, 9-10, 10B, 12, 15-16, no Teredinidae present.
p = long-term panel submerged May 1-3, 1978.
c = short-term panel submerged October 2-3, 1978.
Species not identified - too small; pallets missing or broken.

TABLE A-15. NUMBER OF *Bankia gouldi* IN LONG-TERM PANELS REMOVED JULY, 1975, THROUGH NOVEMBER, 1978

		1	2	3	4	4A	5	6	7*	8	9	10	10A	10B	11	12	13	14	15	16	17
1975	Jul									-	-										
	Aug			2	13	-	2	42	14	-	-	4	-	-	387	16	100	335	1	5	
	Sep			4	51	-	988	268	-			27	-	-	323	45	340	400	8	3	2
	Oct		3	2	47	-		135		3	2	27	-	-	374	50	399	400	4	4	1
	Nov	1	4	4	26	-	8	100		5	2	12	-	-	251	46	400	400	2	10	1
	Dec		12	9	15	-	4	18		1	1	8	-		220	18	399	400	2	1	
1976	Jan	--	2	14	10	-	9	160		1	1	5	-	-	240	22	64	400	6	1	
	Feb		2	1	5	-		2		1	1		-	-	64	8	--	8			
	Mar					-							-	-							
	Apr					-							-	-							
	May					-							-	-							
	Jun					-							-	-							
	Jul					-	1		2				-	-	4			2			
	Aug				2	-	2		2	2	1		-	-	6	2	24	7	3		
	Sep				3	-	1	2	2	3		1	-	-	23	5	31	11	7		
	Oct				1	-	3	1	4	1	1	1	-	-	11	8	26	19	1		
	Nov	1			5	-	4		5	1			-	-	33	7	20	17	2		
	Dec				4	-		1	3	5		2	-	-	31	6	21	10	3		
1977	Jan					-		1	2				-	-	42	6	5	2			
	Feb				2	-	1	1	1				-	-	31	2	2				
	Mar					-							-	-							
	Apr					-							-	-							
	May												-	-							
	Jun												-	-							
	Jul												-	-							
	Aug				1		1		3			1	-	-	15	1	5	1	1		
	Sep				2	1	6		4	1		1	-	-	82	3	13	5			
	Oct			1		3	3		7			2	-	-	59	7	10	9			
	Nov				1		5		7			1	-	-	39	7	8	5			
	Dec					1	4	1	7	1		2	-	-	25	7	18	9			
1978	Jan			2	1	1	1		2	2	2	1	-	-	34	5	4	6			
	Feb												-	-	1			1		1	
	Mar												-	-							
	Apr																				
	May																				
	Jun																				
	Jul													1			2				
	Aug								7					1	2		1				
	Sep				1				1				2		14		7	9			
	Oct				4	1	1						5	2	30	2	6	9	1		
	Nov				1		1		2	1			3		10		8	13			1

* = New rack submerged September, 1975 - = Panel station not in operation -- = Panel missing

TABLE A-16. NUMBER OF *Teredo navalis* IN LONG-TERM PANELS REMOVED JULY, 1975, THROUGH NOVEMBER, 1978

Year	Month	1	2	3	4	4A	5	6	7*	8	9	10	10A	10B	11	12	13	14	15	16	17
1975	Jul					-				-	-		-	-							
	Aug					-				-	-		-	-							
	Sep					-			-				-	-							
	Oct			1	1	-							-	-		3			2		87
	Nov	3	10			-						2	-	-		1			2		90
	Dec	17	4		3	-				1			-	-	100		1		4		
1976	Jan	--	5			-							-	-	156				3		103
	Feb	60	6			-				1	1		-	-	3		--		7		33
	Mar	400				-							-	-							
	Apr					-							-	-							
	May					-							-	-							
	Jun					-							-	-							
	Jul					-							-	-							
	Aug	37				-							-	-							
	Sep	423				-				1			-	-	23				1		
	Oct	230			1	-			3				-	-	13						8
	Nov	400				-			2				-	-	22						17
	Dec	400	1			-			1				-	-	11				1		22
1977	Jan	300	3			-							-	-	11						4
	Feb	400				-							-	-	4						2
	Mar	1				-							-	-							
	Apr					-							-	-							
	May												-	-							
	Jun												-	-							
	Jul												-	-							
	Aug												-	-							
	Sep	160											-	-				1	1		
	Oct	300	1										-	-	1			1			
	Nov	390											-	-	6				1		
	Dec	380									1		-	-	1						
1978	Jan	400	3										-	-	2						4
	Feb	375											-	-							1
	Mar	220											-	-							
	Apr								2				-	-							
	May																				
	Jun																				
	Jul														1						
	Aug	1																			
	Sep	115													1						1
	Oct	329	3																		
	Nov	430	5												2						4

* = New rack submerged September, 1975 - = Panel station not in operation -- = Panel missing

TABLE A-17. NUMBER OF *Teredo bartschi* IN LONG-TERM PANELS REMOVED JULY, 1975, THROUGH NOVEMBER, 1978

		1	2	3	4	4A	5	6	7*	8	9	10	10A	10B	11	12	13	14	15	16	17
1975	Jul					-				-	-		-	-							
	Aug					-				-	-		-	-							
	Sep					-	2962	402	-				-	-							
	Oct					-	46	315					-	-							
	Nov					-	392	300					-	-							
	Dec					-	21	7					-	-							
1976	Jan	--				-	46	240					-	-							
	Feb					-	350	398					-	-			--				
	Mar					-	14	14					-	-							
	Apr					-							-	-							
	May					-							-	-							
	Jun					-							-	-							
	Jul					-							-	-							
	Aug					-							-	-							
	Sep					-							-	-							
	Oct					-							-	-							
	Nov					-			11				-	-							
	Dec					-							-	-							
1977	Jan					-							-	-							
	Feb					-			4				-	-							
	Mar					-							-	-							
	Apr					-							-	-							
	May												-	-							
	Jun												-	-							
	Jul												-	-							
	Aug												-	-							
	Sep								1				-	-							
	Oct								11				-	-							
	Nov								185				-	-							
	Dec								130				-	-							
1978	Jan								160				-	-							
	Feb								200				-	-							
	Mar						1	2	81				-	-							
	Apr												-	-							
	May																				
	Jun																				
	Jul								71												
	Aug						2		129												
	Sep						91		536												
	Oct						90	1	360												
	Nov						79	22	300												

* = New rack submerged September, 1975 - = Panel station not in operation -- = Panel missing

TABLE A-18. NUMBER OF *Teredo furcifera* IN LONG-TERM PANELS REMOVED JULY, 1975, THROUGH NOVEMBER, 1978

		1	2	3	4	4A	5	6	7*	8	9	10	10A	10B	11	12	13	14	15	16	17
1975	Jul					-							-	-							
	Aug		11			-							-	-							
	Sep		29			-			-				-	-	57						
	Oct		38		1	-						4	-	-	26				2		30
	Nov	4	13			-						1	-	-	44						33
	Dec					-							-	-	80						
1976	Jan	--	4			-							-	-	4						
	Feb					-							-	-			--				
	Mar					-							-	-							
	Apr					-							-	-							
	May					-							-	-							
	Jun					-							-	-							
	Jul					-							-	-							
	Aug					-							-	-							
	Sep					-			1				-	-							
	Oct					-							-	-							
	Nov					-							-	-							
	Dec					-							-	-							
1977	Jan					-							-	-							
	Feb				1	-							-	-	2						
	Mar					-							-	-							
	Apr					-							-	-							
	May												-	-							
	Jun												-	-							
	Jul												-	-							
	Aug												-	-							
	Sep												-	-							
	Oct												-	-							
	Nov												-	-							
	Dec												-	-							
1978	Jan												-	-							
	Feb												-	-							
	Mar												-	-							
	Apr												-	-							
	May																				
	Jun																				
	Jul																				
	Aug																				
	Sep																				
	Oct																				
	Nov																				

* = New rack submerged September, 1975 - = Panel station not in operation -- = Panel missing

Bankia gouldi was the most widely distributed of all the borers and was present at 18 of the panel locations. It continues to be the dominant species at all stations on the west side of Barnegat Bay except at Manahawkin and Oyster Creek. *Bankia gouldi* was present but not dominant at Oyster Creek Stations 5, 6, and 7. It was the only species present at Oyster Creek Station 8. No *Bankia gouldi* were present at Stations 1 and 2 during this period (Table A-19).

Teredo navalis occurred in panels from six locations, Stations 1, 2, 7, 9, 11 and 17, but was dominant only at Stations 1, 2 and 17. No *T. navalis* were present in panels removed from the other stations during the period December, 1977 through November, 1978 (Table A-19).

Teredo bartschi occurred only in Oyster Creek and was present and dominant at three of the four stations in the creek. No *T. bartschi* were found at Oyster Creek Station 8 or at other stations in Barnegat Bay (Table A-19).

Teredo spp. includes those specimens whose taxonomic characters were partially lacking or were too small for definitive species identification. *Teredo* spp. were found in panels removed from eight stations (Table A-19).

<u>Teredinid Reproduction</u>

Macroexamination of specimens did not show the presence of reproductively active *Teredo navalis* from the latter part of the season but ripening gonads were observed as late as November, 1978 at Station 2 (Table A-20).

At Station 7, Oyster Creek, *Teredo bartschi* from the 1977 season contained umbonate larvae as late as January, 1978. Hoagland, (1978) reported the presence of straight hinged larvae in *T. bartschi* specimens removed in February, 1978 from an adjacent location in Oyster Creek. During the first half of the 1978 season, umbonate larvae were present from July through November at Station 7, from September through November at Station 5, and October and November at Station 6 (Table A-20). Results for the remainder of the 1978 season will be obtained from the continuation of the monitoring program.

TABLE A-19. DOMINANCE OF SPECIES OF TEREDINIDAE IN LONG-TERM PANELS DECEMBER, 1977, THROUGH NOVEMBER, 1978

Location	*Bankia gouldi*	*Teredo navalis*	*Teredo bartschi*	*Teredo* spp.*
1		√ dominant		√
2		√ dominant		√
3	√ dominant			√
4	√ dominant			
4A	√ dominant			
5	√		√ dominant	√
6	√		√ dominant	√
7	√	√	√ dominant	√
8	√ dominant			
9	√ dominant	√		
10	√ dominant			
10A	√ dominant			
10B	√ dominant			
11	√ dominant	√		√
12	√ dominant			
13	√ dominant			
14	√ dominant			
15	√ dominant			
16	√ dominant			
17	√	√ dominant		√

* – Specimens too small or in too poor condition for speciating.
√ – Species present.
Stations 10A and 10B installed April, 1978.

TABLE A-20. REPRODUCTIVE ACTIVITY OF TEREDINIDS REMOVED FROM LONG-TERM PANELS FROM DECEMBER, 1977 THROUGH NOVEMBER, 1978 BY STATIONS

Month	*T. navalis*	*T. bartschi*	*B. gouldi*
December			
January		7	
February			
March			
April			
May			
June			
July		7	
August		7	
September	1	5,7	10A
October		5,6	
November	2	5,6,7	

Macroinspection of specimens showed that *Bankia gouldi* removed in September, 1978 from Station 10A were the only *Bankia* in the latter part of the 1977 or early 1978 seasons to show obvious gonadal development (Table A-20).

Detailed data on teredinid gonadal development is presented in Appendix B.

Settlement on Short-term Panels

Data for settlement of teredinid borers in short-term panels gives an indication of the survival of the larvae and the season of the year when successful reproduction takes place. In 1978, all settlement in short-term panels occurred during the months of July through November (Table A-21). Similar settling patterns occurred in 1975, 1976 and 1977. Hoagland, et al. (1978) observed the same patterns for the winters of 1977 and 1978.

Settlement in the short-term panels in the 1978 season was less than from 1975-1977 at stations throughout Barnegat Bay except at the Inlet and in Oyster Creek. As in previous seasons, the greatest number of settlement occurred in August. No settlement was observed after November. The amount of 1978 settlement at the Inlet was greater than in 1977, but not as great as in 1975 or 1976. No specimens were developed enough for generic identification.

There was a significant increase in settlement in 1978 at Station 7, Oyster Creek. Young specimens of *Teredo bartschi* were present in the July, August, and September short-term panels. Specimens settling in the October short-term panel were too small for positive generic identification, and no settlement took place in November (Table A-21).

Teredinid settlement also occurred during July through October at Oyster Creek Stations 5 and 6 and *Teredo bartschi* were present in short-term panels removed in September from Station 5. The 1978 settlement at these two locations was significantly less than in 1975, but greater than that of 1976 and 1977. The increase in the 1978 settlement is attributed to the presence of increased numbers of *Teredo bartschi*. The 1975 settlement was primarily *Bankia gouldi*.

TABLE A-21. NUMBERS OF TEREDINIDS IN SHORT-TERM PANELS REMOVED MONTHLY DECEMBER, 1977, THROUGH NOVEMBER, 1978*

Site	July	August	September	October	November	Total #	% Total	$\bar{x}$	α
1		4	330	31	650	1015	24.71	203.0	285.63
2			1			1	0.02	0.20	0.45
3									
4									
4A									
5		4	18^{Tb}	53		75	1.83	15.00	22.49
6	1	1	2	11		15	0.37	3.00	4.53
7	58^{Tb}	1800^{Tb}	1104^{Tb}	21		2983	72.61	596.60	818.99
8									
9									
10									
10A**		1^{Bg}				1	0.02	0.20	0.45
10B**									
11		5^{Bg}				5	0.12	1.00	2.24
12		1				1	0.02	0.20	0.45
13			4^{B}			4	0.10	0.80	1.79
14		1	7^{Bg}			8	0.19	1.60	3.05
15									
16									
17									

* - Short-term panels removed from December, 1977, through June, 1978 were free of Teredinids.
** - Stations 10A and 10B established April, 1978.
Tb - *Teredo bartschi*
Bg - *Bankia gouldi*
B - *Bankia* spp.

Of the twenty short-term panels removed in July, 1978, only two had teredinid entrances; one entrance recorded from Station 6 and 58 from Station 7. Five specimens were large enough for identification and were *Teredo bartschi*.

Eight of the short-term panels removed in August, 1978 had teredinid entrances. 1,800 entrances were present in the Station 7 panel. One to five entrances were present in the remaining seven panels from Stations 1, 5, 6, 10A, 11, 12 and 14. *Teredo bartschi* was identified at Station 7, and *Bankia gouldi* was identified at Stations 10A and 11.

In September, 1978, settlement occurred in short-term panels from seven locations, the number of recorded entrances ranging from one *Teredo* spp. at Station 2 to 1,100+ including 154 *Teredo* spp. and *T. bartschi* at Station 7. The short-term panel from Station 1 had 330 teredinid entrances. Two to 18 entrances were recorded in panels from Station 5, 6, 13 and 14. *Teredo bartschi* were identified at Station 5 and *Bankia gouldi* were identified at Stations 13 and 14.

October teredinid settlement took place in short-term panels from the Inlet, Station 1, and Oyster Creek Stations 5, 6 and 7. No settlement occurred in panels from the other locations.

The November, 1978 settlement occurred only at Station 1 and was the largest November settlement at this location since the beginning of the program. 650 entrances were recorded.

There was no settlement in any other short-term panels removed.

No settlement occurred in 1978 in short-term panels removed from Stations 3, 4, 4A, 8, 9, 10, 10B, 15, 16 and 17.

Settlement data from the short-term panels indicate that in 1978 *Teredo bartschi* began to reproduce and settle in June and continued through September. *Bankia gouldi* settled in June through August with the greatest amount occurring in July. The largest settlement of *Teredo navalis* was during the month of August.

Destruction to Short-term Panels

The amount of destruction is indicative of the size and successful growth of the specimens in a panel and is not necessarily directly proportional to the number of entrances.

The amount of destruction to the short-term panels removed from July through November, 1978 is shown in Table A-22. No attack was present in any short-term panels removed December, 1977 through June, 1978.

From a total of 100 short-term panels removed and examined from July through November, 1978, 22 showed teredinid attack. More than 85 percent of this number (19 panels) had one or less than one percent destruction. Three percent destruction occurred in the short-term panel removed from Station 7 in July. The largest amount of destruction occurred in the September panels from Stations 1 and 7 (5 and 10 percent, respectively).

The total destruction to the short-term panels was less in 1978 than that in 1976 and 1977 except at Stations 5, 6 and 7, Oyster Creek.

Destruction to Long-term Panels

All attack in long-term panels removed in December, 1977 through April, 1978 was caused by the 1977 generation of marine borers since there was no settlement on long- or short-term panels submerged on or after November 9, 1977 and removed on or before June 1, 1978. Since this pattern of attack was similar during 1975 and 1976, the attack for each yearly generation is determined from long-term panels removed July through the following April. The amount of destruction is determined by the percentage of the panel filled with Teredinidae and is not directly proportional to the number of specimens present.

Table A-23 presents the percent of long-term panels filled with teredinids for the last half of the 1977 season and the first half of the season. The numbers of teredinids present for these periods is presented in Table A-24. The percent destruction from 1975-1978 is shown in Figure A-5 .

All long-term panels were exposed for six months with the following exceptions: the July panel from Station 13 was retrieved in August and was exposed for seven months; Stations 10A and 10B were

TABLE A-22. PERCENT OF SHORT-TERM PANELS FILLED WITH TEREDINIDAE REMOVED MONTHLY FROM DECEMBER, 1977, THROUGH NOVEMBER, 1978*

Site	July	August	September	October	November	$\bar{x}$	α
1		<1	5	<1	1	1.60	1.95
2			<1			0.20	0.45
3							
4							
4A							
5		<1	<1	1		0.60	0.55
6	<1	<1	<1	<1		0.80	0.45
7	3	1	10	<1		3.00	4.06
8							
9							
10							
10A*		<1				0.20	0.45
10B*							
11		<1				0.20	0.45
12		<1				0.20	0.45
13			<1			0.20	0.45
14		<1	1			0.40	0.55
15							
16							
17							

* - Teredinids were not present in short-term panels removed from December, 1977, through June, 1978.

** - Stations 10A and 10B established April, 1978.

TABLE A-23. PERCENT OF LONG-TERM PANELS FILLED WITH TEREDINIDAE, SUBMERGED JUNE, 1977 TO MAY, 1978 AND REMOVED SEQUENTIALLY DECEMBER, 1977, THROUGH NOVEMBER, 1978

Site	Submerged Removed	Jun Dec	Jul Jan	Aug Feb	Sep Mar	Oct Apr	Nov May	Dec Jun	Jan Jul	Feb Aug	Mar Sep	Apr Oct	May Nov	$\bar{x}$	α
1		98	100	99	25	1				<1	25	80	98	43.92	46.24
2			10								<1	15	17	3.58	6.47
3		<1	6											0.58	1.73
4			2								1	7	4	1.17	2.21
4A		8	4									1		1.08	2.47
5		35	7		<1					2	20	25	50	11.67	16.98
6		7			1	<1				<1	<1	1	15	2.25	4.45
7		95	75	30	20	<1			10	20	98	99	99	45.58	43.40
8		8	10										13	2.58	4.80
9		2	12											1.17	3.46
10		15	2											1.42	4.32
10A*		–	–	–	–	–					8	25	15	6.86	9.87
10B*		–	–	–	–	–			<1	2		12		2.14	4.41
11		80	75	<1	<1				<1	1	22	50	45	23.00	31.17
12		40	25									5		5.83	12.94
13**		90	20						4	1	12	14	45	16.55	28.03
14		60	25	2						<1	17	25	70	16.67	24.73
15												2		0.17	0.58
16				1										0.08	0.29
17			5	2							<1	<1	15	2.00	4.35

* – Stations 10A and 10B established April, 1978.

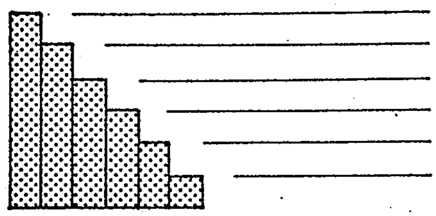
** – July long-term panel removed August, 1978.

TABLE A-24. NUMBERS OF TEREDINIDS IN LONG-TERM PANELS SUBMERGED JUNE, 1977 TO MAY, 1978 AND REMOVED SEQUENTIALLY DECEMBER, 1977, THROUGH NOVEMBER, 1978

Site	Submerged / Removed	Jun / Dec	Jul / Jan	Aug / Feb	Sep / Mar	Oct / Apr	Nov / May	Dec / Jun	Jan / Jul	Feb / Aug	Mar / Sep	Apr / Oct	May / Nov.	Total #	% Total	$\bar{x}$	α
1		380	400	375	320	165				9	130	364	430	2573	28.89	214.42	180.24
2			3								1	3	5	12	0.13	1.00	1.71
3		1	2											3	0.03	0.25	0.62
4			1								1	4	1	7	0.08	0.58	1.16
4A		1	1									1		3	0.03	0.25	0.45
5		4	1		1					12	121	171	680	990	11.11	82.50	196.51
6		1			2	1				1	1	15	58	79	0.89	6.58	16.72
7		207	192	240	94	14			93	730	567	360	2460	4957	55.65	413.08	683.77
8		1	2										1	4	0.04		
9		1	2											3	0.03	0.25	0.62
10		2	1											3	0.03	0.25	0.62
10A*		-	-	-	-	-					2	5	3	10	0.11	1.43	1.99
10B*		-	-	-	-	-			1	1		2		4	0.04	0.57	0.79
11		26	36	4	2				1	4	14	33	12	132	1.48	11.00	13.44
12		7	5									2		14	0.16	1.17	2.37
13**		18	4						-	4	7	6	8	47	0.53	4.27	5.52
14		11	6	1						1	9	9	13	50	0.56	4.17	5.06
15												1		1	0.01	0.08	0.29
16				1										1	0.01	0.08	0.29
17			5	1							1	2	5	14	0.16	1.17	1.90

* - Stations 10A and 10B established April, 1978.
** - July long-term panel removed August, 1978.

Key



Percent	Destruction
76-100	Very Heavy
51-75	Heavy
26-50	Moderately Heavy
11-25	Moderate
6-10	Slight
1-5	Trace

FIGURE A-5. PERCENT TEREDINID DESTRUCTION OF LONG-TERM EXPOSURE PANELS FROM JULY, 1975, THROUGH NOVEMBER, 1978

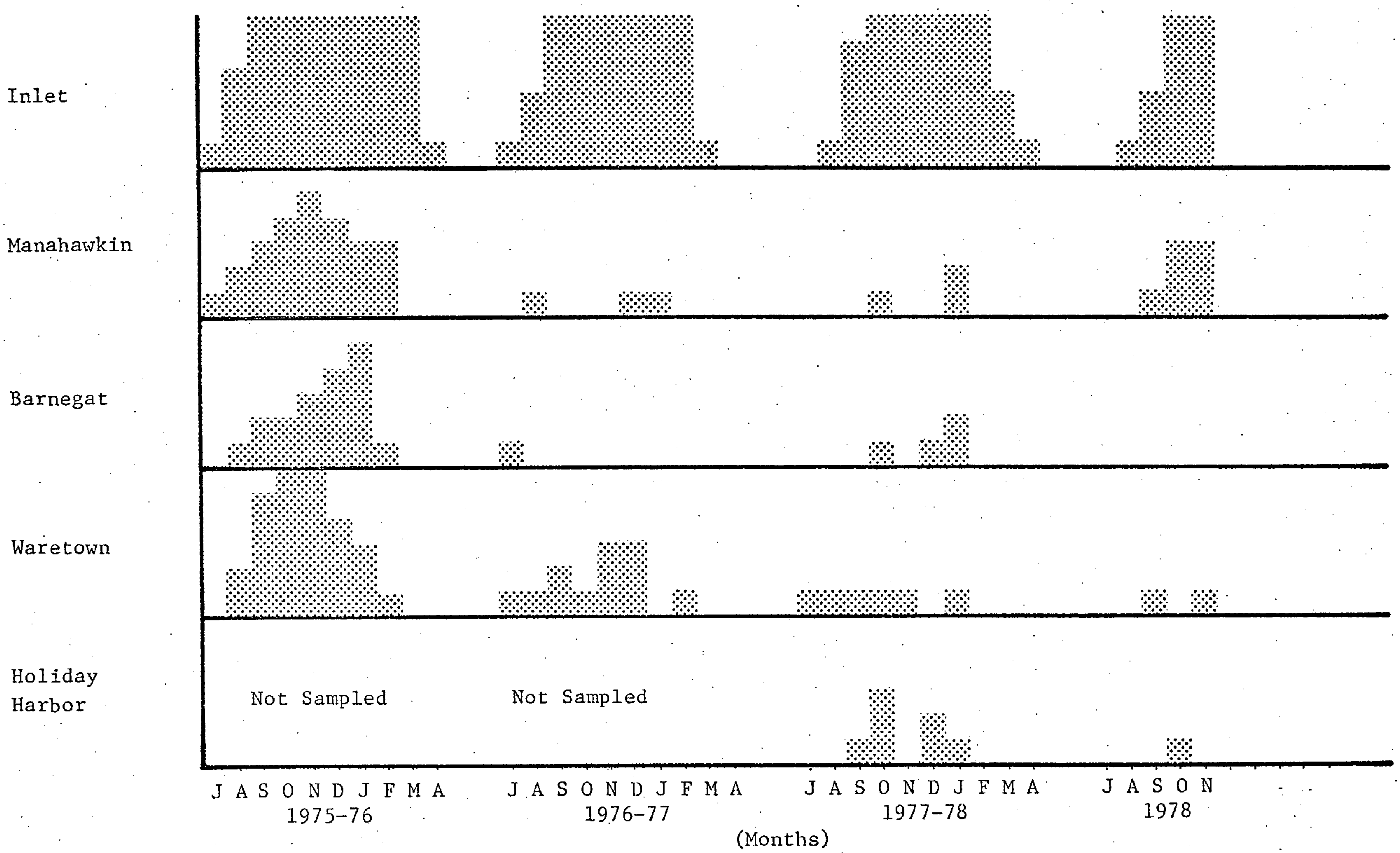


FIGURE A-5. (continued)

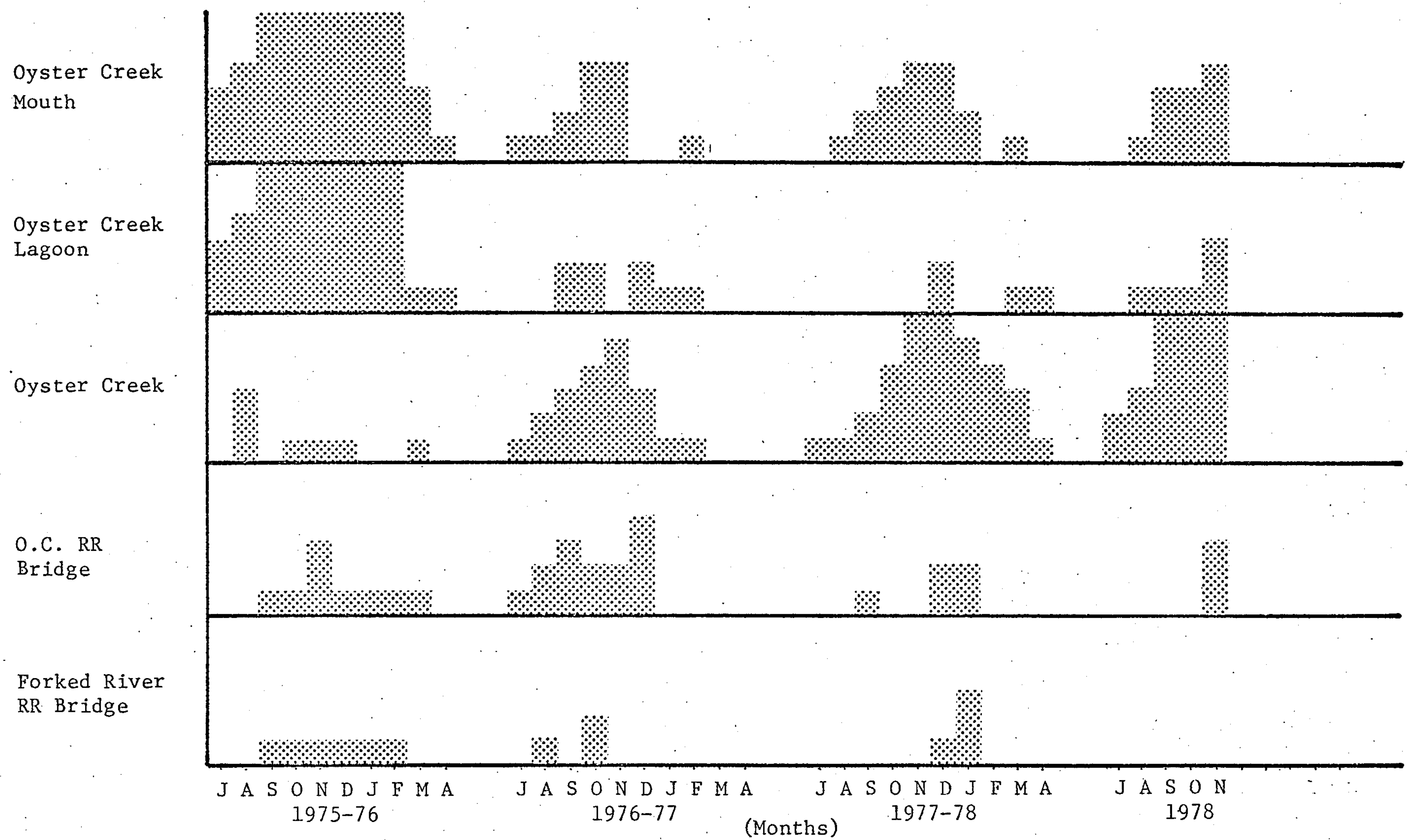


FIGURE A-5. (continued)

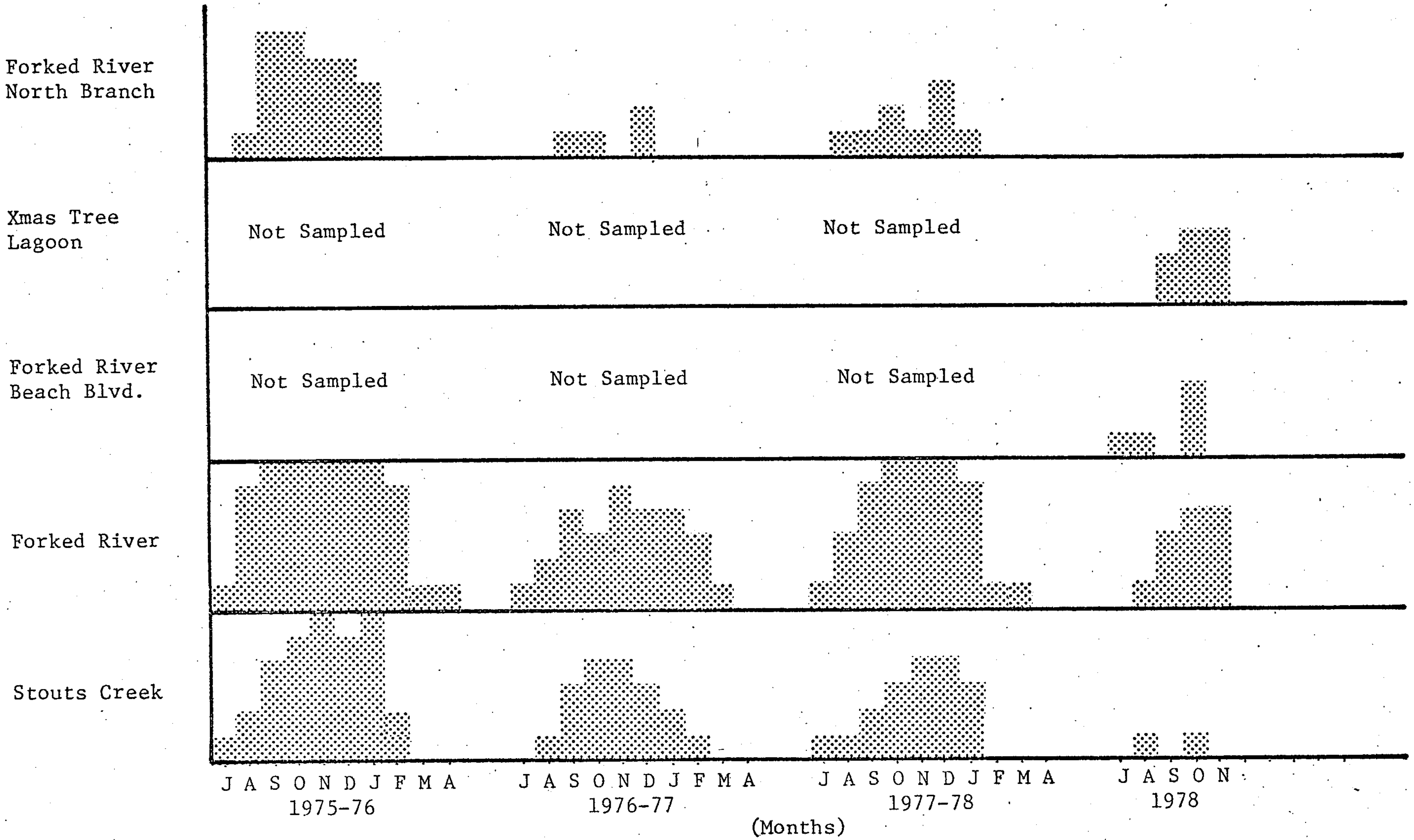


FIGURE A-5. (continued)

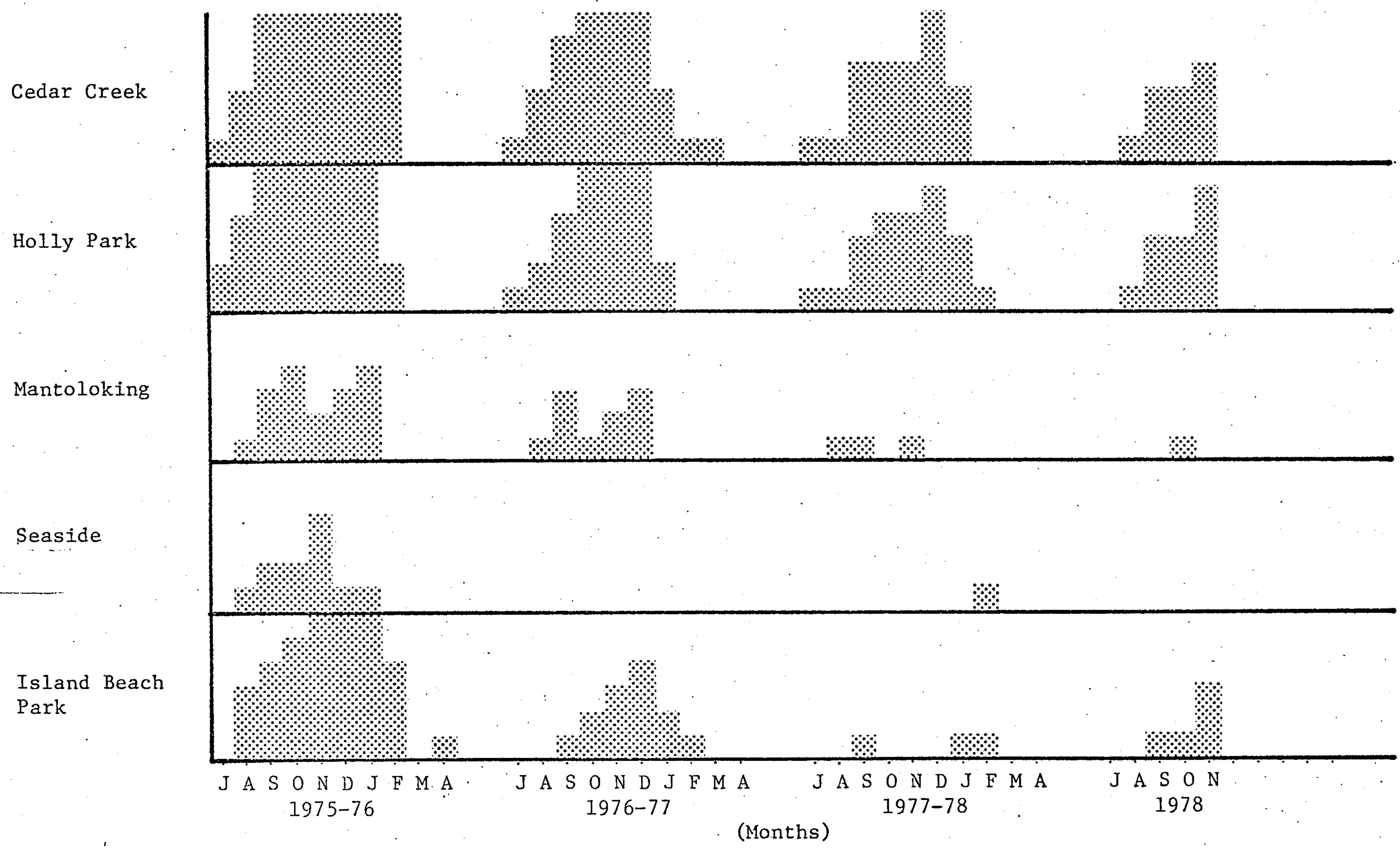


FIGURE A-5. (continued)

established in April, 1978 so that the six-month cycle was not reached until the October removal.

During the 1977 season, the greatest amount of destruction took place at Station 1 and panels removed December, 1977, January and February, 1978 were 98-100 percent destroyed (Table A-23, Figure A-5). The attack was caused by *Teredo navalis*. A trace to light attack by *T. navalis* occurred at Stations 2 and 17 in panels removed February, 1978.

Severe attack also occurred at Oyster Creek, Station 7, where panels removed in December, 1977 and January, 1978 were 97 and 75 percent filled, respectively, with *Teredo bartschi*.

Eighty to 90 percent destruction by *Bankia gouldi* occurred in panels removed in December, 1977 from Stations 11 and 13. The *B. gouldi* attack was rated moderate to heavy in long-term panels removed in December, 1977 and January, 1978 from Stations 5, 12 and 14, and rated light at Stations 3, 4A, 6 and 8. Trace to light attack was present in panels removed from Stations 4 and 9.

Teredinid attack was present in long-term panels at six locations in February, five in March and three in April, 1978. The attack remained heavy to moderate at Stations 1 (*Teredo navalis*) and 7 (*Teredo bartschi*). The trace attack at Stations 5 and 6 in the March panels was caused by the presence of *Teredo bartschi*.

All teredinid attack in the long-term panels removed in July through November, 1978 was the result of the 1978 generation (Table A-23).

Panels removed in July, 1978 showed trace attack at Stations 10B, 11 and 13 and light attack at Station 7.

In August, 1978, the panel removed from Station 7 showed the greatest attack being 20 percent filled with borers including identified specimens of *Teredo bartschi*. Trace borer attack (<1 to 2 percent) was present at seven locations and panels from the remaining stations were completely free of attack.

By September, attack was present at 11 stations and had increased to 98 percent at Station 7, to 20-25 percent at Stations 1, 5 and 11, and 8-17 percent at Stations 10A, 13 and 14. Panels from Stations 2, 4, 6 and 17 were less than one percent filled. There was no attack in panels from the remaining stations. *Bankia gouldi* was the only species in panels from Stations 4, 10A, 11, 13 and 14. *Teredo navalis* was recorded in panels from Station 1, and *Teredo bartschi* from Stations 5 and 7 (Tables A-15 through A-18).

Wherever possible, comparisons of the amount of destruction were made with the previous three seasons.

A two-factor analysis of variance was performed to determine if percent destruction to the panels by teredinids was significantly different at any of the exposure panel stations since the program was initiated in 1975. Data for panels removed April through July of each year were omitted due to absences of, or insufficient attack (Table A-25). The results show that there are differences due to month ($\alpha \leq .001$) and differences due to station effects ($\alpha \leq .001$). There were no station-month interactions present ($\alpha = .903$) so station means may be directly compared.

The amount of destruction to the panels was significantly greater at Station 1 (Figure A-6). At Station 11, the destruction to the panels was less than at Station 1, but not significantly different from Stations 5 and 7 which are in the thermal discharge and Stations 13 and 14 which are beyond the influence of the thermal discharge. There was no significant difference ($\alpha = .05$) in the destruction to the panels from Station 12, the control station, and the remaining stations.

Data for Stations 4A, 10A and 10B were not included in the analysis due to insufficient data. These stations were added to the program in 1977 and 1978.

An attempt was made to relate the percent destruction of the long-term panels to the water quality parameters (Figures A-7 through A-10). Average values of water temperature, pH, salinity and oxygen content were calculated for each six-month exposure of the long-term panels. These values were then examined versus the percent destruction.

TABLE A-25. TWO FACTOR ANALYSIS OF VARIANCE OF THE PERCENT DESTRUCTION OF LONG-TERM PANELS BY MONTHS* AND STATIONS FOR THE PERIOD AUGUST, 1975 THROUGH NOVEMBER, 1978

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	261066.400	23	11350.713	16.230	.001
Station Effects	187560.792	16	11722.550	16.762	.001
Month Effects	75179.026	7	10739.861	15.357	.001
Month/Station Interaction	63608.292	112	567.931	.812	.903**
Residual	234281.083	335	699.347		
Total	558955.775	470	1189.268		

* = Panels removed April through July omitted due to lack of significant data.
** = Not significant.

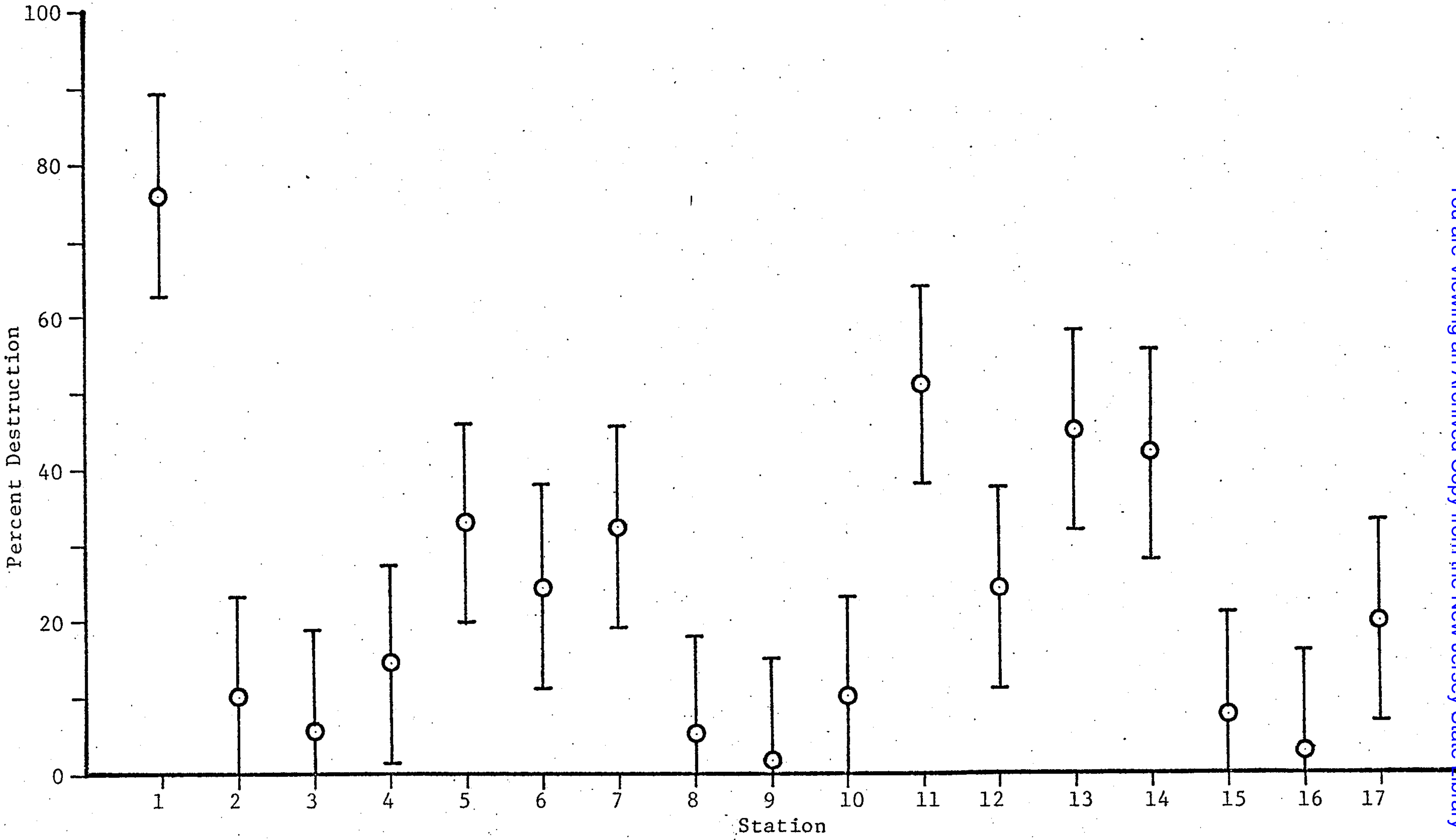


FIGURE A-6. MEAN PERCENT DESTRUCTION AND INTERVAL OF SIGNIFICANT DIFFERENCE ($\alpha = .05$) FOR LONG-TERM PANELS REMOVED FROM AUGUST, 1975, THROUGH NOVEMBER, 1978* AT SEVENTEEN EXPOSURE PANEL STATIONS IN BARNEGAT BAY

* = Except March through July of each year due to absence of or extremely low attack.

Stations 4A, 10A and 10B not included, newly installed 1977 and 1978.

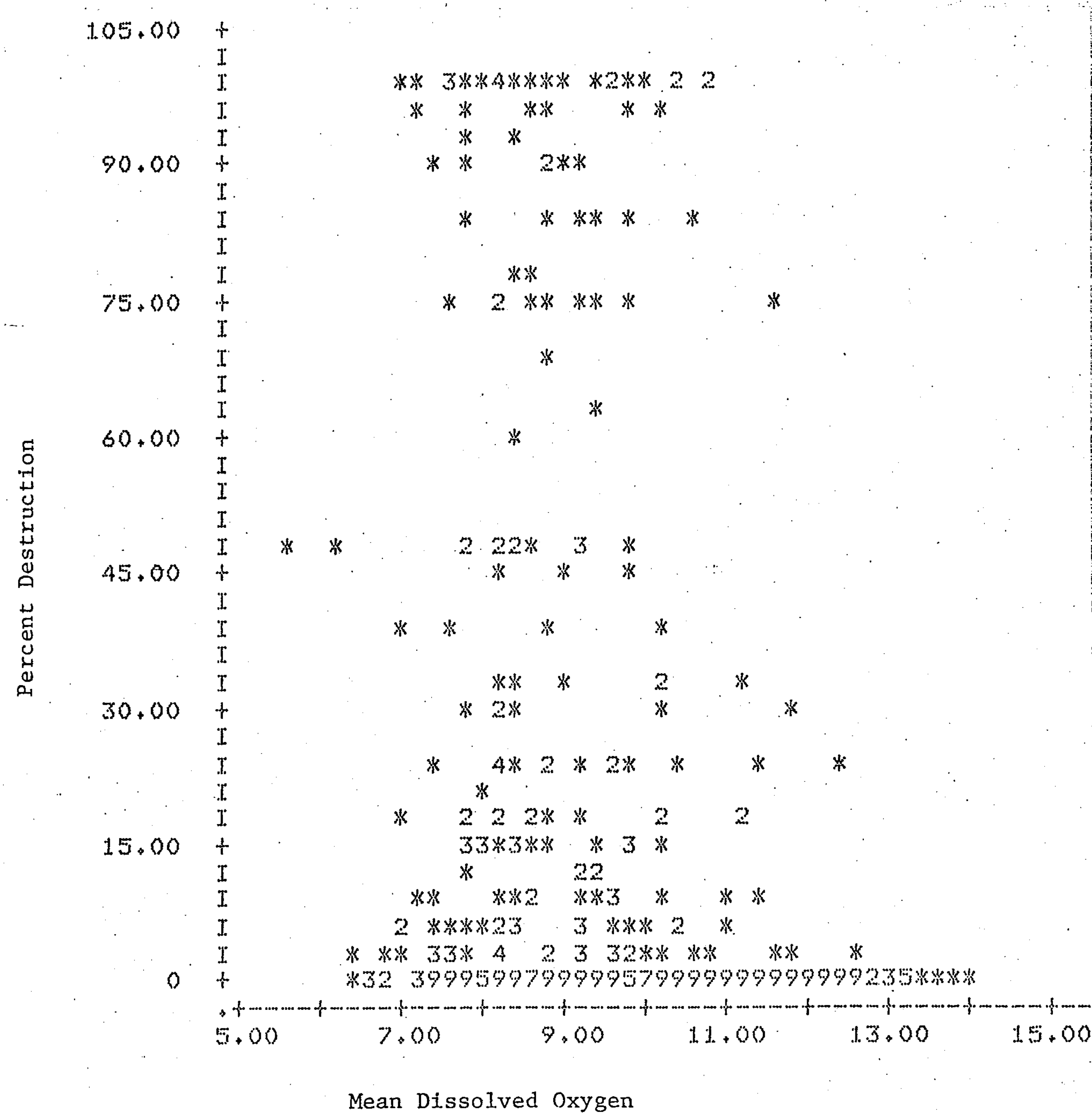


FIGURE A-7. PERCENT DESTRUCTION VERSUS MEAN DISSOLVED OXYGEN FOR EACH 6-MONTH EXPOSURE PANEL REMOVED FROM DECEMBER, 1975, THROUGH NOVEMBER, 1978

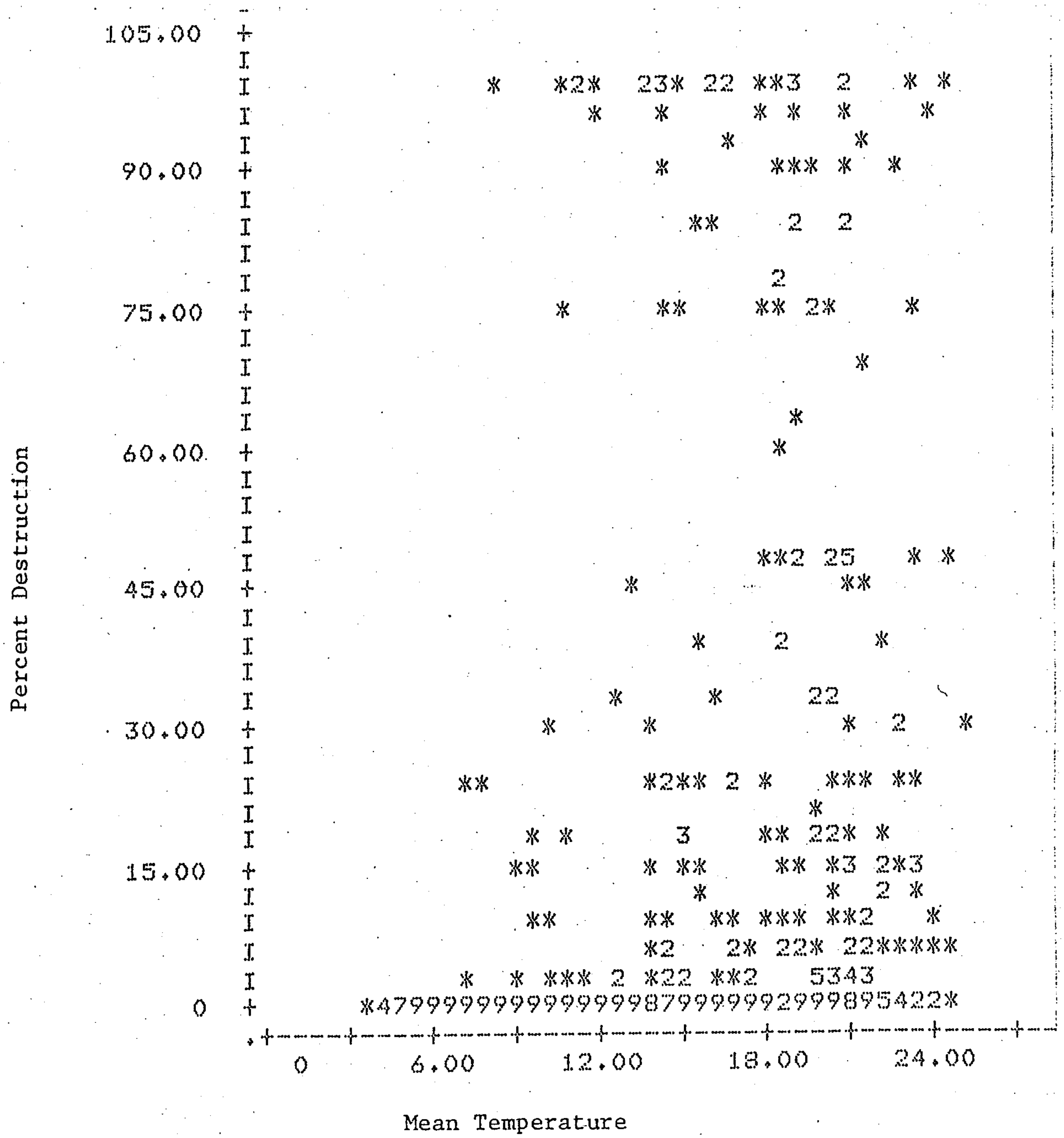


FIGURE A-8. PERCENT DESTRUCTION VERSUS MEAN TEMPERATURE FOR EACH 6-MONTH EXPOSURE PANEL REMOVED FROM DECEMBER, 1975, THROUGH NOVEMBER, 1978

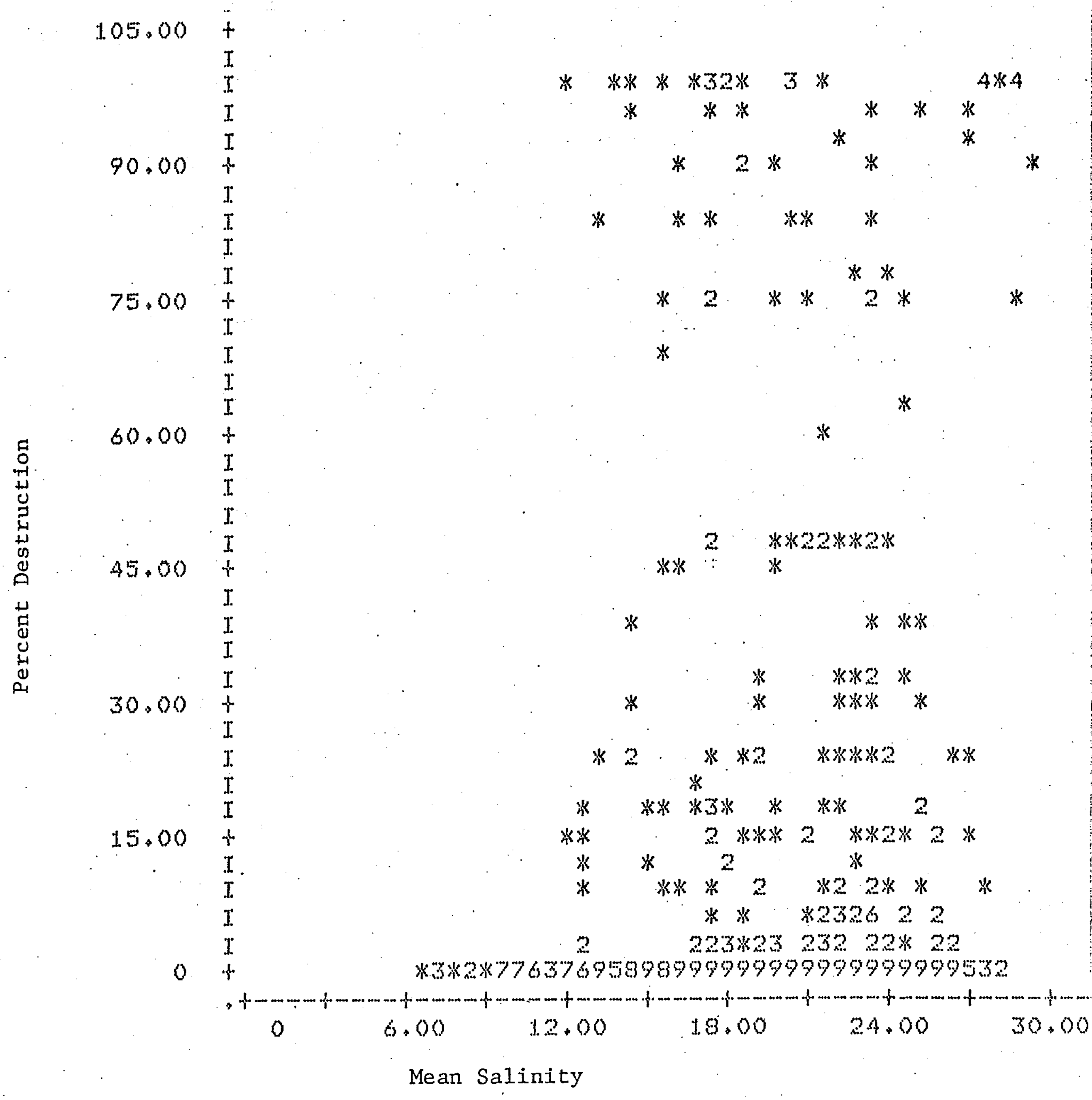


FIGURE A-9. PERCENT DESTRUCTION VERSUS MEAN SALINITY FOR EACH 6-MONTH EXPOSURE PANEL REMOVED FROM DECEMBER, 1975, THROUGH NOVEMBER, 1978

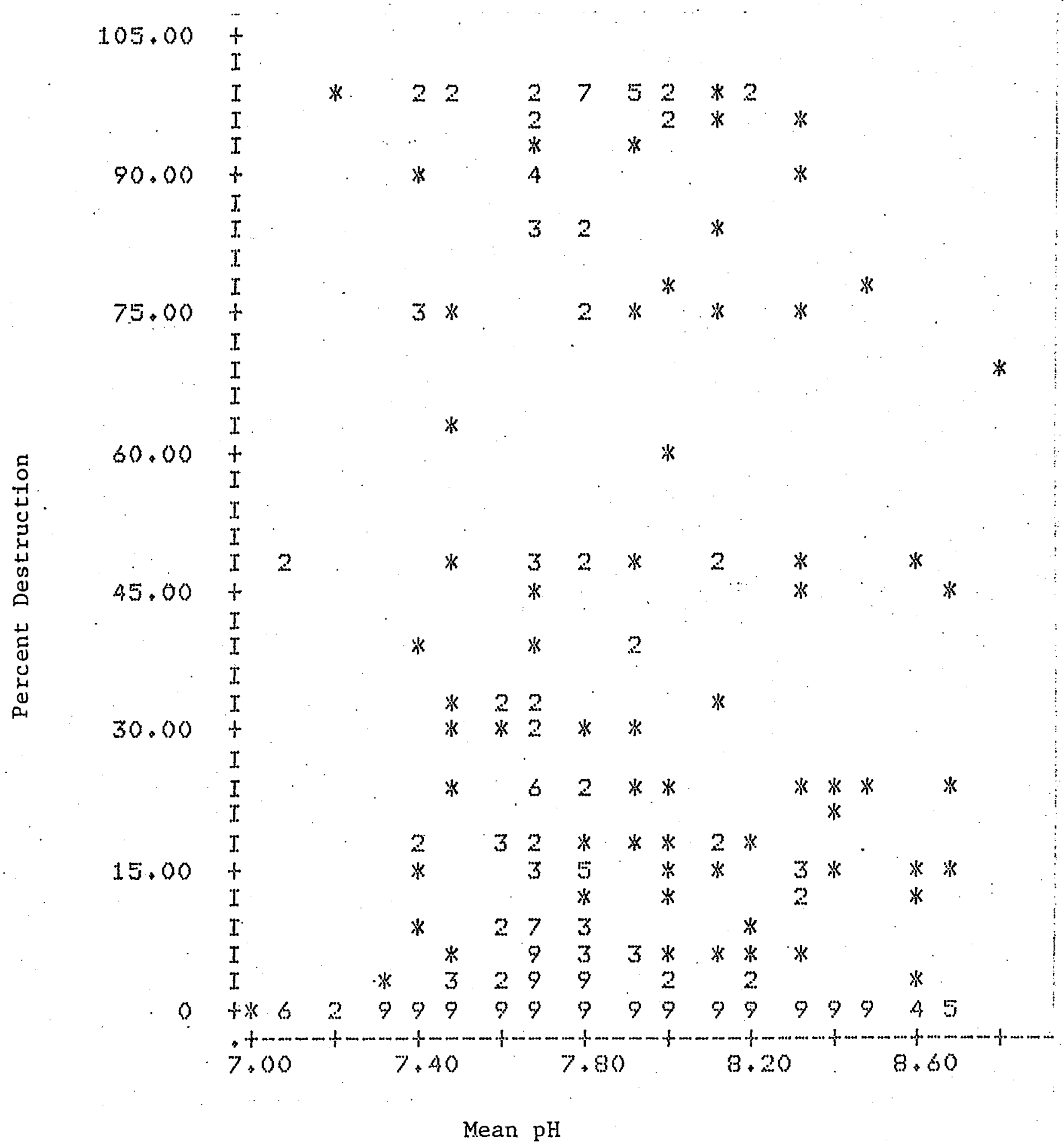


FIGURE A-10. PERCENT DESTRUCTION VERSUS MEAN pH FOR EACH 6-MONTH EXPOSURE PANEL REMOVED FROM DECEMBER, 1975 THROUGH NOVEMBER, 1978

There was no relationship seen between the percent destruction and any of the water quality parameters.

The seasonal mean percent attack for 1975-1977 and the first half of the 1978 season is presented in Table A-26. The results show a consistent decrease in attack since 1975 at all stations except Station 7. The increase at Station 7 in 1978 is attributed to the increase in population of *Teredo bartschi* at that location.

These means were used to rank stations in descending order (Table A-27). Stations 1, 13 and 14, all of which are beyond the influence of the thermal discharge, were ranked in the upper third for all four seasons. Station 1 which had ranked number one for 1975-1977 was ranked second to Station 7 for the first half of the 1978 season. This change in rank was due to the increased *Teredo bartschi* population at Station 7. The attack by *Teredo navalis* at Station 1 continues to be very heavy.

Overall, the greatest decrease in teredinid attack occurred between the 1975 and 1976 seasons following a severe winter and, in the instance of the stations located in the thermal discharge, following the removal of the trash wood in Oyster Creek.

Results to date from the 1978 season show a light increase over the 1977 attack at Stations 2, 14 and 17 which are beyond the influence of the thermal discharge, and a slight increase in attack at Stations 4, 6 and 8 which are influenced by the thermal discharge. Stations 1, 4A, 11, 12, 13 and 15 show a decrease in attack as do Stations 3, 9, 10 and 16. The last four stations had no teredinid attack during the first half of the 1978 season. No significance should be applied to these results because the data are for the period July through November, 1978 and the mean attack may be different when data for the complete 1978 season (July, 1978 through April, 1979) are available.

Mortality

1978 teredinid mortality occurring in exposure panels removed through November, 1978 occurred at fewer stations than in 1976 or 1977,

TABLE A-26. MEAN PERCENT TEREDINID DESTRUCTION BY SEASON AND STATION

Station	1975	1976	1977	1978
1	72.7*	61.1	58.8	40.8
2	23.7	0.4	1.1	6.6
3	15.4	0.1	0.9	0
4	33.0	5.1	1.3	2.4
5	67.9	7.2	9.9	19.4
6	65.1	3.1	0.9	3.6
7	2.1*	18.1	36.5	65.2
8	3.5*	7.4	2.1	2.6
9	2.3*	1.1	1.4	0
10	23.7	1.6	3.3	0
11	64.5	24.5	43.1	23.8
12	39.6	15.7	12.4	1.0
13	57.2*	38.2	24.9	14.6
14	56.3	32.4	19.2	22.6
15	15.4	5.1	0.5	0.4
16	6.6	0	0.1	0
17	44.4	8.5	0.8	3.4
4A	–	–	3.1	0.2
10A	–	–	–	9.6
10B	–	–	–	3.0

* = Incomplete data.
– = Panel not exposed.
1975: July, 1975-April, 1976
1976: July, 1976-April, 1977
1977: July, 1977-April, 1978
1978: July, 1978-November, 1978

TABLE A-27. RANK OF STATIONS IN DESCENDING ORDER OF TEREDINID ATTACK*

1975	1976	1977	1978**
1	1	1	7
5	13	11	1
6	14	7	11
11	11	13	14
14	7	14	5
13	12	12	13
		5	10A
17	17	10	2
12	8	4A	6
4	5	8	~~7~~ 5
10	4	9	10B
2	15	4	8
3	6	2	4
			12
15	10	3	15
16	9	6	4A
8	2	17	3
9	3	15	9
7	16	16	10
			16

* = From mean percentages, Table A-26.
** = Half season.

and was restricted to Stations 5, 7 and 10A (Table A-28). The greatest amount of mortality was in July at Station 7 when all specimens (93) were dead. Since there were no unusual hydrological conditions at Station 7 or at any of the other stations, and there was no mortality of teredinids in other panels removed in July, it is theorized that the specimens died in transit. This theory is substantiated by the fact that the subsequent panel removed in August from this location had but one dead and 729 live specimens. The August panel was submerged during the same teredinid breeding period as the July panel.

The only other mortality in August, 1978 was one of 12 specimens in the long-term panel from Station 5. In November, 1978, one of the three *Bankia gouldi* was dead in the long-term panel from Station 10A.

Water temperatures were within the optimum range for teredinids in July through October (Tables B-8 through B-11). The generating plant was not operating from September 16 to December 7 so that ambient temperatures prevailed throughout the bay. It is possible that the drop in ambient temperature in November affected the mortality at Station 10A, but this is unlikely as other specimens throughout the bay survived the same temperature conditions.

Possibly, the decline in teredinid mortality can be attributed to the pathological demise of weaker specimens in 1977. This possibility is presented in Appendix B.

<u>Lengths of Teredinids</u>

The length of teredinids in a panel varies according to species and to availability of space. Size as well as number has a definite effect on the amount of destruction that takes place. Table A-29 gives the length in millimeters of the longest teredinid recorded each month in exposure panels removed December, 1977 through November, 1978.

All data for December, 1977 through April, 1978 are for growth of the 1977 teredinid generation, and each long-term panel in this period had been submerged during the 1977 breeding season. The data for panels removed July through November, 1978 are for growth of the 1978 teredinid

TABLE A-28. TEREDINID MORTALITY IN LONG-TERM PANELS REMOVED FROM EXPOSURE DECEMBER, 1977, THROUGH NOVEMBER, 1978

Date Removed	Station	*Bankia gouldi*	*Teredo bartschi*	Teredinidae	Total Dead	Total Specimens
1/4/78	10	1/1			1	1
3/1/78	5		1/1		1	1
3/1/78	6		1/2		1	2
7/11/78	7		71/71	22/22	93	93
8/8/78	5		1/2	0/10	1	12
8/8/78	7	1/1	0/129	0/600	1	730
11/9/78	10A*	1/3			1	3

Dead/total of each species.
* Station 10A established April, 1978.

TABLE A-29. LONGEST (MILLIMETER) TEREDINID RECORDED EACH MONTH IN EXPOSURE PANELS REMOVED DECEMBER, 1977, THROUGH NOVEMBER, 1978

Site	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Long-term												
1	140	55*	100	42	2				17	80	100	150
2		155								13	185	175
3	1	110										
4		95								65	100	155
4A	260	170									37	
5	430	260		24					52	100	160	220
6	230			45	6				9	2	57	52
7	280	210	75	39	18			36	77	150	80	115
8	270	240										450
9	95	270										
10	250	90										
10A**										170	200	245
10B**								2	70		260	
11	195	190	9	2				13	48	145	140	200
12	230	225									110	
13	260	220						35***	28	88	150	250
14	300	200	100						2	120	165	255
15			63								95	
16												
17		100	80							24	1	180
Short-term												
1									1	14	2	1
2										4		
3												
4												
4A												
5									1	10	1	
6								<1	<1	<1	<1	
7								35	11	10	3	
8												
9												
10												
10A									13			
10B												
11									11			
12									1			
13										3		
14									1	27		
15												
16												
17												

* - Long-term panel removed in October, 1977 due to deterioration.
** - Stations 10A and 10B established April, 1978.
*** - July long-term panel removed August, 1978.

generation. Although all long-term panels were submerged six months, the 1978 set did not start until after the June, 1978 panels were removed. Therefore, the length of the teredinids in August was attained within a two-month period, those in September within three months, etc.

The longest (185mm) *Teredo navalis* recorded from the 1978 season was in the long-term panels removed at Station 2 in October. In the short-term panels at Station 1, *T. navalis* attained lengths of 10 and 14mm in the period between August and September removals. This growth rate is similar to that reported by Clapp (1925).

The largest *Teredo bartschi* were 100 and 110 millimeter specimens obtained from the September and November, 1978 long-term panels at Stations 5 and 7. *T. bartschi* attained a length of 35 millimeters in one month in the short-term panel removed in July from Station 7. The specimens in the long-term panels were longer than those recorded in 1976-77, but the growth rate in the short-term panels was similar.

Bankia gouldi are the largest teredinid species found in Barnegat Bay, and specimens up to 450 millimeters long were retrieved in November, 1978. The 450 millimeter specimen was the only specimen in the November panel from Station 8 and had destroyed more than 10 percent of the panel. The growth in the short-term panels, 11-27 millimeters in one month, is less than that reported by Turner (1973) and 25 percent less than that of the longest specimen (110 millimeters) in short-term panels exposed in 1975 (Richards et al., 1976).

Limnoria

The distribution of *Limnoria* in Barnegat Bay is restricted to the Inlet and locations in the bay south of Oyster Creek. This distribution is the same as in previous years. Tables A-30 through A-41 present the numbers present each month from December, 1977 through November, 1978. *Limnoria tripunctata* was the only species present.

April was the only month when panels from all stations were free of *Limnoria*, although only 1-2 specimens were recorded in March at Stations 2 and 4A and but two specimens were recorded in May at Station 4A. This

TABLE A-30. SUMMARY DATA FOR INCIDENCE OF *Limnoria tripunctata* IN PANELS REMOVED DECEMBER 6-7, 1977

Site	Panel	No. of Tunnels±	No. of Specs.±
1	p	170	65
	c	0	0
2	p	6	0
	c	0	0
3	p	0	0
	c	0	0
4	p	29	1
	c	0	0
4A	p	750	480
	c	0	0

Sites 5 through 17 - no *Limnoria* present.
p = long-term panels, submerged June 6-7, 1977.
c = short-term paenls, submerged November 8-9, 1977.

TABLE A-31. SUMMARY DATA FOR INCIDENCE OF *Limnoria tripunctata* IN PANELS REMOVED JANUARY 4, 1978

Site	Panel	No. of Tunnels	No. of Specs.
1	p*	155	140
	c	0	0
2	p	29	12
	c	0	0
3	p	13	1
	c	0	0
4	p	38	16
	c	0	0
4A	p	87	20
	c	0	0

Sites 5 through 17 - no *Limnoria* present.
p = long-term panels, submerged July 12-13, 1977.
c = short-term panels, submerged December 6-7, 1977.
* = panels removed October 12, 1977 due to severe teredinid attack.
Juveniles present at Sites 1, 3, 4A.

TABLE A-32. SUMMARY DATA FOR INCIDENCE OF *Limnoria tripunctata* IN PANELS REMOVED FEBRUARY 1, 1978

Site	Panel	No. of Tunnels	No. of Specs.
1	p	47	11
	c	0	0
2	p	5	1
	c	0	0
3	p	16	4
	c	0	0
4	p	11	4
	c	0	0
4A	p	68	17
	c	0	0

Sites 5 through 17 - no *Limnoria* present.
p = long-term panels, submerged August 9-11, 1977.
c = short-term panels, submerged January 4, 1978.

TABLE A-33. SUMMARY DATA FOR INCIDENCE OF *Limnoria tripunctata* IN PANELS REMOVED MARCH 1-2, 1978

Month	Site	Panel	No. of Tunnels	No. of Specimens
March	2	p	1	0
	4A	p	2	1

Sites 1, 3, 4, 5-17, no *Limnoria* present.
p = long-term panels submerged September 13-14, 1977.
short-term panels submerged February 1, 1978.

TABLE A-34. SUMMARY DATA FOR INCIDENCE OF *Limnoria tripunctata* IN PANELS REMOVED APRIL 4-5, 1978

Month	Site	Panel	No. of Tunnels	No. of Specimens
	_	Sites 1-17 No *Limnoria* present		

Long-term panels submerged October 11-12, 1977.
Short-term panels submerged March 1-2, 1978.

TABLE A-35. SUMMARY DATA FOR INCIDENCE OF *Limnoria tripunctata* IN PANELS REMOVED MAY 1-3, 1978

Month	Site	Panel	No. of Tunnels	No. of Specimens
May	4A	p	2	0

Sites 1-4, 5-17, no *Limnoria* present.
p = long-term panels submerged November 8-9, 1977.
short-term panels submerged April 4-5, 1978.

TABLE A-36. SUMMARY DATA FOR INCIDENCE OF *Limnoria tripunctata* IN PANELS REMOVED MAY 31 THROUGH JUNE 1, 1978

Site	Panel	No. of Tunnels	No. of Specimens
1	p	2	2
	c	0	0
2	p	3	3
	c	0	0
4	p	19	24
	c	8	10
4A	p	17	25
	c	7	11

Sites 3, 5-17, no *Limnoria* present.
p = long-term panels submerged December 6-7, 1977.
c = short-term panels submerged May 1-3, 1978.

TABLE A-37. SUMMARY DATA FOR INCIDENCE OF *Limnoria tripunctata* IN PANELS REMOVED JULY 10-12, 1978

Site	Panel	No. of Tunnels±	No. of Specimens±
1	p	22	40
	c	6	10
2	p	51	88
	c	8	14
4	p	670	735
	c	74	110
4A	p	415	760
	c	67	102

Sites 3, 5-17, no *Limnoria* present.
p = long-term panels submerged January 4, 1978.
c = short-term panels submerged May 31-June 1, 1978.
Gravid females and juveniles present at Sites 1, 2, 4, 4A.

TABLE A-38. SUMMARY DATA FOR INCIDENCE OF *Limnoria tripunctata* IN PANELS REMOVED AUGUST 8-9, 1978

Site	Panel	No. of Tunnels±	No. of Specimens±
1	p	83	135
	c	5	9
2	p	550	800
	c	8	14
4	p	560	800
	c	0	0
4A	p	430	650
	c	16	11

Sites 3, 5-17, no *Limnoria* present.
p = long-term panels submerged February 1, 1978.
c = short-term panels submerged July 10-12, 1978.
Gravid females and juveniles present at Sites 1, 2, 4, 4A.

TABLE A-39. SUMMARY DATA FOR INCIDENCE OF *Limnoria tripunctata* IN PANELS REMOVED SEPTEMBER 6-7, 1978

Site	Panel	No. of Tunnels±	No. of Specimens±
1	p	245	280
	c	1	1
2	p	950	1100
	c	9	10
3	p	14	12
	c	0	0
4	p	515	300
	c	0	0
4A	p	1800	2000
	c	1	2

Sites 5-17, no *Limnoria* present.
p = long-term panels submerged March 1-2, 1978.
c = short-panels submerged August 8-9, 1978.
Gravid females and juveniles present at all locations.

TABLE A-40. SUMMARY DATA FOR INCIDENCE OF *Limnoria tripunctata* IN PANELS REMOVED OCTOBER 2-3, 1978

Site	Panel	No. of Tunnels±	No. of Specimens±
1	p	260	300
	c	0	0
2	p	1000	1300
	c	0	0
4	p	475	350
	c	0	0
4A	p	1250	1500
	c	0	0

Sites 3, 5-17, no *Limnoria* present.
p = long-term panel submerged April 4-5, 1978.
c = short-term panel submerged September 6-7, 1978.
Gravid females and juveniles present at all locations.

TABLE A-41. SUMMARY DATA FOR INCIDENCE OF *Limnoria tripunctata* IN PANELS REMOVED NOVEMBER 8-9, 1978

Site	Panel	No. of Tunnels±	No. of Specimens±
1	p	97	81
	c	0	0
2	p	900	950
	c	0	0
4	p	360	410
	c	0	0
4A	p	900	800
	c	0	0

Sites 3, 5-17, no *Limnoria* present.
p = long-term panel submerged May 1-3, 1978.
c = short-term panel submerged October 2-3, 1978.
Gravid females and juveniles present at all locations.

would indicate that very little migration occurred from October (when these panels were submerged) to May. Table A-42 shows the number of *Limnoria* tunnels in panels removed December, 1977 through November, 1978.

It may be seen from Figure A-11 that there has been a light but steady increase in attack at Station 1. The attack at Stations 2 and 3 was heavy in 1976 and decreased in 1977. The attack continued to decrease in 1978 at Station 3, but there was a sharp increase at Station 2.

The heaviest attack occurred at Holiday Harbor and it was greater in 1978 than in 1977. The severe *Limnoria* attack to the pilings observed in 1977 indicates that the attack at that location was not new. However, due to the proximity to Oyster Creek, the amount of attack at this station is very important.

No *Limnoria* were found in panels at the remaining 15 locations or in any of the creosoted panels.

TABLE A-42. NUMBER OF *Limnoria* TUNNELS IN PANELS REMOVED DECEMBER, 1977, THROUGH NOVEMBER, 1978

Month	Barnegat Light		Manahawkin		Conklin Island		Waretown		Waretown	
	P	C	P	C	P	C	P	C	P	C
Dec, 1977	170		6				29		750	
Jan, 1978	155		29		13		38		87	
Feb	47		5		16		11		68	
Mar			1						2	
Apr										
May									2	
June	2		3				19	8	17	7
July	22	6	51	8			670	74	415	67
Aug	83	5	550	8			560		430	16
Sept	245	1	950	9	14		515		1800	1
Oct	260		1000				475		1250	
Nov	97		900				360		900	

P = Long-term panel.
C = Short-term panel.
No *Limnoria* at other panel exposure stations.

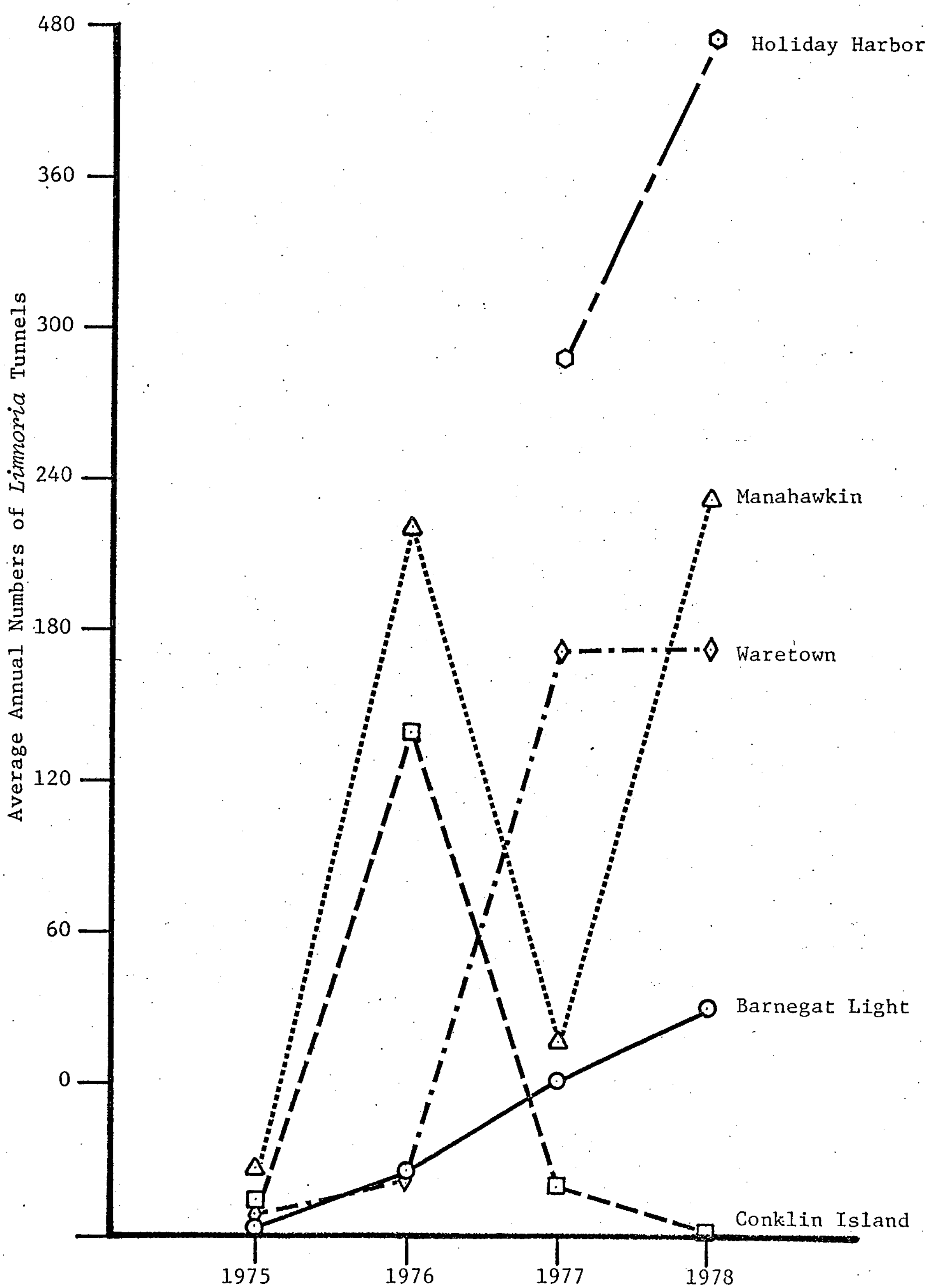


FIGURE A-11. AVERAGE ANNUAL NUMBERS OF *Limnoria* TUNNELS

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APPENDIX B

APPENDIX B

WATER QUALITY

Introduction

Various water quality parameters were used to describe the physical-chemical environment at the exposure panel stations. These parameters, particularly water temperature and salinity, were used to define the minimum/maximum limits for the marine borers found in Barnegat Bay. This phase of the study reports on water quality parameters for the period December, 1977 through November, 1978.

Materials and Methods

Water quality measurements were taken each month at the 20 exposure panel stations (Figure B-1).

Water temperature, salinity, pH, and dissolved oxygen were measured monthly at each exposure panel station by Battelle personnel with a Hydrolab Model II B. The Hydrolab was calibrated prior to each day's use.

In January, there was up to five inches of ice in the northern part of the Bay, Stations 12 through 17. The ice was 10 to 14 inches thick in February at Stations 2, 3, 10, 12 and 16; two to five inches thick at Stations 1, 6, 13, 14, 15 and 17; and three inches of mush at Stations 4, 4A and 11. There was open water at Stations 5, 7, 8 and 9.

In March, one to two feet of ice was still present at Stations 3, 12, 14, 16 and 17. Station 4 had two inches of ice. All other locations had open water.

In July, the water at the sites in Stouts Creek and Forked River near Teds Marina had a dark discoloration, probably due to the presence of humic material. The humic material is believed to be carried from the swamps down the creeks after heavy rains.

Results

The water quality values recorded each month at each of the exposure panel stations from December, 1977 through November, 1978 are

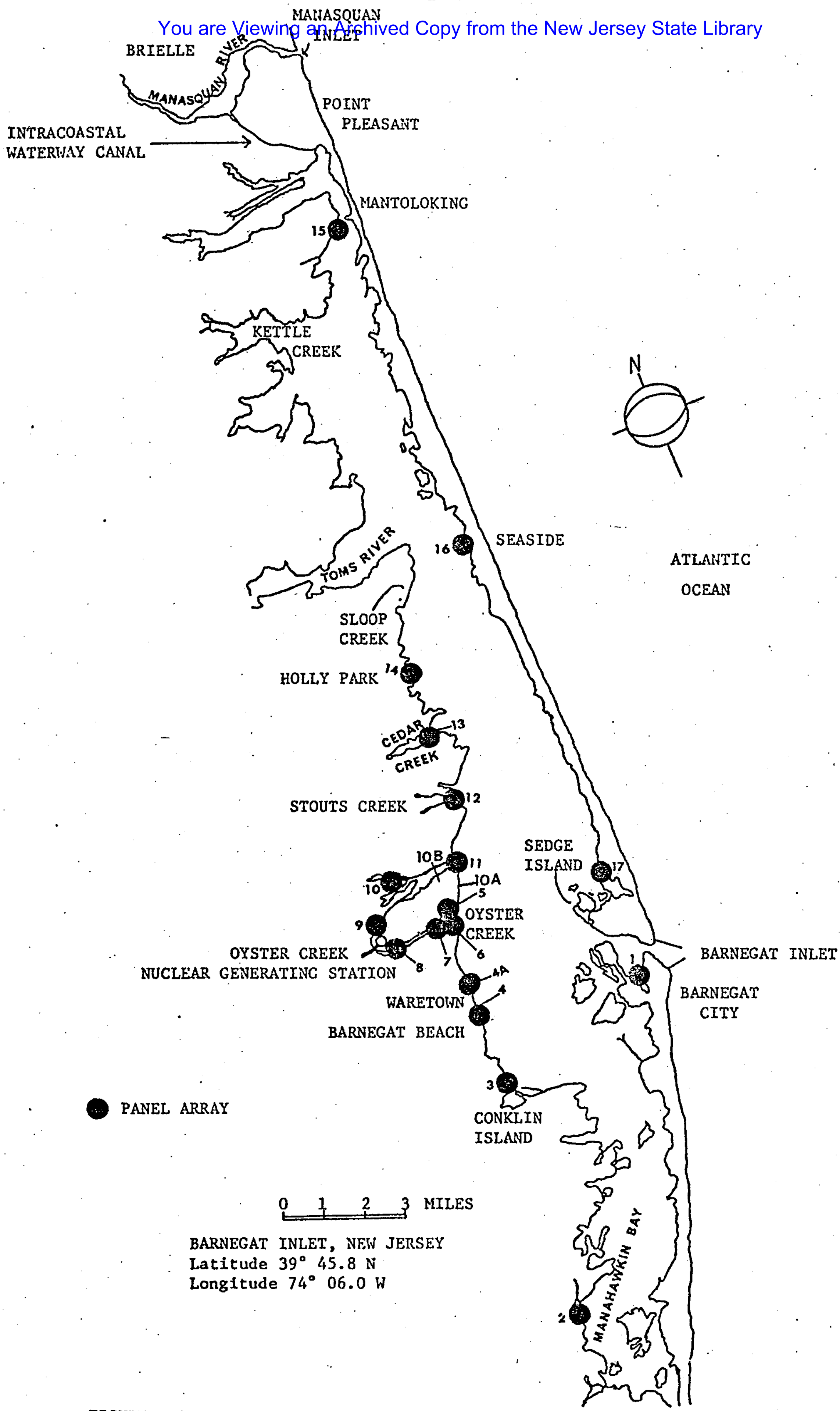

FIGURE B-1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHICAL LOCATIONS OF EXPOSURE PANELS presented in Tables B-1 through B-12. Tables B-13 through B-32 give the same water quality values by station.

Table B-33 gives the mean temperature, salinity, their standard deviation and range at each of the exposure panel stations for the same time period.

Figure B-2 shows the monthly average water temperature at the Oyster Creek Railroad Bridge for the months June through May for the period June, 1975 through November, 1978. These temperature data were provided by Jersey Central Power & Light Company.

During the teredinid reproductive season June to November, established by settlement on short-term panels (Table A-21), the water quality parameters were within range to support the four species of teredinids found in Barnegat Bay (Table B-34).

Temperatures recorded at each panel removal period show that during the 1975 season, the water temperature was within the teredinid breeding range (13-30C) from the beginning of the program in June through November at all locations. In the spring of 1976, the water was within this range in April at Stations 12, 13, 15, 16 and 17, as well as the four stations in Oyster Creek. The remaining Stations 2, 3, 4, 9, 10, 11 and 14 came within range in May. The water temperature was below the breeding range at all locations after October, 1976, except at Stations 7 and 8 in Oyster Creek.

During the 1977 season, temperature was within the breeding range in March in Oyster Creek, in April at Stations 1 through 4, and not until May at Stations 4A and 9 through 17. Temperatures were below range after November except at Station 7.

Records to date for the 1978 season show the temperatures to be within the breeding range for the months June to November at Stations 1 and 4; June to October at Stations 2, 3 and 4; May to November at Stations 10 through 17; and April to November in Oyster Creek.

Figure B-2 depicts the months of each year when the generating plant was not operating. It may be seen that the overall temperature

TABLE B-1. WATER QUALITY AT EXPOSURE PANELS 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
4A	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 B-2. WATER QUALITY AT EXPOSURE PANEL STATIONS, JANUARY 4, 1978

Station	Time	Depth in Feet	Salinity-o/oo	Temp.-°C	O_2	pH
1	1514	7	30.6	3.0	13.4	8.0
2	1550	1	19.9	0.5	15.0	7.8
3	1627	1	25.6	2.0	14.8	7.8
4	1644	2	24.9	1.5	15.4	7.8
4A	1703	2	24.9	1.5	14.6	7.8
5	1727	2	18.5	2.5	14.6	7.5
6	1739	1	18.5	3.5	13.4	7.3
7	1750	3	17.9	6.0	14.2	7.4
8	1415	6	19.2	5.5	15.0	7.5
9	1343	6	19.9	1.5	14.8	7.7
10	1230	4	17.2	4.2	13.9	7.1
11	1330	2	18.5	1.5	14.6	7.7
12	1215	3	13.9	2.0	13.4	7.0
13	1145	3	18.5	2.0	14.9	7.6
14	1115	3	9.8	1.0	15.0	7.5
15	1030	3	14.6	-0.8	15.1	7.7
16	1000	3	10.8	1.0	14.0	7.3
17	0910	2	22.7	1.7	9.9	8.5

TABLE B-3. WATER QUALITY AT EXPOSURE PANEL STATIONS, FEBRUARY 1, 1978

Station	Time	Depth in Feet	Salinity-o/oo	Temp.-°C	O_2	pH
1	0915	6	27.0	1.2	14.7	7.9
2	0943	1	17.0	1.5	15.0	8.0
3	1013	3	17.2	-0.5	12.3	8.0
4	1030	2	20.6	-0.5	15.0	7.9
4A	1100	2	15.2	1.2	15.7	7.9
5	1115	2	17.3	3.0	14.9	7.8
6	1125	2	18.4	4.0	15.2	7.6
7	1135	3	18.0	4.4	14.4	7.7
8	1200	5	17.9	4.5	15.2	7.8
9	1217	5	19.2	0.5	14.6	8.0
10	1338	4	17.9	2.0	16.2	7.5
11	1320	2	19.2	0	14.6	8.1
12	1407	2	14.5	1.0	14.2	7.4
13	1440	3	15.2	1.5	16.0	8.0
14	1503	4	11.1	1.0	15.6	7.8
15	1623	4	11.8	0.5	15.2	7.7
16	1758	1	4.0	0.5	15.2	6.9
17	1717	1	17.2	2.0	15.8	8.2

TABLE B-4. WATER QUALITY AT EXPOSURE PANEL STATIONS, MARCH, 1978

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temp.-°C	O_2	pH
1	3/1/78	0909	8	24.3	0.6	13.0	8.5
2	3/1/78	0936	2	18.2	0.0	14.0	8.7
3	3/1/78	1000	2	15.2	1.0	15.0	8.4
4	3/1/78	1140	2	21.3	1.8	15.8	8.7
4A	3/1/78	1210	3	22.0	2.4	14.8	8.6
5	3/1/78	1330	3	19.2	6.0	16.4	8.5
6	3/1/78	1350	3	19.2	5.0	14.8	8.4
7	3/1/78	1410	3	18.9	6.0	13.4	8.5
8	3/1/78	1440	6	19.2	5.5	16.0	8.6
9	3/1/78	1450	6	19.2	1.5	15.6	8.6
10	3/1/78	1538	4	17.9	4.0	15.0	8.3
11	3/1/78	1522	4	19.2	1.0	15.2	8.6
12	3/1/78	1614	4	21.3	2.5	14.8	8.5
13	3/1/78	1648	4	15.8	2.5	15.8	8.7
14	3/1/78	1717	3	2.3	0.5	14.8	8.7
15	3/2/78	1101	3	0.6	1.0	15.6	8.5
16	3/1/78	1819	3	1.2	2.0	15.0	7.6
17	3/1/78	1015	2	23.4	2.5	10.0	8.6

TABLE B-5. WATER QUALITY AT EXPOSURE PANEL STATIONS, APRIL, 1978

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temp.-°C	O_2	pH
1	4/4/78	0939	3.0	28.4	5.5	12.4	8.0
		0942	8.0	27.7	5.2	12.6	8.0
2	4/4/78	0905	1.5	19.9	8.0	11.5	7.9
3	4/4/78	1025	1.5	21.4	7.5	11.6	7.8
4	4/4/78	1050	3.0	19.3	8.2	11.8	8.0
4A	4/4/78	1115	3.0	16.5	8.8	12.0	8.0
5	4/4/78	1133	4.5	14.6	13.5	11.5	7.7
6	4/4/78	1145	2.0	14.5	13.0	9.0	7.7
		1155	3.5	16.2	13.0	11.2	7.7
7	4/4/78	1202	6.0	15.2	15.3	11.4	7.7
8	4/4/78	1315	10.0	16.2	16.3	11.4	7.7
9	4/4/78	1400	2.0	6.1*	12.5	10.4	7.8
			6.0	13.1*			
10	4/4/78	1500	2.5	0.0*	11.2	10.8	7.9
		1505	9.0	13.5*	11.0	10.8	7.7
10A	4/5/78	1545	5.0	13.5*	11.8	12.0	7.7
10B	4/5/78	1600	1.0	2.9*	12.0	11.8	7.8
11	4/4/78	1530	2.0	14.5*	11.5	14.2	8.2
12	4/4/78	1615	5.0	2.9*	10.0	11.4	7.7
13	4/4/78	1700	2.0	1.7*	11.3	10.8	6.6
14	4/4/78	1720	4.0	2.9*	9.5	11.2	7.7
15	4/3/78	1709	4.0	11.8	8.0	12.6	7.8
16	4/4/78	1800	4.0	3.5*	8.0	11.7	8.0
17	4/3/78	1813	3.0	27.0	8.0	11.4	7.5

*Malfunction of Hydrolab.

TABLE B-6. WATER QUALITY AT EXPOSURE PANEL STATIONS, MAY, 1978

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temp.-°C	O_2	pH
1	5/2/78	1000	6	24.9	9.9	11.0	8.7
2	5/2/78	0900	2	17.9	11.5	10.6	8.5
3	5/2/78	1100	3	24.9	11.4	10.6	8.6
4	5/2/78	1125	3	24.8	12.3	10.8	8.7
4A	5/2/78	1150	2	21.0	11.5	10.7	8.7
5	5/2/78	1320	2	20.6	11.3	10.6	8.5
6	5/2/78	1332	2	19.8	17.0	10.5	8.5
7	5/2/78	1334	2	20.4	17.4	10.8	8.4
8	5/3/78	0945	1	20.5	16.5	9.8	8.3
9	5/2/78	1505	1	21.0	13.5	10.6	8.7
10	5/3/78	1140	3	14.2	13.0	9.8	8.0
10A	5/3/78	1045	2	10.5	14.5	9.5	8.5
10B	5/3/78	1105	1.5	12.5	14.0	10.9	8.5
11	5/3/78	1115	2	7.2	13.5	10.6	8.5
12	5/3/78	1200	2	19.5	13.0	10.4	8.5
13	5/3/78	1220	2	17.5	15.0	11.2	8.5
14	5/3/78	-	-	16.5	13.2	10.0	8.6
15	5/3/78	-	4	15.2	13.5	11.1	8.9
16	5/3/78	1745	2	9.8	14.5	10.4	8.6
17	5/1/78	1630	2	11.3	15.5	10.3	8.6

TABLE B-7. WATER QUALITY AT EXPOSURE PANELS STATIONS, JUNE, 1978

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temp.-°C	O_2	pH
1	5/31/78	1000	8	21.5	15.6	9.4	8.5
2	5/31/78	1040	3	17.7	21.9	9.2	8.2
3	5/31/78	1117	2	17.9	19.6	7.8	8.1
4	5/31/78	1145	5	18.5	20.0	8.1	8.0
4A	5/31/78	1200	3	17.9	21.1	8.6	8.2
5	5/31/78	1215	2	15.2	24.7	8.9	7.6
6	5/31/78	1230	2	15.8	25.2	8.9	7.6
7	5/31/78	1245	2	16.5	25.5	8.0	7.7
8	5/31/78	1350	2	16.9	26.5	7.5	7.8
9	5/31/78	1400	4	17.9	21.0	8.0	8.1
10	5/31/78	1520	5	14.5	17.5	8.3	7.2
10A	5/31/78	1435	3	16.5	25.0	8.0	8.0
10B	5/31/78	1450	4	16.5	23.0	10.5	8.5
11	5/31/78	1500	3	17.2	20.2	7.7	8.1
12	5/31/78	1540	4	15.2	21.0	9.3	8.2
13	5/31/78	1617	3	11.2	22.5	8.3	7.5
14	5/31/78	1645	3	14.5	22.5	9.0	8.3
15	5/31/78	1730	3	9.2	24.5	9.1	8.3
16	6/1/78	0815	3	15.2	21.5	9.0	8.3
17	5/31/78	0715	2	16.5	22.3	8.4	8.1

TABLE B-8. WATER QUALITY AT EXPOSURE PANEL STATIONS JULY, 1978

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temp.-°C	O_2	pH
1	7/11/78	1115	5.0	24.9	21.5	7.6	9.3
2	7/11/78	1000	1.0	18.5	24.5	6.7	9.0
3	7/11/78	1210	1.0	20.6	24.5	6.7	9.3
4	7/11/78	1230	2.0	21.3	25.0	5.2	8.8
4A	7/11/78	1300	2.0	21.3	25.5	5.6	9.0
5	7/11/78	1330	1.5	17.6	28.5	7.6	9.2
6	7/11/78	1335	1.0	17.9	29.5	8.3	9.4
7	7/11/78	1345	1.5	16.5	28.5	5.6	9.1
8	7/11/78	1355	0.5	15.5	28.0	7.6	9.3
9	7/11/78	1415	0.5	18.5	26.0	8.4	9.5
10	7/11/78	1745	2.0	14.5	24.5	4.5	8.1
10A	7/11/78	1625	0.5	18.2	25.5	8.4	9.4
10B	7/11/78	1615	0.5	18.9	24.0	9.3	9.6
11	7.11/78	1545	1.0	18.9	23.0	7.1	9.4
12	7/11/78	1800	2.5	16.2	26.5	6.5	9.6
13	7/11/78	1900	0.5	10.4	25.5	8.2	9.1
14	7/11/78	1915	0.5	13.5	25.5	7.9	9.5
15	7/12/78	0930	3.0	15.2	24.0	7.8	9.1
16	7/11/78	1945	2.0	11.1	26.0	7.4	9.2
17	7/10/78	0825	1.5	22.0	26.5	7.7	9.4

TABLE B-9. WATER QUALITY AT EXPOSURE PANEL STATIONS AUGUST, 1978

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temp.-°C	O_2	pH
1	8/8/78	0925	6.0	23.4	24.5	6.4	8.3
2	8/8/78	0855	2.0	17.9	26.0	6.2	8.0
3	8/8/78	1020	3.0	18.5	26.5	6.4	7.9
4	8/8/78	1040	3.5	20.6	26.0	5.0	7.7
4A	8/8/78	1100	3.5	20.6	26.5	7.6	8.1
5	8/8/78	1125	4.0	18.5	30.0	6.8	8.0
6	8/8/78	1137	4.0	17.9	30.0	8.0	8.0
7	8/8/78	1150	3.0	18.5	30.5	6.4	7.8
8	8/8/78	1235	6.0	19.2	30.5	7.4	8.0
9	8/8/78	1306	6.0	19.2	27.5	7.4	8.2
10	8/8/78	1525	3.0	16.5	25.0	4.1	7.5
10A	8/8/78	1415	3.5	19.9	28.5	7.2	8.3
10B	8/8/78	1405	3.5	13.8	28.0	7.8	8.2
11	8/8/78	1333	4.0	20.6	28.0	7.4	8.2
12	8/8/78	1545	3.5	18.5	26.5	7.2	8.4
13	8/8/78	1625	3.0	15.8	25.5	6.1	8.0
14	8/8/78	1700	3.0	13.1	26.0	7.2	8.6
15	8/9/78	0815	3.5	13.1	26.0	6.4	8.4
16	8/8/78	1745	4.5	10.4	27.0	4.5	7.4
17	8/8/78	1820	1.5	23.4	28.0	15.0	9.0

TABLE B-10. WATER QUALITY AT EXPOSURE PANEL STATIONS, SEPTEMBER, 1978

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temp.-°C	O_2	pH
1	9/7/78	0930	6.0	21.0	23.3	8.4	7.8
2	9/7/78	0955	2.0	19.0	24.0	7.3	7.5
3	9/7/78	1025	3.0	19.9	23.7	6.8	7.7
4	9/7/78	1040	3.0	20.4	24.0	5.0	7.4
4A	9/7/78	1055	3.0	19.5	24.5	5.4	7.5
5	9/7/78	1110	4.0	15.8	27.0	6.8	7.7
6	9/7/78	1120	4.0	15.8	25.8	7.7	7.6
7	9/7/78	1128	3.0	17.0	27.4	6.5	7.3
8	9/7/78	1151	6.0	15.8	26.0	6.2	7.4
9	9/7/78	1204	6.0	17.0	24.0	6.7	7.7
10	9/7/78	1403	3.0	11.8	25.0	7.0	7.2
10A	9/7/78	1237	3.0	17.0	24.0	7.4	7.8
10B	9/7/78	1250	3.0	17.0	24.5	8.1	7.7
11	9/7/78	1303	4.0	17.2	24.5	7.8	7.8
12	9/7/78	1427	3.0	17.2	24.5	6.5	7.7
13	9/7/78	1453	3.0	19.2	24.0	7.4	7.2
14	9/7/78	1523	3.0	13.1	25.0	8.4	7.9
15	9/7/78	1621	3.0	13.8	24.5	8.4	8.1
16	9/6/78	1600	4.0	14.6	24.3	8.3	8.2
17	9/6/78	1645	2.0	27.4	22.6	8.2	8.8

TABLE B-11. WATER QUALITY AT EXPOSURE PANEL STATIONS, OCTOBER, 1978

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temp.-°C	O_2	pH
1	10/3/78	0915	6.0	29.9	18.2	8.7	8.1
2	10/3/78	0950	2.0	23.3	17.7	8.1	8.4
3	10/3/78	1030	3.0	22.7	18.1	8.1	8.4
4	10/3/78	1047	3.5	22.7	17.8	7.8	8.5
4A	10/3/78	1100	3.5	22.7	18.3	8.4	8.7
5	10/3/78	1115	4.0	17.9	19.0	8.7	8.7
6	10/3/78	1130	4.0	17.7	18.7	9.5	8.7
7	10/3/78	1140	3.0	17.9	17.3	8.8	8.6
8	10/3/78	1155	6.0	19.2	17.5	8.8	8.7
9	10/3/78	1206	6.0	19.9	18.0	9.2	8.8
10	10/3/78	1411	3.0	19.9	19.0	7.7	9.1
10A	10/3/78	1320	3.5	20.6	18.5	9.4	9.1
10B	10/3/78	1343	3.5	22.7	19.0	8.9	9.1
11	10/3/78	1350	4.0	18.5	18.5	8.0	9.3
12	10/3/78	1423	3.5	17.2	20.0	8.4	9.2
13	10/3/78	1447	3.0	17.2	19.5	8.5	9.2
14	10/3/78	1508	3.0	15.2	18.5	8.4	9.2
15	10/3/78	1600	3.5	22.0	18.7	8.4	9.5
16	10/2/78	1602	4.5	20.6	19.7	8.4	9.4
17	10/2/78	1645	1.5	27.0	20.5	8.6	8.1

TABLE B-12. WATER QUALITY AT EXPOSURE PANEL STATIONS, NOVEMBER, 1978

Station	Date	Time	Depth in Feet	Salinity - o/oo	Temp.-°C	O_2	pH
1	11/9/78	0930	6.0	29.1	12.7	10.8	7.9
2	11/9/78	1000	2.0	23.6	11.7	10.2	8.4
3	11/9/78	1030	3.0	24.2	11.3	10.4	8.5
4	11/9/78	1055	3.5	25.6	13.3	9.6	8.5
4A	11/9/78	1107	3.5	23.4	12.3	10.1	8.7
5	11/9/78	1125	4.0	20.2	13.0	11.0	8.7
6	11/9/78	1135	4.0	19.9	12.4	10.0	8.7
7	11/9/78	1140	3.0	19.9	12.5	10.0	8.5
8	11/9/78	1200	6.0	22.7	12.5	10.0	8.8
9	11/9/78	1220	6.0	24.1	12.5	11.5	8.9
10	11/9/78	1445	3.0	22.0	13.5	8.5	8.8
10A	11/9/78	1345	3.5	23.4	12.5	10.0	9.0
10B	11/9/78	1415	3.5	23.4	12.5	10.0	9.1
11	11/9/78	1430	4.0	25.6	13.0	11.0	9.2
12	11/9/78	1510	3.5	22.0	13.5	10.0	8.9
13	11/9/78	1535	3.0	18.5	14.0	12.5	9.0
14	11/9/78	1600	3.0	23.4	13.5	12.5	9.1
15	11/8/78	1620	3.5	17.7	12.0	10.9	8.5
16	11/9/78	1620	4.5	17.7	13.5	11.0	9.1
17	11/8/78	1710	1.5	27.2	12.5	10.8	8.6

TABLE B-13. EXPOSURE PANEL STATION 1, WATER QUALITY DATA FROM DECEMBER, 1977, THROUGH NOVEMBER, 1978

Date	Time	Depth in Feet	Salinity-o/oo	Temperature-°C	O_2	pH
12/6/77	0925	7.0	28.4	8.7	8.9	7.8
1/4/78	1514	7.0	30.6	3.0	13.4	8.0
2/1/78	0915	6.0	27.0	1.2	14.7	7.9
3/1/78	0909	8.0	28.3	0.6	13.0	8.5
4/4/78	0942	8.0	27.7	5.2	6.3	8.0
5/2/78	1000	6.0	24.9	9.9	11.0	8.7
5/31/78	1000	8.0	21.5	15.6	9.4	8.5
7/11/78	1115	5.0	24.9	21.5	7.6	9.3
8/8/78	0925	6.0	23.4	24.5	6.4	8.3
9/7/78	0930	6.0	21.0	23.3	8.4	7.8
10/3/78	0915	6.0	29.9	18.2	8.7	8.1
11/9/78	0930	6.0	29.1	12.7	10.8	7.9

TABLE B-14. EXPOSURE PANEL STATION 2, WATER QUALITY DATA FROM DECEMBER, 1977, THROUGH NOVEMBER, 1978

Date	Time	Depth in Feet	Salinity-o/oo	Temperature-°C	O_2	pH
12/6/77	1015	3.0	20.0	6.4	10.9	7.8
1/4/78	1550	1.0	19.9	0.5	15.0	7.8
2/1/78	0943	1.0	17.0	1.5	15.0	8.0
3/1/78	0936	2.0	18.2	0.0	14.0	8.7
4/4/78	0905	1.5	19.9	8.0	5.8	7.9
5/2/78	0900	2.0	17.9	11.5	10.6	8.5
5/31/78	1040	3.0	17.7	21.9	9.2	8.2
7/11/78	1000	1.0	18.5	24.5	6.7	9.0
8/8/78	0855	2.0	17.9	26.0	6.2	8.0
9/7/78	0955	2.0	19.0	24.0	7.3	7.5
10/3/78	0950	2.0	23.3	17.7	8.1	8.4
11/9/78	1000	2.0	23.6	11.7	10.2	8.4

TABLE B-15. EXPOSURE PANEL STATION 3, WATER QUALITY DATA FROM DECEMBER, 1977, THROUGH NOVEMBER, 1978

Date	Time	Depth in Feet	Salinity-o/oo	Temperature-°C	O_2	pH
12/6/77	1054	3.0	20.8	6.7	10.6	8.1
1/4/78	1427	1.0	25.6	2.0	14.8	7.8
2/1/78	1013	3.0	17.2	-0.5	12.3	8.0
3/1/78	1000	2.0	15.2	1.0	15.0	8.4
4/4/78	1025	1.5	21.4	7.5	5.8	7.8
5/2/78	1100	3.0	24.9	11.4	10.6	8.6
5/31/78	1117	2.0	17.9	19.6	7.8	8.1
7/11/78	1210	1.0	20.6	24.5	6.7	9.3
8/8/78	1020	3.0	18.5	26.5	6.4	7.9
9/7/78	1025	3.0	19.9	23.7	6.8	7.7
10/3/78	1030	3.0	22.7	18.1	8.1	8.4
11/9/78	1030	3.0	24.2	11.3	10.4	8.5

TABLE B-16. EXPOSURE PANEL STATION 4, WATER QUALITY DATA FROM DECEMBER, 1977, THROUGH NOVMEBER, 1978

Date	Time	Depth in Feet	Salinity-o/oo	Temperature-°C	O_2	pH
12/6/77	1114	3.0	23.1	7.4	12.4	7.7
1/4/78	1644	2.0	24.9	1.5	15.4	7.8
2/1/78	1030	2.0	20.6	-0.5	15.0	7.9
3/1/78	1140	2.0	21.3	1.8	15.8	8.7
4/4/78	1050	3.0	19.3	8.2	5.9	8.0
5/2/78	1125	3.0	24.8	12.3	10.8	8.7
5/31/78	1145	5.0	18.5	20.0	8.1	8.0
7/11/78	1230	2.0	21.3	25.0	5.2	8.8
8/8/78	1040	3.5	20.6	26.0	5.0	7.7
9/7/78	1040	3.0	20.4	24.0	5.0	7.4
10/3/78	1047	3.5	22.7	17.8	7.8	8.5
11/9/78	1055	3.5	25.6	13.3	9.6	8.5

TABLE B-17. EXPOSURE PANEL STATION 4A, WATER QUALITY DATA FROM DECEMBER, 1977, THROUGH NOVEMBER, 1978

Date	Time	Depth in Feet	Salinity-o/oo	Temperature-°C	O_2	pH
12/6/77	1135	3.0	25.2	7.7	9.4	8.0
1/4/78	1703	2.0	24.9	1.5	14.6	7.8
2/1/78	1100	2.0	15.2	1.2	15.7	7.9
3/1/78	1210	3.0	22.0	2.4	14.8	8.6
4/4/78	1115	3.0	16.5	8.8	6.0	8.0
5/2/78	1150	2.0	21.0	11.5	10.7	8.7
5/31/78	1215	2.0	15.2	24.7	8.9	7.6
7/11/78	1300	2.0	21.3	25.5	5.6	9.0
8/8/78	1100	3.5	20.6	26.5	7.6	8.1
9/7/78	1055	3.0	19.5	24.5	5.4	7.5
10/3/78	1100	3.5	22.7	18.3	8.4	8.7
11/9/78	1107	3.5	23.4	12.3	10.1	8.7

TABLE B-18. EXPOSURE PANEL STATION 5, WATER QUALITY DATA FROM DECEMBER, 1977, THROUGH NOVEMBER, 1978

Date	Time	Depth in Feet	Salinity-o/oo	Temperature-°C	O_2	pH
12/6/77	1155	2.0	16.5	5.2	11.4	7.6
1/4/78	1727	2.0	18.5	2.5	14.6	7.5
2/1/78	1115	2.0	17.3	3.0	14.9	7.8
3/1/78	1330	3.0	19.2	6.0	16.4	8.5
4/4/78	1133	4.5	14.6	13.5	5.8	7.7
5/2/78	1320	2.0	20.6	11.3	10.6	8.5
5/31/78	1215	2.0	15.2	24.7	8.9	7.6
7/11/78	1330	1.5	17.6	28.5	7.6	9.2
8/8/78	1125	4.0	18.5	30.0	6.8	8.0
9/7/78	1110	4.0	15.8	27.0	6.8	7.7
10/3/78	1115	4.0	17.9	19.0	8.7	8.7
11/9/78	1125	4.0	20.2	13.0	11.0	8.8

TABLE B-19. EXPOSURE PANEL STATION 6, WATER QUALITY DATA FROM DECEMBER, 1977, THROUGH NOVEMBER, 1978

Date	Time	Depth in Feet	Salinity-o/oo	Temperature-°C	O_2	pH
12/6/77	1204	3.0	16.2	10.5	10.4	7.5
1/4/78	1739	1.0	18.5	3.5	13.4	7.3
2/1/78	1125	2.0	18.4	4.0	15.2	7.6
3/1/78	1350	3.0	19.2	5.0	14.8	8.4
4/4/78	1145	2.0	14.5	13.0	4.5	7.7
5/2/78	1332	2.0	19.8	17.0	10.5	8.5
5/31/78	1230	2.0	15.8	25.2	8.9	7.6
7/11/78	1335	1.0	17.9	29.5	8.3	9.4
8/8/78	1137	4.0	17.9	30.0	8.0	8.0
9/7/78	1120	4.0	15.8	25.8	7.7	7.6
10/3/78	*	4.0	17.7	18.7	9.5	8.7
11/9/78	1135	4.0	19.9	12.4	10.0	8.7

* Time not recorded.

TABLE B-20. EXPOSURE PANEL STATION 7, WATER QUALITY DATA FROM DECEMBER, 1977, THROUGH NOVEMBER, 1978

Date	Time	Depth in Feet	Salinity-o/oo	Temperature-°C	O_2	pH
12/6/77	1217	2.0	15.8	10.5	10.7	7.6
1/4/78	1750	3.0	17.9	6.0	14.2	7.4
2/1/78	1135	3.0	18.0	4.4	14.4	7.7
3/1/78	1410	3.0	18.9	6.0	13.4	8.5
4/4/78	1202	6.0	15.2	15.3	5.7	7.7
5/2/78	1345	2.0	20.4	17.4	10.8	8.4
5/31/78	1245	2.0	16.5	25.5	8.0	7.7
7/11/78	1345	1.5	16.5	28.5	5.6	9.1
8/8/78	1150	3.0	18.5	30.5	6.4	7.8
9/7/78	1128	3.0	17.0	27.4	6.5	7.3
10/3/78	*	3.0	17.9	17.3	8.8	8.6
11/9/78	1140	3.0	19.9	12.5	10.0	8.5

* Time not recorded.

TABLE B-21. EXPOSURE PANEL STATION 8, WATER QUALITY DATA FROM DECEMBER, 1977, THROUGH NOVEMBER, 1977

Date	Time	Depth in Feet	Salinity-o/oo	Temperature-°C	O_2	pH
12/6/77	1325	8.0	18.5	10.5	11.6	7.8
1/4/78	1415	6.0	19.2	5.5	15.0	7.5
2/1/78	1200	5.0	17.9	4.5	15.2	7.8
3/1/78	1440	6.0	19.2	5.5	16.0	8.6
4/4/78	1315	10.0	16.2	16.3	5.7	7.7
5/3/78	0945	1.0	20.5	16.5	9.8	8.3
5/31/78	1350	2.0	16.9	26.5	7.5	7.8
7/11/78	1355	0.5	15.5	28.0	7.6	9.3
8/8/78	1235	6.0	19.2	30.5	7.4	8.0
9/7/78	1151	6.0	15.8	26.0	6.2	7.4
10/3/78	1155	6.0	19.2	17.5	8.8	8.7
11/9/78	1200	6.0	22.7	12.5	10.0	8.8

TABLE B-22. EXPOSURE PANEL STATION 9, WATER QUALITY DATA FROM DECEMBER, 1977, THROUGH NOVEMBER, 1978

Date	Time	Depth in Feet	Salinity-o/oo	Temperature-°C	O_2	pH
12/6/77	1344	5.0	19.2	7.0	11.4	8.0
1/4/78	1343	6.0	19.9	1.5	14.8	7.7
2/1/78	1217	5.0	19.2	0.5	14.6	8.0
3/1/78	1450	6.0	19.2	1.5	15.6	8.6
4/4/78	1400	2.0	6.1*	12.5	5.2	7.9
5/2/78	1505	1.0	21.0	13.5	10.6	8.7
5/31/78	1400	4.0	17.9	21.0	8.0	8.1
7/11/78	1415	0.5	18.5	26.0	8.4	9.5
8/8/78	1306	6.0	19.2	27.5	7.4	8.2
9/7/78	1204	6.0	17.0	24.0	6.7	7.7
10/3/78	1206	6.0	19.9	18.0	9.2	8.8
11/9/78	1220	6.0	24.1	12.5	11.5	8.9

* Hydrolab salinity probe malfunctioning.

TABLE B-23. EXPOSURE PANEL STATION 10, WATER QUALITY DATA FROM DECEMBER, 1977, THROUGH NOVEMBER, 1978

Date	Time	Depth in Feet	Salinity-o/oo	Temperature-°C	O_2	pH
12/6/77	1422	3.0	17.5	7.5	10.0	7.3
1/4/78	1230	4.0	17.2	4.2	13.9	7.1
2/1/78	1338	4.0	17.9	2.0	16.2	7.5
3/1/78	1538	4.0	17.9	4.0	15.0	8.3
4/4/78	1505	9.0	13.5*	11.0	5.4	7.7
5/3/78	1140	3.0	14.2	13.0	9.8	8.0
5/31/78	1520	5.0	14.5	17.5	8.3	7.2
7/11/78	1745	2.0	14.5	24.5	4.5	8.1
8/8/78	1525	3.0	16.5	25.0	4.1	7.5
9/7/78	1403	3.0	11.8	25.0	7.0	7.2
10/3/78	1410	3.0	19.9	19.0	7.7	9.1
11/9/78	1445	3.0	22.0	13.5	8.5	8.8

* Hydrolab salinity probe malfunctioning.

TABLE B-24. EXPOSURE PANEL STATION 10A, WATER QUALITY DATA FROM APRIL, 1978*, THROUGH NOVEMBER, 1978

Date	Time	Depth in Feet	Salinity-o/oo	Temperature-°C	O_2	pH
4/4/78	1545	5.0	13.5**	11.8	6.0	7.7
5/3/78	1045	2.0	10.5	14.5	9.5	8.5
5/31/78	1435	3.0	16.5	25.0	8.0	8.0
7/11/78	1625	0.5	18.2	25.5	8.4	9.4
8/8/78	1415	3.5	19.9	28.5	7.2	8.3
9/7/78	1237	3.0	17.0	24.0	7.4	7.8
10/3/78	1320	3.5	20.6	18.5	9.4	9.1
11/9/78	1345	3.5	23.4	12.5	10.0	9.0

* Station 10A established April, 1978.
** Hydrolab salinity probe malfunctioning.

TABLE B-25. EXPOSURE PANEL STATION 10B, WATER QUALITY DATA FROM APRIL, 1978*, THROUGH NOVEMBER, 1978

Date	Time	Depth in Feet	Salinity-o/oo	Temperature-°C	O_2	pH
4/4/78	1600	1.0	2.9**	12.0	5.9	7.8
5/3/78	1105	1.5	10.5	14.0	10.9	8.5
5/31/78	1450	4.0	16.5	23.0	10.5	8.5
7/11/78	1615	0.5	18.9	24.0	9.3	9.6
8/8/78	1405	3.5	13.8	28.0	7.8	8.2
9/7/78	1250	3.0	17.0	24.5	8.1	7.7
10/3/78	1343	3.5	22.7	19.0	8.9	9.1
11/9/78	1415	3.5	23.4	12.5	10.0	9.1

* Station 10B established April, 1978.
** Hydrolab salinity probe malfunctioning.

TABLE B-26. EXPOSURE PANEL STATION 11, WATER QUALITY DATA FROM DECEMBER, 1977, THROUGH NOVEMBER, 1978

Date	Time	Depth in Feet	Salinity-o/oo	Temperature-°C	O_2	pH
12/6/77	1403	3.0	19.2	6.5	11.6	8.0
1/4/78	1330	2.0	18.5	1.5	14.6	7.7
2/1/78	1320	2.0	19.2	0.0	14.6	8.1
3/1/78	1522	4.0	19.2	1.0	15.2	8.6
4/4/78	1530	2.0	14.5*	11.5	7.1	8.2
5/3/78	1115	2.0	12.5	13.5	10.6	8.5
5/31/78	1500	3.0	17.2	20.2	7.7	8.1
7/11/78	1545	1.0	18.9	23.0	7.1	9.4
8/8/78	1333	4.0	20.6	28.0	7.4	8.2
9/7/78	1303	4.0	17.2	24.5	7.8	7.8
10/3/78	1350	4.0	18.5	18.5	8.0	9.3
11/9/78	1430	4.0	25.6	13.0	11.0	9.2

* Hydrolab salinity probe malfunctioning.

TABLE B-27. EXPOSURE PANEL STATION 12, WATER QUALITY DATA FROM DECEMBER, 1977, THROUGH NOVEMBER, 1978

Date	Time	Depth in Feet	Salinity-o/oo	Temperature-°C	O_2	pH
12/6/77	1440	3.0	17.2	5.5	11.4	7.8
1/4/78	1330	2.0	18.5	1.5	14.6	7.7
2/1/78	1320	2.0	19.2	0.0	14.6	8.1
3/1/78	1614	4.0	21.3	2.5	14.8	8.5
4/4/78	1615	5.0	2.9*	10.0	5.7	7.7
5/3/78	1200	2.0	19.5	13.0	10.4	8.5
5/31/78	1540	4.0	15.2	21.0	9.3	8.2
7/11/78	1800	2.5	16.2	26.5	6.5	9.6
8/8/78	1545	3.5	18.5	26.5	7.2	8.4
9/7/78	1427	3.0	17.2	24.5	6.5	7.7
10/3/78	1423	3.5	17.2	20.0	8.4	9.2
11/9/78	1510	3.5	22.0	13.5	10.0	8.9

* Hydrolab salinity probe malfunctioning.

TABLE B-28. EXPOSURE PANEL STATION 13, WATER QUALITY DATA FROM DECEMBER, 1977, THROUGH NOVEMBER, 1978

Date	Time	Depth in Feet	Salinity-o/oo	Temperature-°C	O_2	pH
12/6/77	1502	2.0	9.2	5.5	11.0	7.1
1/4/78	1145	3.0	18.5	2.0	14.9	7.6
2/1/78	1440	3.0	15.2	1.5	16.0	8.0
3/1/78	1648	4.0	15.8	2.5	15.8	8.7
4/4/78	1700	2.0	1.7*	11.3	5.4	6.6
5/3/78	1220	2.0	17.5	15.0	11.2	8.5
5/31/78	1617	3.0	11.2	22.5	8.3	7.5
7/11/78	1900	0.5	10.4	25.5	8.2	9.1
8/8/78	1625	3.0	15.8	25.5	6.1	8.0
9/7/78	1453	3.0	19.2	24.0	7.4	7.2
10/3/78	1447	3.0	17.2	19.5	8.5	9.2
11/9/78	1535	3.0	18.5	14.0	12.5	9.0

* Hydrolab salinity probe malfunctioning.

TABLE B-29. EXPOSURE PANEL STATION 14, WATER QUALITY DATA FROM DECEMBER, 1977, THROUGH NOVEMBER, 1978

Date	Time	Depth in Feet	Salinity-o/oo	Temperature-°C	O_2	pH
12/6/77	1527	3.0	17.9	5.5	11.0	7.9
1/4/78	1115	3.0	9.8	1.0	15.0	7.5
2/1/78	1503	4.0	11.1	1.0	15.6	7.8
3/1/78	1717	3.0	2.3	0.5	14.8	8.7
4/4/78	1720	4.0	2.9*	9.5	5.6	7.7
5/3/78	**	**	16.5	13.2	10.0	8.6
5/31/78	1645	3.0	14.5	22.5	9.0	8.3
7/11/78	1915	0.5	13.5	25.5	7.9	9.5
8/8/78	1700	3.0	13.1	26.0	7.2	8.6
9/7/78	1523	3.0	13.1	25.0	8.4	7.9
10/3/78	1508	3.0	15.2	18.5	8.4	9.2
11/9/78	1600	3.0	23.4	13.5	12.5	9.1

* Hydrolab salinity probe malfunctioning.
** Time and depth of water not recorded.

TABLE B-30. EXPOSURE PANEL STATION 15, WATER QUALITY DATA FROM DECEMBER, 1977, THROUGH NOVEMBER, 1978

Date	Time	Depth in Feet	Salinity-o/oo	Temperature-°C	O_2	pH
12/7/77	0925	4.0	17.2	4.5	12.4	7.9
1/4/78	1030	3.0	14.6	-0.8	15.1	7.7
2/1/78	1623	4.0	11.8	0.5	15.2	7.7
3/2/78	1101	3.0	0.6	1.0	15.6	8.5
4/3/78	1709	4.0	11.8	8.0	6.3	7.9
5/3/78	*	4.0	15.2	13.5	11.1	8.9
5/31/78	1730	3.0	9.2	24.5	9.1	8.3
7/12/78	0930	3.0	15.2	24.0	7.8	9.1
8/9/78	0815	3.5	13.1	26.0	6.4	8.4
9/7/78	1621	3.0	13.8	24.5	8.4	8.1
10/3/78	1600	3.5	22.0	18.7	8.4	9.5
11/8/78	1620	3.5	17.7	12.0	10.9	8.5

* Time not recorded.

TABLE B-31. EXPOSURE PANEL STATION 16, WATER QUALITY DATA FROM DECEMBER, 1977, THROUGH NOVEMBER, 1978

Date	Time	Depth in Feet	Salinity-o/oo	Temperature-°C	O_2	pH
12/6/77	1647	3.0	13.2	6.0	12.4	7.8
1/4/78	1010	3.0	10.8	1.0	14.0	7.3
2/1/78	1758	1.0	4.0	0.5	15.2	6.9
3/1/78	1819	3.0	1.2	2.0	15.0	7.6
4/4/78	1800	4.0	3.5*	8.0	5.9	8.0
5/3/78	1745	2.0	9.8	14.5	10.4	8.6
6/1/78	0815	3.0	15.2	21.5	9.0	8.3
7/11/78	1945	2.0	11.1	26.0	7.4	9.2
8/8/78	1745	4.5	10.4	27.0	4.5	7.4
9/6/78	1600	4.0	14.6	24.3	8.3	8.2
10/2/78	1602	4.5	20.6	19.7	8.4	9.4
11/9/78	1620	4.5	17.7	13.5	11.0	9.1

* Hydrolab salinity probe malfunctioning.

TABLE B-32. EXPOSURE PANEL STATION 17, WATER QUALITY DATA FROM DECEMBER, 1977, THROUGH NOVEMBER, 1978

Date	Time	Depth in feet	Salinity-o/oo	Temperature-°C	O_2	pH
12/6/77	1630	2.5	25.6	6.5	12.6	8.1
1/4/78	0910	2.0	22.7	1.7	9.9	8.5
2/1/78	1717	1.0	17.2	2.0	15.8	8.2
3/2/78	1015	2.0	23.4	2.5	10.0	8.6
4/3/78	1813	3.0	27.0	8.0	5.7	7.5
5/1/78	1630	2.0	11.3	15.5	10.3	8.6
5/31/78	0715	2.0	16.5	22.3	8.4	8.1
7/10/78	0825	1.5	22.0	26.5	7.7	9.4
8/8/78	1820	1.5	23.4	28.0	15.0	9.0
9/6/78	1645	2.0	27.4	22.6	8.2	8.8
10/2/78	1645	1.5	27.0	20.5	8.6	8.1
11/8/78	1710	1.5	27.2	12.5	10.8	8.6

TABLE B-33. MEAN, STANDARD DEVIATION, MINIMUM AND MAXIMUM WATER QUALITY VALUES OBSERVED DURING EACH MONTH AT EXPOSURE PANEL STATIONS IN BARNEGAT BAY, NEW JERSEY FROM DECEMBER, 1977, THROUGH NOVEMBER, 1978

		Mean	Standard Deviation	Minimum	Maximum
	Dec 1977	7.1	1.8548	4.5	10.5
	Jan 1978	2.2	1.6949	-0.8	6.0
	Feb	1.2	1.8285	-0.5	4.5
	Mar	2.5	1.9452	0.0	6.0
	Apr	10.5	2.8439	5.2	15.3
Temperature	May	13.6	2.0131	9.9	17.4
	Jun	22.1	2.7538	15.6	26.5
	Jul	25.6	1.9526	21.5	29.5
	Aug	27.3	1.8229	24.5	30.5
	Sep	24.6	1.1640	22.6	27.4
	Oct	18.6	.8372	17.3	20.5
	Nov	12.7	.6769	11.3	14.0
	Dec 1977	18.9	4.5736	9.2	28.4
	Jan 1978	19.2	5.2297	9.8	30.6
	Feb	16.6	4.6527	4.0	27.0
	Mar	16.6	7.3663	0.6	24.3
	Apr	13.6	7.6857	1.7	27.7
Salinity	May	17.2	4.6535	9.8	24.9
	Jun	17.2	4.2542	9.2	27.0
	Jul	17.6	3.6152	10.4	24.9
	Aug	18.0	3.3764	10.4	23.4
	Sep	17.5	3.3823	11.8	27.4
	Oct	20.7	3.5286	15.2	29.9
	Nov	22.7	3.0845	17.2	29.1
	Dec 1977	7.8	.2679	7.1	8.1
	Jan 1978	7.6	.3468	7.0	8.5
	Feb	7.8	.3027	6.9	8.2
	Mar	8.5	.2521	7.6	8.7
	Apr	7.8	.3170	6.6	8.2
pH	May	8.5	.1818	8.0	8.9
	Jun	8.0	.3453	7.2	8.5
	Jul	9.2	.3376	8.1	9.6
	Aug	8.1	.3656	7.4	9.0
	Sep	7.7	.3713	7.2	8.8
	Oct	8.8	.4160	8.1	9.5
	Nov	8.7	.3137	7.9	9.2
	Dec 1977	11.1	1.0286	8.9	12.6
	Jan 1978	14.2	1.2460	9.9	15.4
	Feb	15.0	.8676	12.3	16.2
	Mar	14.7	1.4619	10.0	16.4
	Apr	5.8	.4998	4.5	7.1
Dissolved Oxygen	May	10.5	.4483	9.5	11.2
	Jun	8.6	.7199	7.5	10.5
	Jul	7.2	1.2254	4.5	9.5
	Aug	7.0	2.1543	4.1	15.0
	Sep	7.2	.9922	5.0	8.4
	Oct	8.5	.4838	7.7	9.5
	Nov	10.5	.9355	9.6	12.5

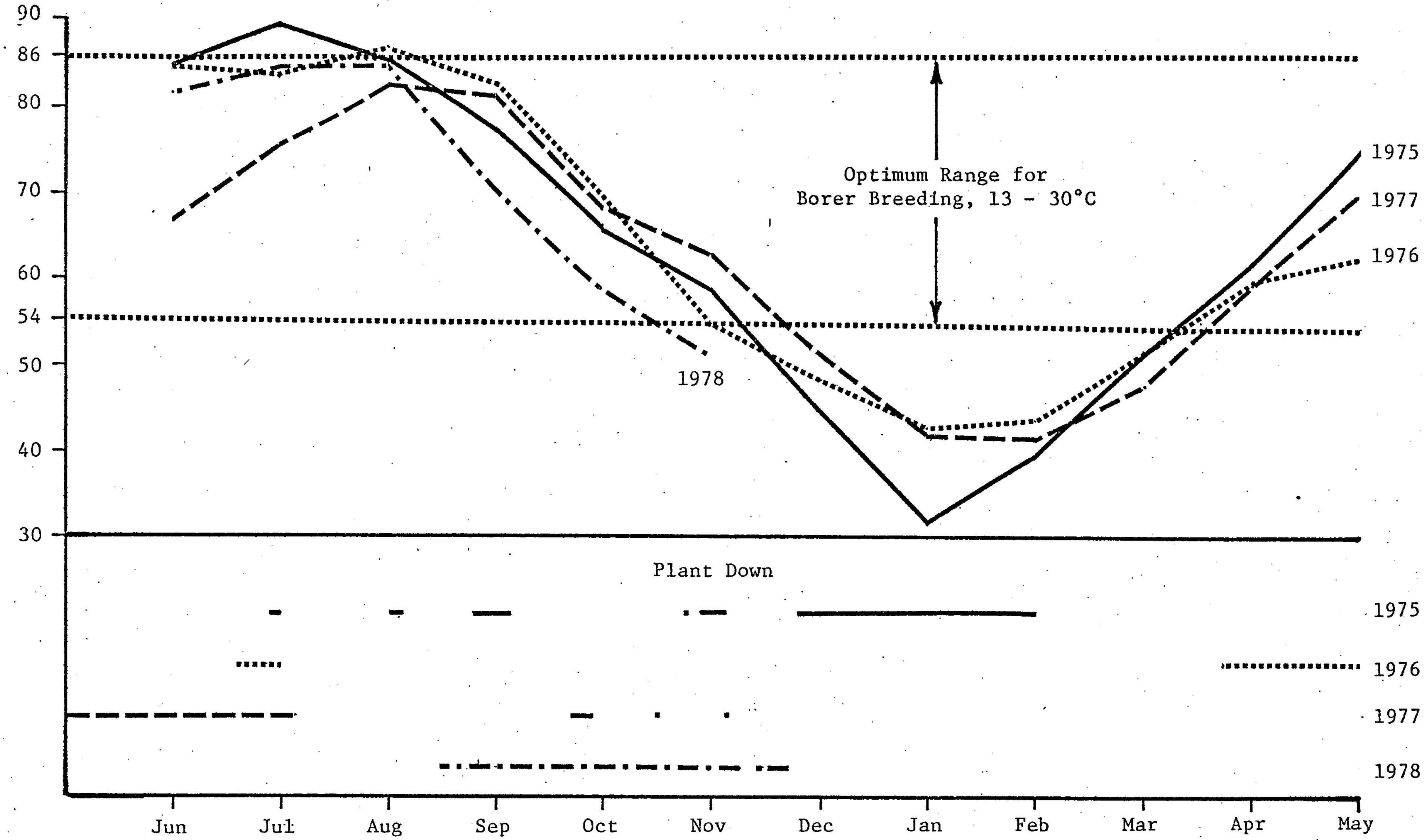

FIGURE B-2. MONTHLY AVERAGE WATER TEMPERATURE °F AT OYSTER CREEK RAILROAD BRIDGE FROM JUNE, 1975, THROUGH NOVEMBER, 1978

Data from Jersey Central Power and Light Company.

TABLE B-34. 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
settle	23-31	10-30			Richards, 1978
Adults				4-5	Mawatari, 1950
			Lab 0.98 mg/1 Natural 9.59-10.30 mg/1		Roch, F., 1932
Bankia gouldi					
Adult	5-33	10-35			Turner, 1973
spawn	17.5-30 16-20	10-32			Turner, 1973 Scheltema and Truitt, 1954
settle	24-27				Maznik, 1977
Adult		14-35	>2-3		Allen, 1924
Teredo furcifera					
Adult	24-33	15			Karande, 1968
Teredo bartschi					
settle	18.6-30.5	17-19			Richards et al. 1978

patterns are similar for each season but the down-times vary. The greatest drop in water temperature occurred between December, 1975 and February, 1976 when the plant was down and the water temperature in Oyster Creek was comparable to the rest of Barnegat Bay. Each season the water temperature in the creek was below the teredinid breeding range (Table B-34) for December through March. During this period, winter-kills could occur.

Since the plant down-times in 1976 and 1977 were during the summer months when ambient temperatures were in the optimum breeding range, there was no effect of the generating plant.

In June through August, 1978, the water temperature was not as high as during the same period in 1975 and 1976 but dropped earlier in the fall due to non-operation of the generating plant after September 16, 1978. The thermal effect on *Teredo bartschi* was apparent from the decline in settlement from >1000 in September to a total of 21 in October. A similar decline in temperature and *T. bartschi* abundance occurred in 1977 with the plant in operation.

Reference to Tables B-13, B-27, and B-29 show that similar water temperature patterns occurred at Stations 1, 12 and 14 which had heavy attack by *Teredo navalis* (Station 1) and *Bankia gouldi* (Stations 12 and 14). These stations are beyond the influence of the thermal plume so that they were not affected by the operation of the generating plant.

An analysis of variance (Tables B-35 through B-38) was performed on water quality parameters observed during the teredinid breeding season. There was no significant differences in pH among the stations. Using the Tukey statistic, slight station differences were found in the temperature and dissolved oxygen observations. Larger differences between stations were observed using salinity readings. Figure B-3 shows the results of station comparisons. Salinity was greatest at Station 1 at the Inlet. Salinity at Station 5, mouth of Oyster Creek, was less than at Stations 1, 2, 3, 4, 9, 11 and 17 but not significantly (α = .05) different from Stations 6, 7, 8 and 12. Salinity at Stations 10, 13, 14,

TABLE B-35. TWO FACTOR ANALYSIS OF VARIANCE OF pH RECORDED DURING THE BREEDING SEASON IN BARNEGAT BAY BY STATION* AND MONTH FOR THE PERIOD JULY, 1975, THROUGH NOVEMBER, 1978

Source of Variation	Sum of Squares	DF	Mean Squares	F	Significance of F
Month	7.459	7	1.066	4.474	.001
Station	3.692	16	.231	.969	.491**
Month/Station Interaction	9.322	112	.083	.349	.999**
Residual	63.122	265	.238		
Total	83.600	400	.209		

* Stations 4A, 10A, and 10B omitted due to insufficient data.
** Not significant.

TABLE B-36. TWO FACTOR ANALYSIS OF VARIANCE OF TEMPERATURE RECORDED DURING THE BREEDING SEASONS IN BARNEGAT BAY BY STATION* AND MONTH FOR THE PERIOD JULY, 1975, THROUGH NOVEMBER, 1978

Source of Variation	Sum of Squares	DF	Mean Squares	F	Significance of F
Month	34645.642	7	4949.377	723.306	.001
Station	528.421	16	33.026	4.826	.001
Month/Station Interaction	271.606	112	2.425	.354	.999**
Residual	1806.478	264	6.843		
Total	37063.764	399			

* Stations 4A, 10A, and 10B omitted due to insufficient data.
** Not Significant.

TABLE B-37. TWO FACTOR ANALYSIS OF VARIANCE OF DISSOLVED OXYGEN RECORDED DURING THE BREEDING SEASON IN BARNEGAT BAY BY STATION* AND MONTH FOR THE PERIOD JULY, 1975, THROUGH NOVEMBER, 1978

Source of Variation	Sum of Squares	DF	Mean Squares	F	Significance of F
Month	2957.935	7	422.562	175.611	.001
Station	79.979	16	4.999	2.077	.010
Month/Station Interaction	252.972	112	2.259	.939	.645**
Residual	637.653	265	2.406		
Total	3946.962	400	9.867		

* Stations 4A, 10A, and 10B omitted due to insufficient data.
** Not significant.

TABLE B-38. TWO FACTOR ANALYSIS OF VARIANCE OF SALINITY RECORDED DURING THE BREEDING SEASON IN BARNEGAT BAY BY STATION* AND MONTH FOR THE PERIOD JULY, 1975, THROUGH NOVEMBER, 1978

Source of Variation	Sum of Squares	DF	Mean Squares	F	Significance of F
Month	2876.344	7	410.906	15.595	.001
Station	3985.880	16	249.118	9.455	.001
Month/Station Interaction	2102.812	112	18.775	.713	.980**
Residual	6956.035	264	26.349		
Total	15886.511	399	39.816		

* Stations 4A, 10A, and 10B omitted due to insufficient data.
** Not significant.

15 and 16 was significantly less than at any of the other locations but still was within teredinid breeding range (Table B-34).

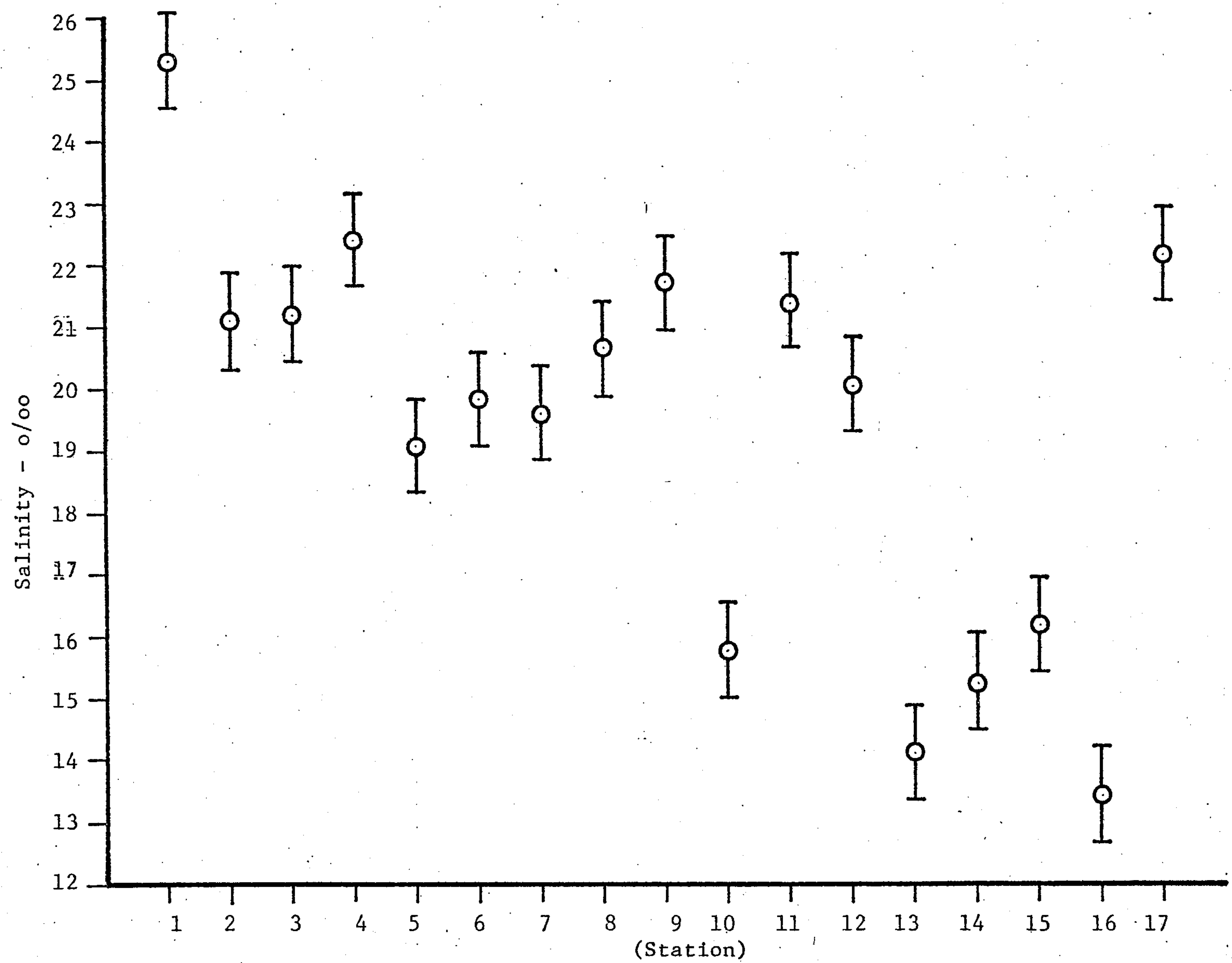

FIGURE B-3. COMPARISON ON MEAN BREEDING SEASON SALINITY AS RESULT OF ANOVA (α = 0.05) FOR STATIONS IN BARNEGAT BAY AUGUST, 1975, THROUGH NOVEMBER, 1978

Stations 4A, 10A and 10B not included due to insufficient data.

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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 through August, 1977 (Richards et al., 1978) did not suggest any major alteration in breeding patterns around Barnegat Bay. The studies continued, and the data reported below summarize the results of observations made throughout the program from August, 1975, through November, 1978.

The occurrence of a species of protozoan parasite in the various species of *Teredo* in Barnegat Bay was discussed in the previous annual report by Battelle to Jersey Central Power & Light (Richards et al., 1978). Because of the often extensive tissue damage to *Teredo*, it was felt that this parasite could have an effect on the abundance and distribution of the borers in Barnegat Bay, and could help explain some of the variations in abundance observed during the overall program. For that reason, more extensive observations of the histopathology of the shipworms collected for gonad analysis were begun in January, 1977. The results of these histopathological studies will also be reported on here.

Materials and Methods

Teredine borers were removed in the laboratory from exposure panels retrieved from Barnegat Bay. Details of the retrieval schedule are given in Appendix A. With the six-month retrieval schedule, there were four months of the year (April through July) when no borers were recovered from the panels because they were immersed when no larvae were in the water. In order to obtain gonad information during those critical spring periods, two special panels, retrieved on an annual basis, were installed in May and June of 1976 at each station. This enables us to obtain some information on the early spring gonadal patterns. In addition, there were separate racks at Stations 2 and 17 to provide additional information on the parasites of *Teredo*.

Upon removal from the exposure panels, the shipworms are placed in one of a variety of fixatives. During the first year or so, when specimens were being shipped to Battelle's Columbus, Ohio facility for sectioning, there were fixed in Bouin's fixative. Since processing was begun at the Duxbury facility the specimens have been fixed in Zenker's, Davidson's, and most recently, Helly's fixative. Each of the fixatives was suitable for the original purpose of the study, i.e., gonad analysis. Helly's fixative, however, may be more useful for pathology studies as well as the gonad studies.

Fixation was generally for about 24 hours, followed by rinsing with 70 percent denatured ethanol. The gonad-containing portion of each shipworm was excised, dehydrated further in ethanol, placed in two changes of methyl benozate and cleared in three changes of xylene. They were embedded in Paraplast and sectioned at six microns. Since January, 1978 at least two slides of each specimen have been prepared. One slide has been stained in hematoxylin and eosin for gonad analysis; the second slide has been stained with Masson's trichrome and used with the hematoxylin and eosin-stained slides for pathological analysis. Occasional slides have been stained with the fluorescent stain, acridine orange.

The slides were examined microscopically to determine the stage of gonad development at the time the exposure panels were removed from the water. Beacuse the Teredinidae are bivalve molluscs, 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 spermotogonia 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.

The slides were also examined for any pathological conditions, including parasites.

Results and Discussion

Gonad analysis. Through November, 1978, a total of 1,363 teredinid borers were examined histologically for gonad condition. This number includes 494 *Teredo navalis*, 24 *Teredo furcifera*, 98 *Teredo bartschi*, 48 immature *Teredo* too small to be identified to species, and 699 *Bankia gouldi*. The stage of gonad development found in each specimen collected from November, 1975 through November, 1978 is shown is Table C-1 .

As in past years, no clear pattern of thermal influence on gonadal cycles of the borers has been demonstated although it is obvious that without the elevated temperature in the discharge canal, *Teredo bartschi* would not be established there as a breeding population.

Reproductive patterns of the most abundant species are discussed below:

TABLE C-1. NUMBERS OF SPECIMENS AND STAGE OF GONAD DEVELOPMENT OF TEREDINE BORERS IN EXPOSURE PANELS AT STATIONS IN BARNEGAT BAY, NEW JERSEY FROM NOVEMBER, 1975, THROUGH NOVEMBER, 1978

EA = Early Active; LA = Late Active; R = Ripe; PS = Partially Spawned; S = Spent; NG = No Discernable Gonad.

			1975		1976								1977								1978										
			Nov	Dec	Jan	Feb	Mar	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Station 1	*Teredo navalis*	EA							2	1							1	3					2					1		9	8
		LA				1	2	1	3			6			11		6		3	5		6			4	1					7
		R				1		2	4		1						3	3	1			4			13	5			2		
		PS																	1						3	3			1	1	
		S																													
		NG	1						1	1							4	4	1	1			6								
	Bankia gouldi	EA								1																					
		LA																													
		R																													
		PS																													
		S																													
		NG																													
Station 2	*Teredo navalis*	EA																			2						1			3	1
		LA	1			2															1										4
		R			2	1																									
		PS																													
		S																													
		NG																													
	Teredo furcifera	EA																													
		LA	1		1																										
		R																													
		PS																													
		S																													
		NG						1																							
	Bankia gouldi	EA	1	2	2	1																									
		LA				1																									
		R																													
		PS																													
		S																													
		NG																													

TABLE C-1. Continued

			1975		1976								1977								1978										
			Nov	Dec	Jan	Feb	Mar	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Station 3	*Bankia goulgi*	EA	4	3	4													1			2										
		LA				1																									
		R																													
		PS																													
		S																													
		NG																													
Station 4	*Teredo navalis*	EA																													
		LA																													
		R																													
		PS		1																											
		S																													
		NG																													
	Teredo furcifera	EA																													
		LA													1																
		R																													
		PS																													
		S																													
		NG																													
	Teredo spp.	EA																													
		LA	1																												
		R																													
		PS																													
		S							1																						
		NG						1	1																						
	Bankia gouldi	EA	3	2	4	2		1		1	4	4							1		1			2						1	1
		LA	1	1																					1					1	
		R																													
		PS																													
		S							1																						
		NG						1	1								2												1	1	
Station 4A	*Bankia gouldi*	EA																3			1									1	
		LA																													
		R															1	1													
		PS																													
		S																													
		NG																		1											

TABLE C-1. Continued

			1975		1976								1977								1978										
			Nov	Dec	Jan	Feb	Mar	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Station 5	*Teredo bartschi*	EA																											1		
		LA																													
		R																													2
		PS																											2	3	2
		S																											2	1	1
		NG																											4	1	4
	Bankia gouldi	EA		1	1				1	1	3			1				3	1	2	1										
		LA	2																												
		R						1		2							2														
		PS																													
		S																												1	
		NG															1		3	1											1
Station 6	*Teredo bartschi*	EA																													
		LA																													
		R																													
		PS																												1	4
		S																													1
		NG			1																										
	Bankia gouldi	EA		5	2				1						1																
		LA	1		1	1																									
		R																													
		PS																													
		S																													
		NG																		1											
Station 7	*Teredo navalis*	EA									1													2							
		LA										1																			
		R																													
		PS																													
		S																													
		NG								1																					
	Teredo furcifera	EA																													
		LA																													
		R							1																						
		PS																													
		S																													
		NG																													

TABLE C-1. Continued

Station	Species	Stage	1975 Nov	1975 Dec	1976 Jan	1976 Feb	1976 Mar	1976 Aug	1976 Sep	1976 Oct	1976 Nov	1976 Dec	1977 Jan	1977 Feb	1977 Mar	1977 Aug	1977 Sep	1977 Oct	1977 Nov	1977 Dec	1978 Jan	1978 Feb	1978 Mar	1978 Apr	1978 May	1978 Jun	1978 Jul	1978 Aug	1978 Sep	1978 Oct	1978 Nov
Station 7 (continued)	*Teredo bartschi*	EA																													
		LA																													
		R									1						1	1	2	3	2	1					3		1		
		PS									1						2	2		1	1	2					9		6		4
		S																											2		4
		NG									3						3	1	4	1	2				1		4		2		1
	Teredo spp.	EA																													
		LA																													
		R		2																											
		PS																													
		S																													
		NG																													
	Bankia gouldi	EA								3	3	1	2	1				2	1	3	2				1						2
		LA														3									2						
		R						1								2									1	2					
		PS		1												1	1									3			1		
		S								2																					
		NG										1						2		2											
Station 8	*Teredo navalis*	EA																													
		LA		1																											
		R							1																						
		PS				1																									
		S																													
		NG																													
	Bankia gouldi	EA	3	1	1				1	1	1	5									1				3						
		LA																													
		R															1														
		PS	1					1																							
		S							1												1										
		NG																		1											1
Station 9	*Teredo navalis*	EA																		1											
		LA																													
		R				1																									
		PS																													
		S																													
		NG																													

TABLE C-1. Continued

			1975		1976								1977								1978										
			Nov	Dec	Jan	Feb	Mar	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Station 9 (continued)	*Teredo* spp.	EA								1																					
		LA																													
		R																													
		PS																													
		S																													
		NG																													
	Bankia gouldi	EA	1	1						1											1										
		LA	2					1																							
		R																													
		PS				1																				1					
		S																													
		NG																			1				1						
Station 10	*Teredo navalis*	EA																													
		LA	1																												
		R																													
		PS																													
		S																													
		NG																													
	Bankia gouldi	EA		2	1				1			2						1		1											
		LA			2																										
		R																													
		PS																								1					
		S																													
		NG		1						1							1	1	1	1											
Station 10A	*Bankia gouldi*	EA																												2	1
		LA																													
		R																											1		
		PS																													
		S																											1		
		NG																										1		2	1
Station 10B	*Bankia gouldi*	EA																												2	
		LA																										1			
		R																													
		PS																													
		S																													
		NG																													

TABLE C-1. Continued

Station	Species	Stage	1975 Nov	1975 Dec	1976 Jan	1976 Feb	1976 Mar	1976 Aug	1976 Sep	1976 Oct	1976 Nov	1976 Dec	1977 Jan	1977 Feb	1977 Mar	1977 Aug	1977 Sep	1977 Oct	1977 Nov	1977 Dec	1978 Jan	1978 Feb	1978 Mar	1978 Apr	1978 May	1978 Jun	1978 Jul	1978 Aug	1978 Sep	1978 Oct	1978 Nov
Station 11	*Teredo navalis*	EA							1		2			4					1	1						1		1			
		LA							2		6	5		2							1										
		R							2		2																				
		PS			2																										
		S							1																						
		NG							2		1			1																	1
	Teredo furcifera	EA																													
		LA												2																	
		R																													
		PS																													
		S																													
		NG												1																	
	Teredo spp.	EA																													
		LA												1																	
		R																													
		PS																													
		S																													
		NG																													
	Bankia gouldi	EA	3	2	1	3			1		8	3		7				3	2	3								3		6	7
		LA			1	1			2		1			1		1										2				1	1
		R							1								1														
		PS																													
		S															1	1	2	1											
		NG							2		1			1			6	2	3	2								2		1	
Station 12	*Bankia gouldi*	EA		2	3	3		1	3	5	6	2			3				3	3	3			1		1					
		LA		1		1											2									1					
		R																													
		PS																													
		S														1															
		NG								1	1	1			1		1		2	3	1										
Station 13	*Bankia gouldi*	EA	2	2					1	6	5	4		1			2	3	3	2	3				4	1		2			6
		LA		1					1		1	1		3				1										1			
		R						5									1														
		PS																													
		S							4																						
		NG										1					3		4	3	1										1

TABLE C-1. Continued

			1975		1976								1977								1978										
			Nov	Dec	Jan	Feb	Mar	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Station 14	*Bankia gouldi*	EA	4		1	1			2	3	3	6			2	1	3	6	4	2	3	1			6				2		11
		LA				1		1		2	3																				
		R						1								1															
		PS							1																						
		S		1					1																						
		NG		1		1				1							1		1	2	1										
Station 15	*Teredo navalis*	EA	1						1										1												
		LA				3																			1						
		R		2	2	1						1																			
		PS			1																										
		S																													
		NG	1														1														
	Bankia gouldi	EA	1		1					1	1	2																		1	
		LA		2	1			2																							
		R						1																							
		PS																													
		S																													
		NG																													
Station 16	*Bankia gouldi*	EA	4	1																		1									
		LA			1																										
		R																													
		PS																													
		S																													
		NG																													
Station 17	*Teredo navalis*	EA		1							1										2	2	1						2	1	1
		LA	2	3		4				2	4	4			2					1											3
		R			1							1																			1
		PS			1															1						2					
		S																			1										
		NG			1					2																					
	Bankia gouldi	EA	1																												1
		LA																													
		R																													
		PS																													
		S																											1		
		NG																													

Bankia gouldi. The most ubiquitous species of the teredinid borer in Barnegat Bay has been *Bankia gouldi*, which appeared at every station at least once throughout the study. In general, the gonadal patterns exhibited by this species were what would be expected. Gonadal activity was greatest in the spring with late active to spent gonads generally having been found from May through October. There were some exceptions to this pattern at stations in the vicinity of the discharge canal. At Station 7, for example, a specimen of *Bankia gouldi* was found in December, 1975 with a partially spent gonad (Table C-1), and a ripe specimen was found in May, 1978 from the panel submerged in May, 1977. All *Bankia* examined from that station were spawned out by October, however. At Stations 8 and 9, partially spent to spent gonads were found as late as January and February, but relatively few *Bankia* have been found at these stations after 1976. Spent gonads were found at Station 11 from September through December 1977 but by 1978, the *Bankia* from that site were examined for gonad condition during those months were primarily in the early active stage with a few in the late active stage or having no discernable gonad. One specimen with a spent gonad was found at Station 14 in December, 1975 but the pattern of development was normal from then November, 1978.

Teredo navalis. *Teredo navalis* occurred, over the course of the study, at ten of the 20 stations. As with the reproductive patterns exhibited in *Bankia gouldi*, there were no indications from the *Teredo navalis* gonadal tissues examined that breeding cycles of that species were affected, except perhaps within the thermal plume itself, and there were very few specimens of *Teredo navalis* recovered from thermally affected sites.

At Station 1, in Barnegat Inlet, ripe gonads were found in February of 1976 and 1978, with partially spent gonads being found as early as May (Table C-1). At Station 17, also on the eastern side of Barnegat Bay, partially spent gonads were found in January, 1976. Ripe gonads were found in December 1976 and 1977 and spent gonads in January, 1978.

Ripe or partially spent gonads also were found in January and February, 1976 at Stations 2, 7, 8, 9, 11 and 15. It is not definite whether these specimens were actively spawning or getting ready to spawn, or whether gonadal activity was suspended by the cold water. There is no evidence from earlier planktonic studies (Richards, et al, 1976) that teredinid larvae are in the water during the colder months.

Teredo bartschi. Specimens of *Teredo bartschi*, examined histologically have come only from Stations 5, 6 and 7. Gonads were examined from specimens of *Teredo bartschi* collected from Station 5 only in 1978. Ripe to partially spent gonads were found from September through November with many specimens having no discernable gonad, but having larvae in the brood pouch. At Station 6, one specimen of *Teredo bartschi* was found with no discernable gonad in January, 1976, and there was one ripe specimen in October. In November, four ripe and one partially spent specimen were examined.

Most *Teredo bartschi* examined were collected at Station 7 in 1977 and 1978. Ripe and/or partially spent gonads were observed from August, 1977 through February, 1978 and again in July, September, and November, 1978. There were also quite a few specimens with no discernable gonad, but with larvae in the brood pouch.

Teredo furcifera. Relatively few specimens of *Teredo furcifera* have been examined for gonad conditions, and those have come from only four stations, Stations 2, 4, 7 and 11. No *Teredo furcifera* were examined after March, 1977. Because of so few specimens, no definite reproductive patterns have been observed. The most advanced stages of gonad development in *Teredo furcifera* included one ripe specimen at Station 7 in September, 1976 (Table C-1).

Histopathology

During the histological examinations for gonad conditions, a number of specimens were found to contain parasites of one sort or another, depending upon the species of shipworm being examined. For example, some specimens of all three species of *Teredo* in Barnegat Bay were found to be infected with a protozoan parasite of the genus *Minchinia* (Hillman, 1978). In addition, many specimens of *Bankia gouldi* were found to contain cysts formed by the encapsulation of another protozoan, *Boveria teredinidi*, which had invaded the tissues of the shipworm.

In most cases, there appeared to be extensive lysing of the tissue in the case of the *Minchinia* infection, and other pathological conditions accompanying the encystment of *Boveria*. Often, the infected specimens were dead by the time they were extracted from the panels. Whether these deaths were caused by the infections was not determined. However, questions arose concerning possible effects of the parasites on the distribution and abundance of the teredine borers in Barnegat Bay. For example, could the parasites be responsible for wide scale mortalities of shipworms, especially at those sites where the parasites were most prevalent?

During this past year, emphasis was placed on observing the incidence of parasites and other histopathological phenomena in those shipworms collected for gonad analysis. The results of that effort are discussed below.

Minchinia spp. in *Teredo*. The occurrence of a haplosporidian parasite (Figure C-1) in species of *Teredo* in Barnegat Bay, New Jersey, was first reported by Hillman (1978). This parasite was subsequently found in *Teredo navalis* from Long Island Sound (Hillman, 1979). The parasite occurred in all three species of *Teredo* found in Barnegat Bay and occasionally in the young *Teredo* spp. too small to be identified to species. Tables C-2 through C-5 show, for all stations from August, 1975 through November, 1978, the monthly incidence of *Minchinia* spp. in *Teredo navalis*, *Teredo furcifera*, *Teredo bartschi* and *Teredo* spp., respectively. Figure C-2 shows the overall infection rate of *Teredo navalis* for all stations each month over the same period.

It would appear that infection may be seasonally cyclic, at least for *Teredo navalis*. In general, peak infections occur in the summer and fall with minimal infection in the colder winter months (Figure C-2). It should be pointed out that "infection" refers to the observation of life cycle stages in the tissues. It is possible that a life cycle stage, which could be a single cell and extremely difficult to identify, existed in the tissues in the winter but was not observed. The specimen would have been infected, but the information was not recorded. During the months of peak infection, the rates of infection for all stations at which *Teredo navalis* was found was over 50 percent.

FIGURE C-1. *Minchinia* SP. IN GILL OF *Teredo navalis* FROM BARNEGAT BAY, NEW JERSEY

TABLE C-2. MONTHLY OCCURRENCE OF *Minchinia* sp. IN *Teredo navalis* COLLECTED IN EXPOSURE PANELS IN BARNEGAT BAY, NEW JERSEY FROM AUGUST, 1975, THROUGH NOVEMBER, 1978

I = Number Infected; N= Total Number Examined.

Year	Month	Station 1	2	3	4	4A	5	6	7	8	9	10	10A	10B	11	12	13	14	15	16	17	I/N	Percent Infection
1975	Aug																						
	Sep																				1/3	1/3	33
	Oct																				3/3	3/3	100
	Nov		1/1						0/1			0/1				0/1			0/3		2/2	3/9	33
	Dec																		0/2		4/4	4/6	67
1976	Jan		2/2												1/2				0/3		3/3	6/10	60
	Feb	0/2	0/3						0/1	0/1									0/4		1/4	1/15	7
	Mar	0/2																				0/2	0
	Aug	0/3													0/8							0/11	0
	Sep	2/8								1/1					6/6				0/1			9/16	56
	Oct	3/7							1/1						3/5						3/4	10/17	59
	Nov	5/5							1/1						3/5						2/5	11/16	69
	Dec	2/6							1/1										0/1		4/5	7/13	54
1977	Jan																						
	Feb														1/7							1/7	14
	Mar	1/11																			1/2	2/13	15
	Apr																						
	May	0/19																				0/19	0
	Jun	1/6																				1/6	17
	Jul																						
	Aug	0/14																				0/14	0
	Sep	0/7																0/1				0/8	0
	Oct	0/13													1/1							1/14	7
	Nov	4/6													1/1			0/1				5/8	63
	Dec	0/6									1/1				1/1						2/2	4/10	40
1978	Jan																				3/3	3/3	100
	Feb	3/10																			2/2	5/12	42
	Mar	0/8																			0/1	0/9	0
	Apr								0/2													0/2	0
	May	11/20																				11/20	55
	Jun	2/9									1/1										2/2	5/12	42
	Jul		1/1																			1/1	100
	Aug	0/1							0/9													0/10	0
	Sep	0/3																			0/2	0/5	0
	Oct	9/10	0/3																		0/1	9/14	64
	Nov	13/15	1/5								0/1										4/5	18/26	69
Total																						121/334	34

TABLE C-3. MONTHLY OCCURRENCE OF *Minchinia* sp. IN *Teredo furcifera* COLLECTED IN EXPOSURE PANELS IN BARNEGAT BAY, NEW JERSEY, FROM AUGUST, 1975, THROUGH NOVEMBER, 1978

I = Number Infected; N = Total Number examined.

		Station																					
		1	2	3	4	4A	5	6	7	8	9	10	10A	10B	11	12	13	14	15	16	17	I/N	Percent Infection
1975	Aus																						
	Sep		1/3												0/4						1/3	2/10	20
	Oct		2/2									0/1			0/1						1/1	3/5	60
	Nov		1/1												0/2							1/3	33
	Dec																						
1976	Jan		1/1																			1/1	100
	Feb																						
	Mar																						
	Aug																						
	Sep								1/1													1/1	100
	Oct																						
	Nov																						
	Dec																						
1977	Jan																						
	Feb																						
	Mar																						
	Apr																						
	May																						
	Jun																						
	Jul																						
	Aug																						
	Sep																						
	Oct																						
	Nov																						
	Dec																						
1978	Jan																						
	Feb														1/3							1/3	33
	Mar				0/1																	0/1	0
	Apr																						
	May																						
	Jun																						
	Jul																						
	Aug																						
	Sep																						
	Oct																						
	Nov																						
	Total																					9/24	38

TABLE C-4. MONTHLY OCCURRENCE OF *Minchinia* sp. IN *Teredo bartschi* COLLECTED IN EXPOSURE PANELS IN BARNEGAT BAY, NEW JERSEY FROM AUGUST, 1975, THROUGH NOVEMBER, 1978

I = Number Infected; N = Total Number Examined.

		Station				Percent
		5	6	7	I/N	Infection
1975	Aug		0/3		0/3	0
	Sep		0/2		0/2	0
	Oct					
	Nov					
	Dec					
1976	Jan					
	Feb		0/1		0/1	0
	Mar					
	Aug					
	Sep					
	Oct					
	Nov		2/5		2/5	40
	Dec					
1977	Jan					
	Feb					
	Mar					
	Apr					
	May					
	Jun					
	Jul					
	Aug					
	Sep			0/5	0/5	0
	Oct			3/6	3/6	50
	Nov			2/6	2/6	33
	Dec			1/5	1/5	20
1978	Jan			3/5	3/5	60
	Feb			3/5	3/3	100
	Mar					
	Apr					
	May			0/1	0/1	0
	Jun					
	Jul			0/7	0/7	0
	Aug					
	Sep	0/9	0/9	0/2	0/20	0
	Oct	0/5	0/1		0/6	0
	Nov	0/9	0/5	0/9	0/23	0
	Total				14/98	14

TABLE C-5. MONTHLY OCCURRENCE OF *Minchinia* sp. IN *Teredo* spp. COLLECTED IN EXPOSURE PANELS IN BARNEGAT BAY, NEW JERSEY, FROM AUGUST, 1975, THROUGH NOVEMBER, 1978

I = Number Infected; N = Total Number Examined.

		Station																					
		1	2	3	4	4A	5	6	7	8	9	10	10A	10B	11	12	13	14	15	16	17	I/N	Percent Infection
1975	Aug	0/9					0/4		0/1						0/2	0/3			0/3		0/6	0/28	0
	Sep	0/1																	0/3			0/4	0
	Oct	0/4																	0/3			0/7	0
	Nov				0/1																	0/1	0
	Dec								0/2													0/2	0
1976	Jan																						
	Feb																						
	Mar																						
	Aug		0/1																			0/1	0
	Sep										1/1											1/1	100
	Oct																						
	Nov																						
	Dec																						
1977	Jan																						
	Feb														1/1							1/1	100
	Mar																						
	Apr																						
	May																						
	Jun																						
	Jul																						
	Aug														0/1							0/1	0
	Sep																	0/1				0/1	0
	Oct																						
	Nov																						
	Dec																						
1978	Jan																						
	Feb																						
	Mar																						
	Apr																						
	May																						
	Jun																						
	Jul																						
	Aug																						
	Sep		0/1																			0/1	0
	Oct																						
	Nov																						
Total																						2/48	4

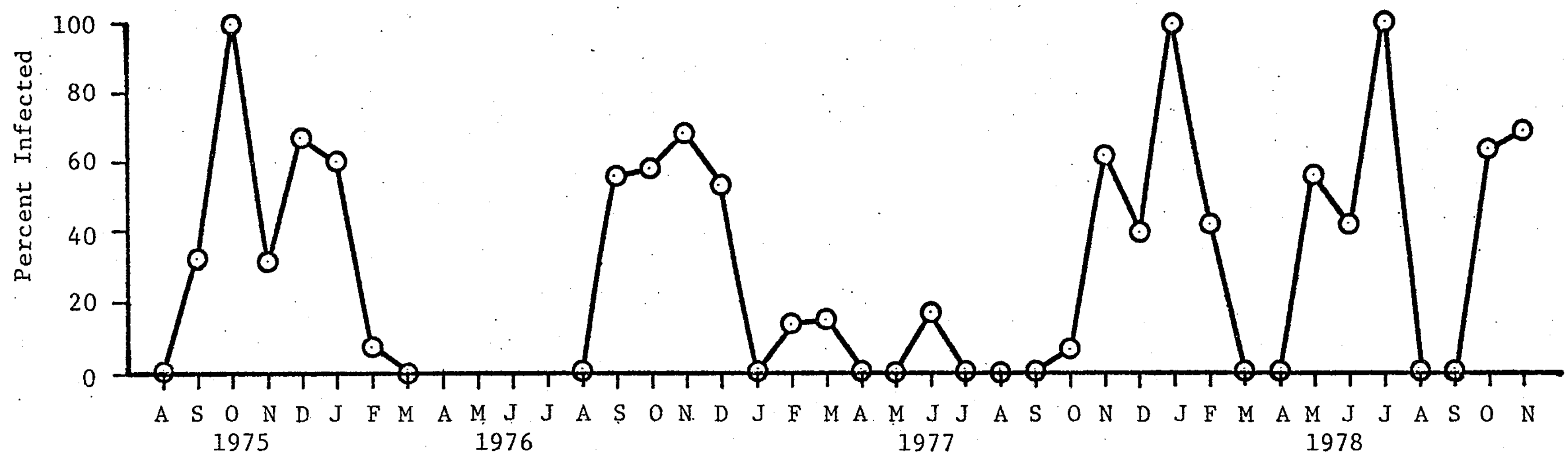

FIGURE C-2. PERCENT OF *Teredo navalis* INFECTED BY *Minchinia* sp. AT ALL EXPOSURE PANEL SITES IN BARNEGAT BAY, NEW JERSEY FROM AUGUST, 1975, THROUGH NOVEMBER, 1978

There are not enough data for the other species of *Teredo* (see Tables C-3 through C-5) to discuss the cyclic nature of the infection. However, all species of *Teredo* in Barnegat Bay are hosts for the parasite. The infection rate per species over the whole study program is 34 percent for *Teredo navalis* (Table C-2), 38 percent for *Teredo furcifera* (Table C-3), 14 percent for *Teredo bartschi* (Table C-4), and four percent for the young *Teredo* spp. (Table C-5).

Tables C-6 through C-9 show the total annual occurrence of *Minchinia* spp. in *Teredo navalis, Teredo furcifera, Teredo bartschi,* and *Teredo* spp. respectively for each year since 1975. The 1975 figures represent only five months' sampling since the panel program was not begun until the summer of that year. The 1978 data represent only January through November.

In 1975 and 1976, about half of all *Teredo navalis* examined were infected with *Minchinia* spp. (Table C-6). There was a sharp decline to only 14 percent in 1977, but through November, 1978 the rate climbed back up to 46 percent.

Although there were far fewer specimens of the other species of *Teredo* examined, the data shown in Tables C-7 through C-9 indicate a dropoff in infection in 1977.

Hillman's (1978) was the first report of a haplosporidian in shipworms. The parasite has been assigned to the genus *Minchinia* but it has yet to be identified to species. Superficially, it resembles *Minchinia nelsoni,* the parasite which devastated the Delaware Bay oyster population several years ago.

<u>*Boveria* encystment in *Bankia gouldi*</u>. Early in the gonad analyses, several sections of *Bankia gouldi* tissue showed what were apparently encysted protozoans in the shipworm's gills. A number of sections of the gills also showed ciliated protozoans on the gill surface, and in some cases, penetrating the gill epithelium and becoming encapsulated. Other sections showed whole ciliates in the intestine. Live ciliates were removed from fresh material and identified as *Boveria teredinidi.*

TABLE C-6. TOTAL ANNUAL OCCURRENCE OF *Minchinia* sp. IN *Teredo navalis* COLLECTED IN EXPOSURE PANELS IN BARNEGAT BAY, NEW JERSEY, FROM AUGUST, 1975, THROUGH NOVEMBER, 1978

I = Number Infected; N = Total Number Examined.

	1975		1976		1977		1978	
Stations	Total I/N	Percent Infection	Total I/N	Percent Infection	Total I/N	Percent Infection	Total I/N	Percent Infection
1			12/33	36	6/82	7	38/76	50
2	1/1	100	2/5	40			2/9	22
3								
4								
4A								
5								
6								
7	0/1	0	3/4	75			0/11	0
8			1/2	50				
9					1/1	100	1/2	50
10	0/1	0						
10A								
10B								
11			13/26	50	4/10	40		
12	0/1	0						
13								
14					0/2	0		
15	0/5	0	0/11	0				
16								
17	10/12	83	13/21	62	3/4	75	11/16	69
Total Infection Rate	11/21	52	44/100	44	14/99	14	52/114	46

TABLE C-7. TOTAL ANNUAL OCCURRENCE OF *Minchinia* sp. IN *Teredo furcifera* COLLECTED IN EXPOSURE PANELS IN BARNEGAT BAY, NEW JERSEY, FROM AUGUST, 1975, THROUGH NOVEMBER, 1978

I = Number Infected; N = Total Number Examined.

Stations	1975 Total I/N	1975 Percent Infection	1976 Total I/N	1976 Percent Infection	1977 Total I/N	1977 Percent Infection	1978 Total I/N	1978 Percent Infection
1								
2	4/6	67	1/1	100				
3								
4							0/1	0
4A								
5								
6								
7			1/1	100				
8								
9								
10	0/1	0						
10A								
10B								
11	0/7	0					1/3	33
12								
13								
14								
15								
16								
17	2/4	50						
Total Infection Rate	6/18	33	2/2	100			1/4	25

TABLE C-8. TOTAL ANNUAL OCCURRENCE OF *Minchinia* sp. IN *Teredo bartschi* COLLECTED IN EXPOSURE PANELS IN BARNEGAT BAY, NEW JERSEY, FROM AUGUST, 1975, THROUGH NOVEMBER, 1978

I = Number Infected; N = Total Number Examined.

	1975		1976		1977		1978	
Stations	Total I/N	Percent Infection	Total I/N	Percent Infection	Total I/N	Percent Infection	Total I/N	Percent Infection
5							0/23	0
6	0/5	0	2/6	33			0/15	0
7					6/22	27	6/27	22
Total Infection Rate	0/5	0	2/6	33	6/22	27	6/65	9

TABLE C-9. TOTAL ANNUAL OCCURRENCE OF *Minchinia* sp. IN *Teredo* sp. COLLECTED IN EXPOSURE PANELS IN BARNEGAT BAY, NEW JERSEY, FROM AUGUST, 1975, THROUGH NOVEMBER, 1978

I = Number Infected; N = Total Number Examined.

	1975		1976		1977		1978	
Stations	Total I/N	Percent Infection	Total I/N	Percent Infection	Total I/N	Percent Infection	Total I/N	Percent Infection
1	0/14	0						
2			0/1	0			0/1	0
3								
4	0/1	0						
4A								
5	0/4	0						
6								
7	0/3	0						
8								
9			1/1	100				
10								
10A								
10B								
11	0/2	0	1/1	100	0/1	0		
12	0/3	0						
13								
14					0/1	0		
15	0/9	0						
16								
17	0/6	0						
Total Infection Rate	0/42	0	2/3	67	0/1	0	0/1	0

Although reports of pathogens of the various species of teredinids are relatively uncommon, there are a number of symbionts occurring either on the tissues directly, or in the shipworms' burrows, with the ciliates being the most common (Turner and Johnson, 1971). Two genera of holotrich ciliates have been reported as existing symbiotically with teredinids (Rancurel, 1967). *Boveria* has been reported on the shipworms (e.g. Nelson, 1923, 1925; Levinson, 1941), while *Orchitophyra* is usually found in shipworm burrows (Rancurel, 1967).

Nelson (1923) suggested that *Boveria teredinidi*, found heavily infesting the gills of *Teredo navalis* and *Bankia gouldi* in New Jersey waters, could mechanically obstruct the gills and remove food particles from the incurrent stream, but was probably not otherwise harmful. Levinson (1941), on the other hand, reported that *Boveria zenkevitchi* which usually occurred in the mantle cavity of *Teredo navalis* from Sebastepol Bay was capable of encysting in the host. Pickard (1927) described the morphology of *Boveria teredinidi* and stated that no invasion of the tissues of *Teredo navalis* was observed.

Although *Boveria* occurred on at least some specimens of all the teredine borers, all of the infected shipworms to date have been *Bankia gouldi*. A total of 699 *Bankia gouldi* have been examined since August, 1975. Figure C-3 is a sagittal section through the gill of a specimen of *Bankia gouldi* from Station 13. Several cysts can be seen in the tissue, and the area around the cysts has been heavily infiltrated with leukocytes.

Table C-10 shows the monthly occurrence of cysts in *Bankia gouldi* at each station from August, 1975 through November, 1978. The percent of *Bankia gouldi* containing encysted *Boveria teredinidi* at all panel sites is shown in Figure C-4 . Infections tended to be heaviest during 1975 and 1976, and the periods of infection appeared to by cyclic for those years, with the heaviest infections being in the fall. Through 1977 and 1978, the incidence of infection has dropped considerably (Table C-11), as has the number of specimens collected.

The annual incidence of infection at each station is shown in Figure C-5 . For the five months of 1975 for which panels were collected,

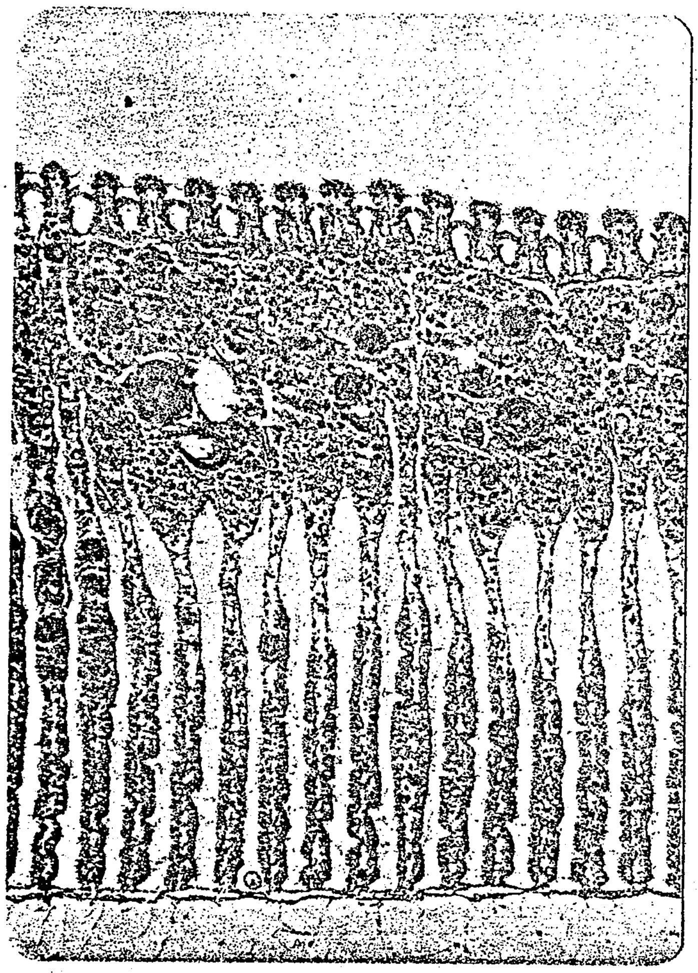

FIGURE C-3. CYSTS OF *Boveria teredinidi* IN THE GILL OF *Bankia gouldi* FROM BARNEGAT BAY, NEW JERSEY

TABLE C-10. MONTHLY OCCURRENCE OF *Boveria terdinidi* CYSTS IN *Bankia gouldi* COLLECTED IN EXPOSURE PANELS IN BARNEGAT BAY, NEW JERSEY, FROM AUGUST, 1975, THROUGH NOVEMBER, 1978

I = Number Infected; N = Total Number Examined.

		Station																					
		1	2	3	4	4A	5	6	7	8	9	10	10A	10B	11	12	13	14	15	16	17	I/N	Percent Infection
	Aug			0/2	0/3		0/1	0/6	0/8			1/2			2/3	0/6	0/5	0/10	0/6	0/6		3/88	5
	Sep			0/4	1/5			0/1				1/5			2/4	0/5	0/6	1/1			0/2	5/33	15
1975	Oct		0/2	0/1	3/4					0/3	0/2	1/4			3/4	0/3	3/3		0/3	0/4		10/33	30
	Nov	0/1	0/1	0/4	4/4		1/2	0/1		0/4	0/2				2/3	3/8	0/2	3/4	0/1	2/4	0/1	15/42	36
	Dec		0/2	0/4	0/3		0/1	4/6		0/1	0/1	0/3			1/2	0/3	3/3	1/2	0/2	0/1		9/34	26
	Jan		0/2	2/4	0/4		0/1	1/3		0/1		0/3			1/2	0/3	3/3	1/1	0/2	0/1		8/30	27
	Feb		1/2	0/1	0/2			1/1			0/1				0/4	0/4		0/3				2/18	11
	Mar																					0/0	0
	Aug				0/2		0/1		0/2	0/1	0/1					0/1	0/5	0/3	0/3			0/19	0
1976	Sep				1/2		0/1	0/1	0/2	0/3		1/1				1/2	4/6	2/5	0/2			8/25	23
	Oct	0/1			0/1		0/3		1/3	0/1	1/1	0/1			0/3	1/6	5/6		1/7			9/33	27
	Nov				2/4		1/3		3/3	0/1					0/2	0/7	6/6	1/6	0/2			13/34	38
	Dec				0/4				1/2	0/5		1/2			0/3	1/3	5/6	2/6	0/2			10/33	30
	Jan								0/2													0/2	0
	Feb						0/1		0/1						0/8		3/4					3/14	21
	Mar							0/1								0/4		1/2				1/7	14
	Aug				0/1				0/6						0/6	0/1		0/2				0/16	0
1977	Sep				0/2	0/1	0/3		0/1	0/1		0/1			0/8	0/3	0/7	0/6				0/33	0
	Oct			0/1		0/3			0/4			0/2			2/6		0/6	0/6				2/28	7
	Nov				0/1		0/4		0/1		1/1				0/13	4/13		1/5				5/38	13
	Dec					1/1	0/3	0/1	0/5	0/1		1/2			0/6	0/6	0/6	0/6				2/36	5
	Jan			0/2	0/1	0/1	0/1		0/2	0/2	0/2				0/6	0/4	2/4	0/4				2/29	7
	Feb																	0/1		0/1		0/2	0
	Mar																					0/0	0
	Apr				0/2											0/1						0/3	0
	May				0/1				0/4	0/3	0/1						0/4	0/1				0/14	0
1978	Jun								0/5		0/1	0/1			1/2	1/2	0/1					2/12	17
	Jul																					0/0	0
	Aug												0/1	0/1	0/5		0/3					0/10	0
	Sep				0/1				0/1				1/2					0/2				1/6	17
	Oct				0/3	0/1	0/1						2/4	1/2	0/10				0/1		0/1	3/23	13
	Nov				0/1		0/1		0/2	0/1			0/2		0/8		0/7	0/11			0/1	0/34	0
	Total																					113/699	16

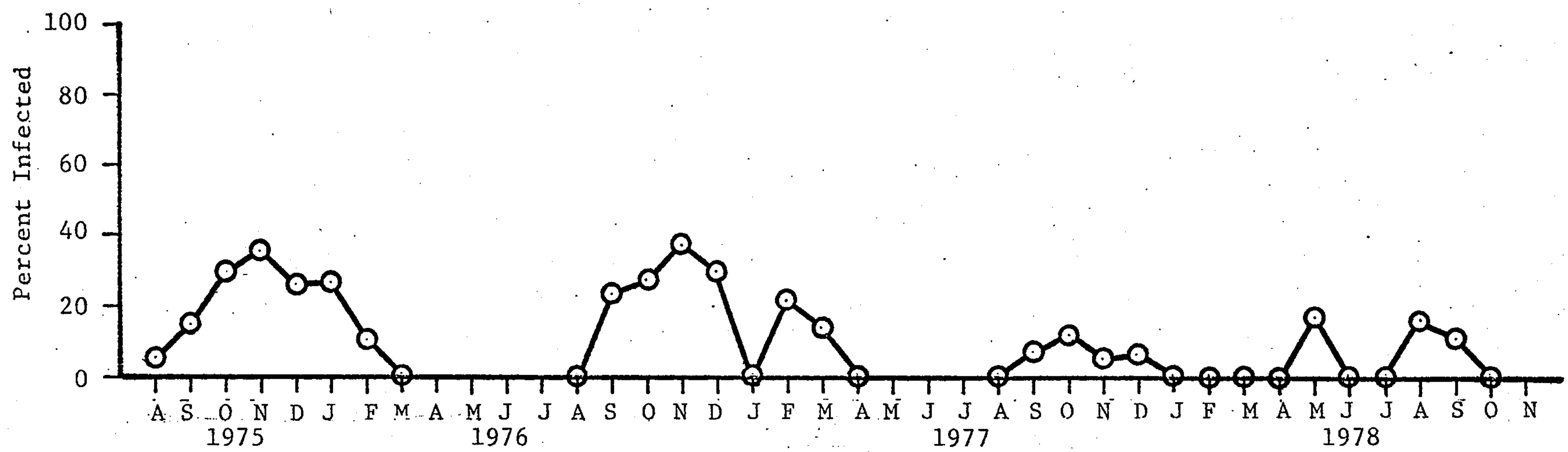

FIGURE C-4. PERCENT OF *Bankia gouldi* CONTAINING ENCYSTED *Boveria teredinidi* AT ALL EXPOSURE PANEL SITES IN BARNEGAT BAY, NEW JERSEY FROM AUGUST, 1975, THROUGH NOVEMBER, 1978

TABLE C-11. TOTAL ANNUAL OCCURRENCE OF *Boveria teredinidi* CYSTS IN *Bankia gouldi* COLLECTED IN EXPOSURE PANELS IN BARNEGAT BAY, NEW JERSEY, FROM AUGUST, 1975, THROUGH NOVEMBER, 1978

I = Number Infected; N = Total Number Examined.

	1975		1976		1977		1978	
Stations	Total I/N	Percent Infection	Total I/N	Percent Infection	Total I/N	Percent Infection	Total I/N	Percent Infection
1	0/1	0	0/1	0				
2	0/5	0	1/4	25				
3	0/15	0	2/5	40	0/1	0	0/2	0
4	8/19	42	3/19	16	0/4	0	0/9	0
4A					1/5	20	0/2	0
5	1/4	25	1/9	11	0/11	0	0/3	0
6	4/14	29	2/5	40	0/2	0		
7	0/8	0	5/12	42	0/20	0	0/14	0
8	0/8	0	0/12	0	0/2	0	0/6	0
9	0/5	0	1/3	33	1/1	100	0/4	0
10	3/14	21	2/7	29	1/5	20	0/1	0
10A							3/9	33
10B							1/3	33
11	11/16	69	1/14	7	2/47	4	1/31	3
12	3/25	12	3/26	12	4/27	15	1/7	14
13	6/19	32	23/32	72	3/23	13	3/19	11
14	6/17	35	6/24	25	2/27	7	0/19	0
15	0/12	0	1/18	6			0/1	0
16	2/15	13					0/1	0
17	0/3	0					0/2	0
Total Infection Rate	44/200	22	51/191	27	14/175	8	8/133	6

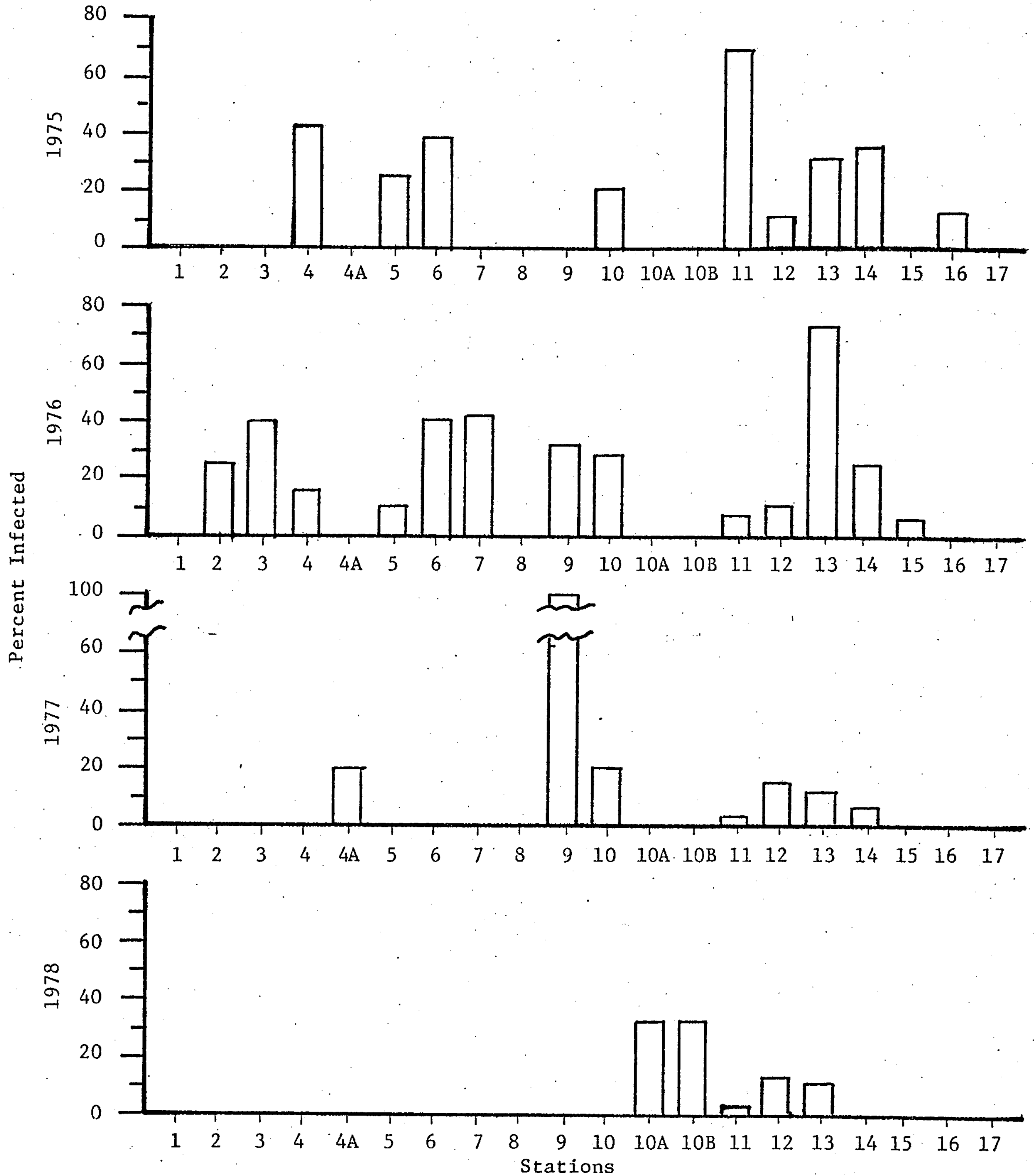

FIGURE C-5. PERCENT OF *Bankia gouldi* AT EACH EXPOSURE PANEL STATION IN BARNEGAT BAY CONTAINING ENCYSTED *Boveria teredinidi* cysts were found at nine of the 17 stations. In 1976, this figure rose to 13 out of 17 stations. By the end of 1976, an additional station (4A) had been added, but the infections were observed at only seven of the 18 stations. This trend continued into 1978, and with two more stations being added (10A and 10B), infections were seen at only five stations, including the two new ones.

The rate of infection at the individual stations has varied throughout the study (Figure C-5). In 1975, the heaviest infections were at Station 11; in 1976, Station 13 has the highest incidence of encystment, and in 1977 it was Station 9. So far in 1978, infections have been few, and primarily at the new stations, 10A and 10B.

The process of encapsulation appears to be of the leukocytic type as described by Cheng and Rifkin (1970). Often clusters of leukocytes can be observed around the individual cysts, and the compressed nuclei of leukocytes making up the cyst wall can also be seen. There was usually considerable leukocytic infiltration into the tissues in which the cysts occurred, and often many of the hyaline leukocytes appeared to be enlarged and very eosinophilic. These enlarged leukocytes were usually found in the immediate area of the cyst. In some cases, there was general leukocytosis throughout the section although the cysts were localized to a specific tissues. Also, many sections showed extensive leukocytosis though no cysts were observed in the section.

The observations of encystment raise several interesting questions. Although *Boveria teredinidi* occurs on the gills of the *Teredo* species and *Bankia gouldi*, encystment has only been observed in *Bankia gouldi*. Perhaps *Bankia gouldi* is in a condition less resistant to invasion than *Teredo*. On the other hand, the species of *Teredo* and *Bankia* could be susceptible to invasion by the ciliate, with only *Bankia gouldi* being able to muster its defense mechanisms and encyst the invader, whereas *Teredo navalis* is killed.

The shipworms collected at Station 8, the station closest to the discharge of the power plant, showed no incidence of infection, and the shipworms removed from the panels at the other stations in the discharge canal had relatively low incidences of infection. Conditions in the immediate thermal discharge from the power plant could be such that the normal defense mechanisms of those individuals of *Bankia gouldi* exposed to the effluent were altered to where they also could not respond to the invasion and were killed by the "parasite". Ciliates have been seen on the gills of some shipworms from Station 8, so a possible biocidal effect of the discharge on the ciliate may be ruled out as a reason for the lack of encystment.

There is also some question whether the extensive leukocytosis is part of the tissue response to the ciliate invasion, since many sections show this condition although no cysts could be found in the section. If cysts occur in the shipworms in the portion of the body not recovered for gonad studies, and the leukocytosis is specifically related to encystment, then the incidence of infection is even higher than reported here. The sharp decline in infection through 1977 and 1978 also still remains to be explained.

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