FINAL ANNUAL REPORT

For the Period December 1, 1982 to November 30, 1983

on

STUDY OF WOODBORER POPULATIONS IN RELATION TO THE OYSTER CREEK GENERATING STATION

to

GPU Nuclear Corporation

May 15, 1984

by

R.E. Hillman, C.I. Belmore, R.A. McGrath, and P.T. Banas

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During the present reporting period, only two species of molluscan woodborers were identified from either short-term or long-term panels. These were the teredinids, *Teredo navalis* and *Bankia gouldi*. A number of specimens too small to be identified to species were collected and categorized as Teredinidae, but they were probably one or the other of the above-mentioned species. A third species, *T. bartschi*, found only in thermally-affected areas since the program began in 1975, was not collected during the present reporting period. It has not been collected in the study area since February, 1982. A fourth species, *T. furcifera*, which was of concern during the first years of the program, has not been identified from any panel since March, 1977.

The crustacean woodborer, *Limnoria* cf. *tuberculata*, was recorded from six stations, none of which were in the area affected by the discharge of the OCNGS.

The total abundance of 5,601 individual teredinids over the present reporting period represents a decline of only 2 percent from the total abundance collected last year. Most of the specimens collected were *Teredo navalis* from Station 1.

In general, patterns of abundance and distribution of *Teredo navalis* have varied very little since the program began. Most *T. navalis* occur at Stations 1 and 17 outside the area affected by the OCNGS discharge. There are also elevated abundances at Stations 2 and 11.

In contrast to the stable patterns of abundance and distribution shown by *Teredo navalis*, there has been a continual and significant decline in the abundance of *Bankia gouldi* over the past several years. This decline continued into the present reporting period, but sharply increased abundances over the last few months indicate a possible reversal of that trend.

Gonad development patterns of *Teredo navalis* and *Bankia gouldi* remained consistent with what has been reported for previous years. Again, there appears to be no effect of the OCNGS on normal gonad cycles. The possibility of an extended breeding season for _T. bartschi_ in the thermal discharge area has been discussed in prior reports. With the disappearance of _T. bartschi_ from our panels, no comments can be made on any effects that the OCNGS might have had on gonad developmental cycles in that species.

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INTRODUCTION

The study conducted by Battelle New England Marine Research Laboratory of populations of woodboring molluscs in Barnegat Bay, New Jersey, began in June, 1975 at the request of the Jersey Central Power & Light Company (JCP&L) which owns the Oyster Creek Nuclear Generating Station (OCNGS), operated by GPU Nuclear Corporation.

The OCNGS has used salt water from Barnegat Bay as condenser cooling water since the plant began commercial operation in December, 1969. The thermal effluent from the plant enters Oyster Creek approximately two miles inland from Barnegat Bay (Figure 1). Oyster Creek flows into the bay about one mile south of Forked River, which provides water to the intake of the plant's cooling system. Recirculation of water from the Oyster Creek discharge canal into Forked River has been calculated to occur between 4 and 22% of the time (M. Kennish, GPU Nuclear Corporation, personal communication), with some of the effluent also flowing south towards Waretown. The morphology and flow direction of the thermal plume is variable, being dependent primarily on the wind with some tidal influence. Consequently, organisms in Oyster Creek and contiguous waters are sometimes exposed to water temperatures above ambient bay levels.

A heavy outbreak of teredinid woodboring molluscs in the Oyster Creek area in the early 1970s raised concern about the possible effect of the operation of the OCNGS on woodborer populations in Oyster Creek and in the Barnegat Bay system. This study has

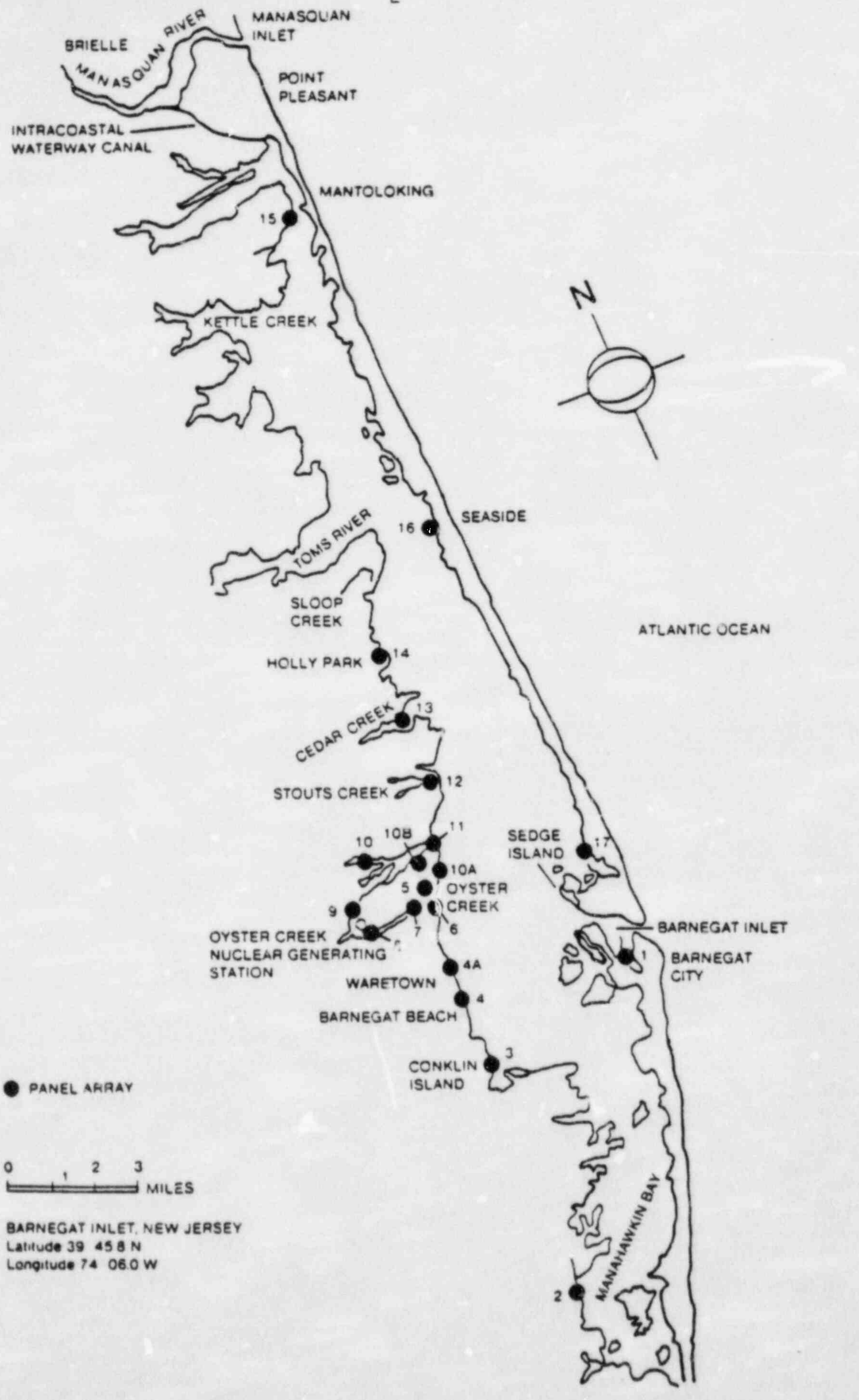

FIGURE 1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHIC LOCATIONS OF EXPOSURE PANELS

been conducted in an effort to determine whether the operation of the OCNGS is indeed having an impact on the distribution, abundance, and/or reproductive patterns of the various species of teredinids occurring in the bay.

This report covers the sampling year from December 1, 1982 through November 30, 1983, with some comparisons being made of these data to those of previous years. Data concerning shipworm distribution and abundance are detailed in Appendix A. Gonad developmental patterns are described in Appendix B, and water quality data collected over the study period are detailed in Appendix C.

PATTERNS OF SPECIES ABUNDANCE

Abundance of teredinids occurring in long-term (6-month) panels are summarized in Table 1. The total abundance of 5,601 individuals over the present reporting period represents a decline of only 2 percent from the total abundance of 5,737 individuals collected last year (Hillman et al., 1983).

Although there was little difference in total numbers of shipworms collected during the present reporting period compared to last year's collections, there was a considerable distribution difference. Almost 80 percent of all shipworms collected from December, 1982 through November, 1983 were collected from Station 1. Over the same period last year, only 53 percent of the shipworms were collected from that station. Part of the difference may have been caused by the fact that, last year, attack was so heavy at Station 1 during the May to November period that no panel was left for examination in November, 1982. However, only 400 individuals were collected at Station 1 in November, 1983. The difference of 1,437 individuals between years comes primarily from the greater abundances during the February to August and March to September periods. Last year, the peak abundance occurred during the April to October period.

Stations 11 and 15 had a total of about 13 percent of all the shipworms collected this year, with the remaining 7 percent distributed over the other 17 stations.

Station 7, at which substantial numbers of shipworms were collected in previous years (Maciolek-Blake et al., 1982; Hillman et al., 1983), contributed only about 3 percent of the total number of shipworms collected during the present reporting period. This decline in abundance began with the disappearance of *Teredo bartschi* in early 1982.

TABLE 1. NUMBERS OF TEREDINIDS IN LONG-TERM (6-month) PANELS SUBMERGED JUNE, 1982 THROUGH MAY, 1983 AND REMOVED SEQUENTIALLY FROM DECEMBER, 1982 THROUGH NOVEMBER, 1983

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 No.	% Total
1		650	700	*	68	327	167		5	900	850	400	400	4467	79.75
2													1	1	0.02
3			2								1			3	0.05
4						2								2	0.04
4A														0	0.00
5		1		1		4				1	2		1	10	0.18
6												1		1	0.02
7		6	4	16	4	84	20			1	3	4	4	146	2.61
8						3	1			2	7	3	3	19	0.34
9		3				1	3						1	8	0.14
10			1											1	0.02
10A		4	2			3				2	1	1	2	15	0.27
10B		1	2							2		2		7	0.12
11		77	62	10	10	45	3		8	46	37	48	52	398	7.11
12			1							2	1	1	1	6	0.11
13		3	1			2					6	23	18	53	0.95
14									28	59	47	120	80	334	5.96
15		2	7	4							1	1	5	20	0.36
16B		1											1	2	0.04
17		9	20	27		4					7	24	17	108	1.93

* No panel examined.

Teredo bartschi was the principal teredinid species at Station 7 during the late 1970's - early 1980's, but no specimens of T. bartschi have been collected anywhere in Barnegat Bay since March, 1982.

Teredinids were recovered from short-term (1-month) panels during December, 1982 and July through November, 1983 (Table 2), an extended period compared to the settling period last year (Hillman et al., 1983). Most of the set was at Station 1 during August and September.

For the second consecutive year, no teredinid larvae were collected from short-term panels at Station 7, whereas two years ago, 17 percent of the total set on short-term panels occurred at Station 7 (Maciolek-Blake et al., 1982). This, again, reflects the disappearance of Teredo bartschi from the study area.

Abundance and Distribution of Teredo navalis

Comparisons among stations of abundances of Teredo navalis in long-term panels produced the following grouping (stations connected by an underline were not significantly different at $p = 0.05$):

16B 6 12 13 4 5 3 10 4A 10B 9 8 7 10A 14 15 2 17 11 1

These observations are generally similar to those described in recent reports (Maciolek-Blake et al., 1982; Hillman et al., 1983) and continue to indicate significantly elevated densities of T. navalis near Barnegat Inlet (Stations 1 and 17) and at Stations 2 and 11.

Analyses of the data by bioyear (see Page A-12) did not indicate as many significant differences as were found among stations. When all data were included in the analyses, a broadly overlapping pattern resulted:

83/84 77/78 78/79 81/82 80/81 82/83 76/77 75/76 79/80

This overall pattern is essentially similar to what was described in the previous report (Hillman et al., 1983), and continues to provide no evidence for either an increase or decrease in T. navalis densities throughout the sampling area as a whole.

TABLE 2. NUMBERS OF TEREDINIDS IN SHORT-TERM PANELS REMOVED MONTHLY FROM DECEMBER, 1982 THROUGH NOVEMBER, 1983*

T = Teredinidae; Tn = Teredo navalis; Ts = Teredo spp;
BG = Bankia gouldi

Site	Dec	Jul	Aug	Sep	Oct	Nov
1	90 T	26 T	1100 T	1040 Tn, T	85 T	42 T
2			1 T			
3						
4						
4A						
5						
6						
7						
8			1 T			
9						
10						
10A						
10B						
11		6 T				
12			1 T	1 Bg		
13		13 T	2 T			
14		37 T	28 T			
15				1 T		
16B						
17				8 Ts, T		5 T

* Short-term panels removed January through June, 1983 were free of teredinid borers.

Patterns of gonad development in Teredo navalis are essentially similar to what has been reported previously (e.g., Hillman et al., 1983. See Appendix B). Development begins in late winter, with maturation through the early spring. Ripening and spawning can occur in late spring and early summer, somewhat earlier than for Bankia gouldi. The larvae from the early spawning can settle, mature, and spawn before the end of the fall. This pattern is irrespective of the discharge from the Oyster Creek Nuclear Generating Station since it occurs outside of the area of the generating station's discharge.

Abundance and Distribution of Banki gouldi

While populations of Teredo navalis have been relatively stable, Bankia gouldi, the other major teredinid borer in Barnegat Bay, has been undergoing some interesting population fluctuations. Last year, for example, it was reported (Hillman et al., 1983) that the population of B. gouldi had been steadily and significantly declining. That trend may be reversing this year.

Bankia gouldi was collected on 6-month panels from 9 of the 20 stations during the December, 1982 through July, 1983 sampling period. Between August and November, B. gouldi was collected at 15 of the 20 sites, a sharp increase over what was observed for the past several seasons. From December through April, B. gouldi was dominant at only four sites and co-dominant at one. After July, 1983, however, it became dominant at 14 of the 20 sites (see Table A-23, Appendix A).

Despite the increased abundance of Bankia gouldi over the last few months of this reporting period, its distribution remained essentially what it has been in recent years. Comparisons among station means for abundances produced the following groupings (groups of stations connected by an underline were not significantly different at p=0.5):

2 17 16B 1 3 9 6 4A 10 8 15 4 10B 7 5 10A 12 13 14 11

These results are generally similar to those presented in the previous two reports (Maciolek-Blake et al., 1982; Hillman et al., 1983) and continue to indicate the unique nature of Station 11. Once again, stations within the area of influence of the generating station (Stations 5, 6, 7, 8) do not tend to group together with respect to *B. gouldi* densities and are not significantly different from most stations in the study area. Stations 13 and 14 have significantly high densities of *B. gouldi*, but not as high as Station 11.

Analysis of *Bankia gouldi* abundance data grouped by bioyear produced a pattern of overlapping significantly different groups that is similar to that reported last year (Hillman et al., 1983):

82/83 81/82 78/79 80/81 83/84 77/78 76/77 79/80 75/76

The trend of decreasing densities of *B. gouldi* throughout the Bay remained evident through the 82/83 bioyear, for which data are now complete. Partial data from the current bioyear (83/84), however, tentatively indicate that this trend may be reversing.

The reasons for the steady decline in *Bankia gouldi* abundance through the 82/83 bioyear, and the possible reversal in trend through the latter part of the present reporting period are not clear. Average temperatures and salinities were not unusual this year (see Appendix C), nor were they out of line with what has been reported previously (Hillman et al., 1983).

Patterns of *Bankia gouldi* gonad development (Appendix B) continue to remain similar from year to year. Gonad development begins very early in the spring, with maturation and spawning continuing through the summer into early fall. There is no apparent change in this pattern at those stations affected by the discharge from the generating station.

Abundance and Distribution of Teredo bartschi

No *T. bartschi* were collected from the study area during the present reporting period. This is the first time since the program began that no *T. bartschi* were collected for an entire reporting period. The reasons for the disappearance of this species from the study area remain unclear.

Abundance and Distribution of Limnoria

During the present report period, the crustacean woodborer, Limnoria, was present at Stations 1, 2, 3, 4, 4A, and 5. Attack was up at Stations 2 and 4A (Appendix A, Figure A-6). At Station 2, it was higher than at any other time during the study, but considerably less than what was recorded at Station 4A. Attack was down sharply at Station 4 after a two-year increase. The presence of Limnoria at Station 2 could perhaps be a contributing factor in the decline of teredinids at that site.

CONCLUSIONS

The following major conclusions were reached on the basis of data collected since July, 1975:

1. There has been a continued decline in the abundance of Bankia gouldi over the past several years. Over the latter portion of the present reporting period, however, a larger number of specimens of B. gouldi were collected over a wider distribution area, indicating a possible reversal in the declining trend.

2. Population dynamics of Teredo navalis have remained relatively stable throughout the study. Most T. navalis are found at Stations 1 and 17, away from the effects of the OCNGS discharge. Significantly elevated densities occur at Stations 2 and 11, although numbers at Station 2 have declined somewhat in recent years.

3. Irrespective of any population fluctuations, reproductive patterns of both Teredo navalis and Bankia gouldi have remained consistent, and apparently unaffected by the discharge from the OCNGS. The only species found throughout the program which may have had its gonadal development pattern influenced by the OCNGS thermal discharge is Teredo bartschi. This species was found only in thermally-affected areas, but hasn't been collected since early 1982.

4. Teredo bartschi has disappeared from the study area. For the first time since the program began in 1975, no T. bartschi were collected throughout the entire reporting period, nor have any been collected since March, 1982. Teredo bartschi is the second major teredinid species to disappear from the study area since the program began. Teredo furcifera, a semi-tropical species, as is T. bartschi, has not been collected since March, 1977.

5. The woodboring crustcean Limnoria cf. tuberculata remains restricted in its distribution within the bay, and is generally not found in areas affected by the OCNGS discharge. Its presence at Station 2 may have a mitigating effect on T. navalis densities at that site.

References Cited

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Maciolek-Blake, N.J., R.E. Hillman, C.I. Belmore, and P.I. Feder. 1982. Study of woodborer populations in relation to the Oyster Creek Generating Station. Annual Report for the period December 1, 1980 to November 30, 1981 to GPU Nuclear Corporation. Battelle New England Marine Research Laboratory, Duxbury, MA.

APPENDIX A

APPENDIX A

EXPOSURE PANELS

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APPENDIX A

EXPOSURE PANELS

Introduction

The study conducted by Battelle New England Marine Research Laboratory of the populations of woodboring molluscs in Barnegat Bay, New Jersey, began in June, 1975 at the request of the Jersey Central Power & Light Company. Since that time, racks of exposure panels have been deployed at 17 to 20 stations in the bay, in an effort to determine whether the operation of the Oyster Creek Nuclear Generating Station (OCNGS) is having an effect on the distribution, abundance and/or reproductive patterns of woodborers found in the bay.

Previous reports (Richards et al., 1976, 1978, 1979, 1980; Maciolek-Blake et al., 1981, 1982; Hillman et al., 1983) presented results of the study for each annual period. The present report discusses data collected from December 1, 1982 through November 30, 1983, and presents an analysis of data collected since the initiation of the program in 1975.

Materials and Methods

Field

Exposure panel arrays are maintained in Barnegat Bay at twenty stations (Figure A-1, Table A-1). The seventeen original stations, studied since June, 1975, were selected to include locations that were representative of different environmental regimes within the bay, as well as areas determined to be within and beyond the influence of the thermal discharge from the OCNGS. One station (4A) was added in April, 1977, and two stations (10A and 10B) were added in April, 1978. The original site for Station 16 was discontinued and 16A was established in December, 1981. That site was discontinued in

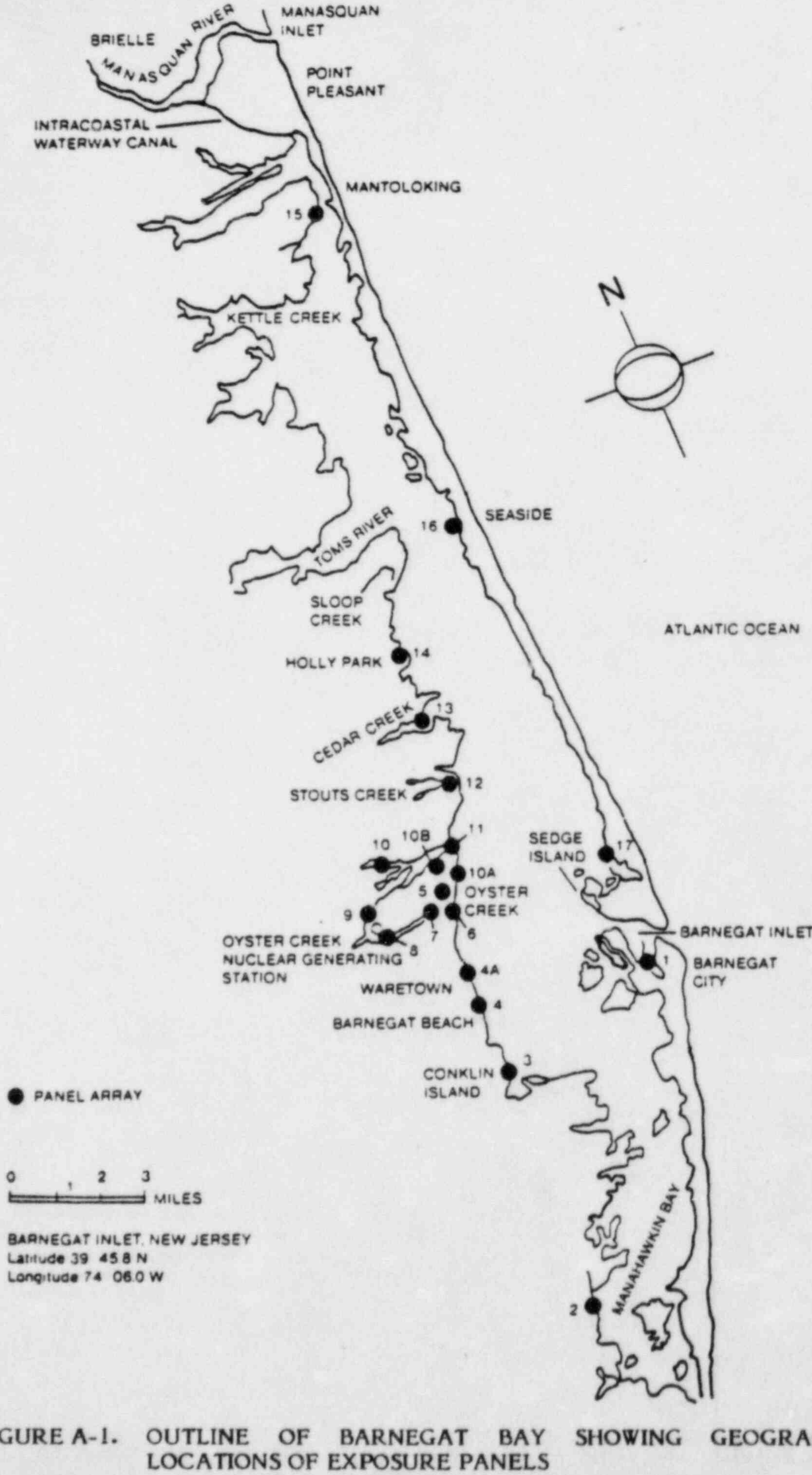

FIGURE A-1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHIC LOCATIONS OF EXPOSURE PANELS

TABLE A-1. GEOGRAPHICAL LOCATIONS OF BATTELLE NEW ENGLAND MARINE RESEARCH LABORATORY'S EXPOSURE PANEL ARRAYS IN 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 Bulkhead	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 R. Turner Rutgers U.	WC 21 Long. 74° 11'N	Lat. 39° 48'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 No. 1 Lagoon, Inshore End 37 Capstan Drive	Dock		Lat. 39° 48.5'N Long. 74° 10.35'W

TABLE A-1. (Continued)

Site No.	Site	Structure to be used for Suspension of Rack	Nearest Previous Data Stations	Approximate Latitude and Longitude
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
8.	1500 Ft. East of Oyster Creek-R.R. Bridge Discharge Canal	Bulkhead	WC 26 Rutgers U.	Lat. 39° 48.7'N Long. 74° 12'W
9.	Forked River South Branch Intake Canal	Metal Pier	WC 31	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 1217 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

TABLE A-1. (Continued)

Site No.	Site	Structure to be used for Suspension of Rack	Nearest Previous Data Stations	Approximate Latitude and Longitude
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
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	Pier	WC 57	Lat. 40° 02.5'N Long. 74° 04.9'W
16.	Berkely Yacht Basin J. Street Seaside	Pier	WC 60, 61	Lat. 39° 55.9'N Long. 74° 04.9'W
16A*.	Municipal Dock Seaside Heights	Pier	WC 60, 61	Lat. 39° 56.6'N Long. 74° 04.9'W
16B*.	Bayside Boats State Highway No. 35 and Bay Boulevard Seaside Heights, NJ	Pier	WC 60, 61	Lat. 39° 56.6'N Long. 74° 04.9'W

TABLE A-1. (Continued)

Site No.	Site	Structure to be used for Suspension of Rack	Nearest Previous Data Stations	Approximate Latitude and Longitude
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 Sites 8 and 9 suspended with wire rope.

WC = Woodward-Clyde
WFCL = William F. Clapp Laboratories

* Site 4-A installed April, 1977.
Sites 10A, 10B installed April, 1978.
Site 16 discontinued November, 1981.
Site 16A installed December, 1981 - discontinued June, 1982.
Site 16B installed June, 1982.

June, 1982 and 16B established at that time. At the time of the November, 1983 panel exchange period, the exposure panel rack at Station 1 was moved to the opposite side of the bulkhead and about 40 feet closer to shore. The exposure panel rack at Station 7 was relocated to the end of the same dock into deeper water. Station 8 was changed to a company-owned dock about 200 feet nearer to the mouth of Oyster Creek. Also, Station 9 was changed to a company-owned property about 2,000 feet closer to the Oyster Creek Nuclear Generating Station. All of the stations are accessible by land, and all panel arrays are placed near or suspended from existing structures such as docks and bulkheads.

The panels are mounted on an iron frame (Figure A-2) which is submerged vertically to within 6 inches of the bottom. Each array consists of seven 25.4 cm x 8.9 cm x 1.9 cm untreated soft pine panels, plus two similar panels which have received a 20-pound treatment of marine-grade creosote. Panels labeled 1-6 are exposed for six months and are referred to as "long-term panels" or "P". The panel exposed for 1 month is called the "short-term panel" and is labeled "C". In adddition, two "special panels" are mounted on each rack. These "special panels" are exposed for 12 months, and are removed and replaced in May and June of each year. These panels provide specimens for histological analysis of the gonads (see Appendix B), and also yield additional data on the occurrence of woodborer species in Barnegat Bay (see below).

The field work was taken over by GPU personnel in March, 1982, and they are now responsible for preparation, replacement, and shipment of the panels to Battelle's laboratory in Duxbury, Massachusetts, where the panels are processed for borer abundance and distribution information. The procedures for preparation and replacement are similar to that conducted by Battelle until March, 1982.

Panels are seasoned for two weeks in sterilized seawater before being placed on the array. During the first week of each month, one long-term and one short-term panel are removed from each array and replaced with a new seasoned panel. Creosoted panels are not removed, but are cleared of fouling organisms and inspected _in situ_ for evidence of attack by the woodboring isopod _Limnoria_. Upon removal, each panel is wrapped in newspaper dampened with seawater and placed in an ice-filled cooler for shipment to Battelle.

Laboratory

At the laboratory, panels are refrigerated until they are examined. Examination of each panel includes determination of the species, numbers, and size of the

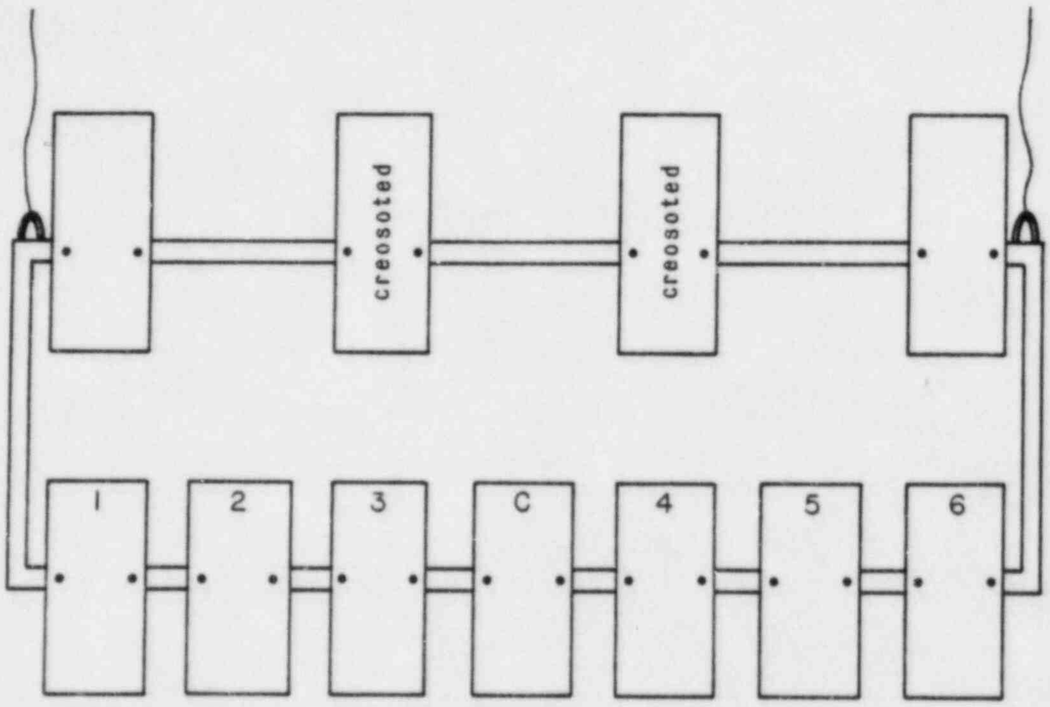

FIGURE A-2. EXPOSURE PANEL ARRAY.

borers (Teredinidae and Limnoria) present, and the extent of destruction of the panel (Table A-2, Figures A-3 and A-4). Notations of sexual conditions and presence of larvae are made if appropriate. The primary reference sources used for species identification are Turner, 1966, 1971; Bartsch, 1908; Purushotham and Raos, 1971; Clapp, 1923, 1925; and Menzies, 1951, 1959. Verification of identifications are periodically requested from Dr. Ruth Turner, Harvard University or Dr. K. Elaine Hoagland, Lehigh University.

Statistical Analysis

Because of the number of times nothing settled on the short-term panels, statistical analysis was made of data from 6-month panels only. Parameters which have been analyzed include presence/absence and abundance of *Teredo navalis*, presence/absence and abundance of *Bankia gouldi*, and percent destruction. Because of the distinctive and limited distribution of *T. bartschi*, statistical analyses were not considered necessary to determine significant differences between stations for this species.

Analyses of variance were carried out on presence/absence data and on $\log_e$ (abundance + 1) for *T. navalis* and *B. gouldi*. These tests were run on data collected from January, 1976 through November, 1983; all data from 1975 were excluded because data were collected only from December for 6-month panels, resulting in an incomplete data set for that year. Essentially no specimens were collected from long-term panels removed in the spring months of April, May and June, therefore, these months were also excluded from the analyses. Occasional long-term panels which may have been exposed for less than 6 months (i.e., 4-5 months) have been included, based on results of analyses performed for last year's report. Those analyses, in which 68 less-than-6-month panels were deleted from the data set, showed that the results and conclusions were essentially the same whether or not the 68 cases were included (Maciolek-Blake et al., 1981).

The ANOVA calculations include main effects for the original factors of month, station and biological year. A "bioyear" is defined as July, Year A through June, Year B, and corresponds to the breeding season of the Teredinidae. Thus we have data for 7 complete bioyears, from July, 1976 through June, 1983. In order to simplify the fitting of the model, 2-way and 3-way interactions were based on summary factors. These

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 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 inch indicate the maximum density beyond which it is impossible to count.

TEREDINIDAE

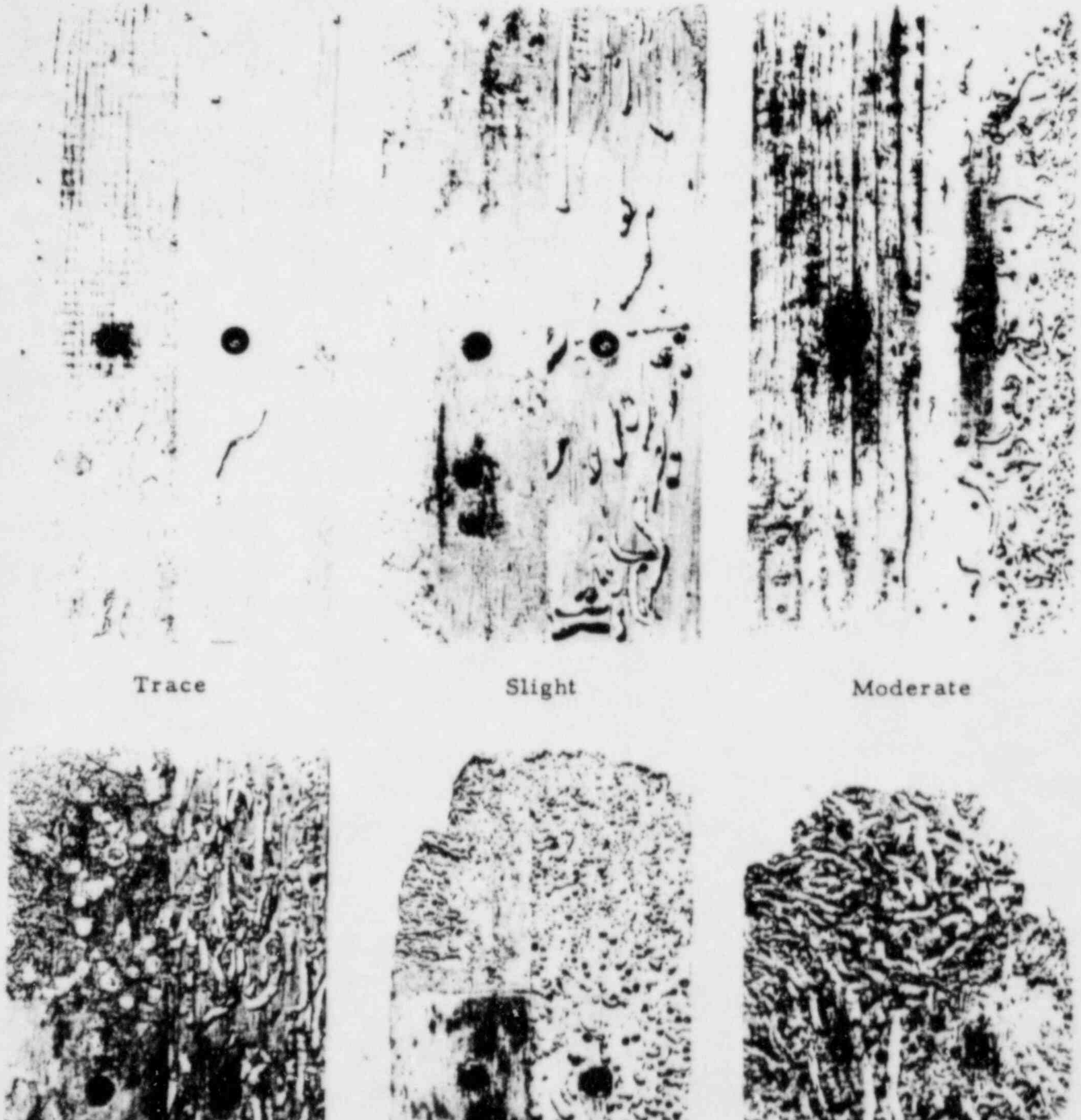

FIGURE A-3. RATING OF TEREDINID ATTACK

LIMNORIDAE

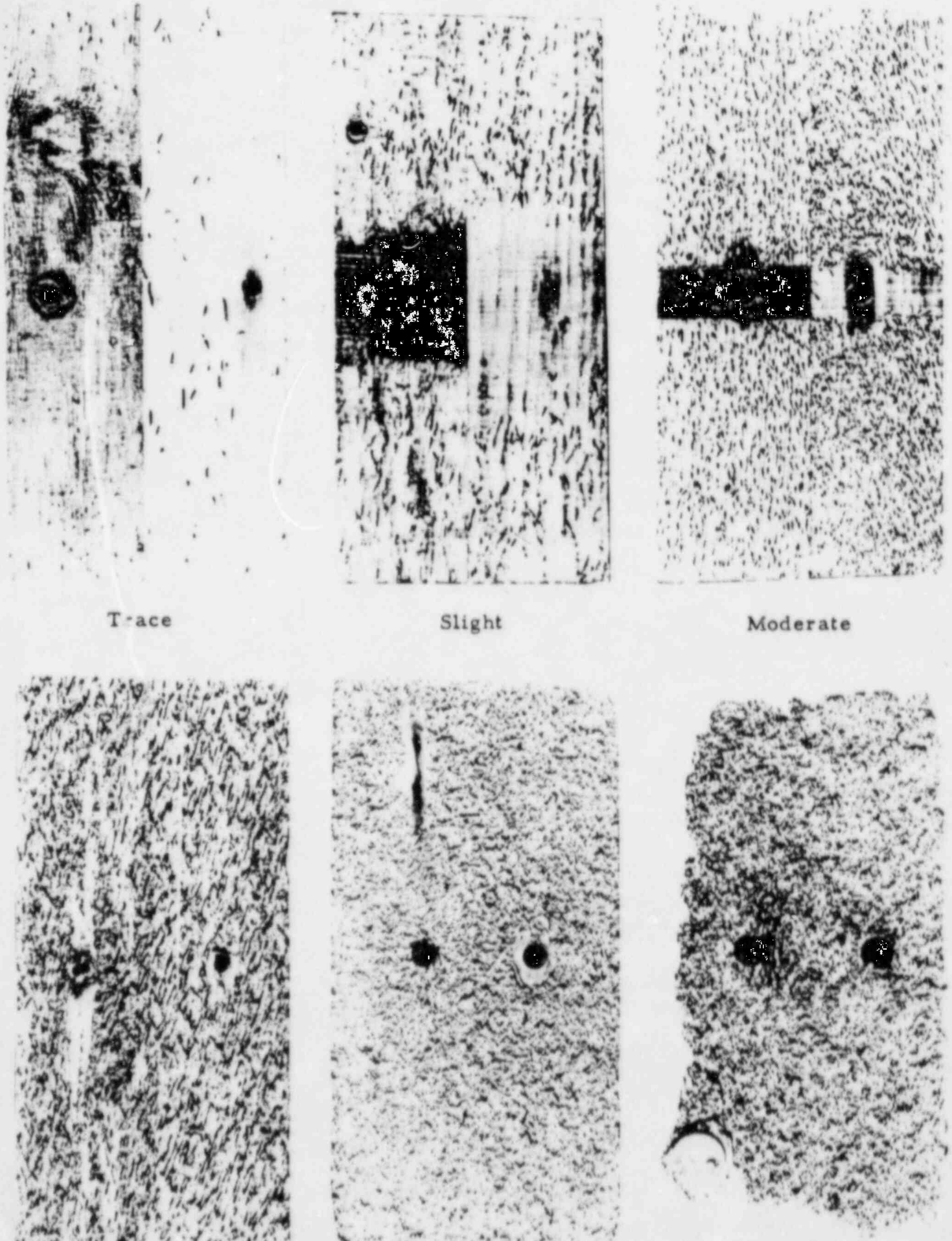

FIGURE A-4. RATING OF LIMNORID ATTACK

include grouping the months into seasons (winter = January, February, March; spring (deleted here) = April, May, June; summer = July, August, September; and fall = October, November, December) and stations into regions (Region 1 (near OCNGS) = Stations 5, 6, 7 and 8; Region 2 (south) = Stations 2, 3, 4 and 4A; Region 3 (east) = Stations 1 and 17; Region 4 (near north) = Stations 9, 10, 10A, 10B and 11; and Region 5 (north) = Stations 12, 13, 14, 15 and 16B). This regional grouping is the same as that initiated last year when Station 16B was included in Region 5. Because the program available would not fit main effects in terms of original factors and interactions in terms of summary factors, the following procedure was used. ANOVAs were first calculated with main effects and interactions in terms of the summary factors (season, region and year). The calculation was then repeated for the main effects of month, station and year. The results of the two ANOVAs were then combined by adding the sums of squares associated with the main effects (full factors), 2-way interactions (summary factors) and 3-way interactions (summary factors). The residual mean square based on the combined fit was used as the error variance estimate and is considered to be more appropriate than the error estimate based on the summary factors. F-ratios and F-tests were recalculated based on the combined fit-error estimates. The program used for ANOVA calculations was that given in "Statistical Package for the Social Sciences" (Nie, Hill, Jenkins, Steinbrenner and Bent, 1975).

Multiple classification analyses (MCA) were used to quantify the systematic variation detected by the analysis of variance procedures (Nie et al., 1975). This output, which is a display rather than a particular test, provides information about the patterns of effects of each factor, and therefore, about the reasons underlying significant effects observed in the analysis of variance calculations. It is appropriate only if the interactions among factors are not practically or statistically significant.

The MCA output provides the grand mean of all the responses. "Unadjusted deviations" are deviations from the grand mean of the sample averages in each level of each factor, not accounting for the effects of any of the other factors. "Adjusted for independent deviation" are deviations from the grand mean of the effects of each category when the other factors are adjusted for in an additive manner. These adjustments are made by fitting an additive analysis of variance model in the factors (i.e., main effects only and not interactions) and estimating the effects of the levels of each factor from the coefficients in the model. For nearly balanced data, the adjusted and unadjusted deviations should be similar.

The Bonferroni t-statistic (Miller, 1966) was used to compare means of treatment levels in a pairwise fashion to determine the sources of significant effects that have been observed in analysis of variance tests. Bonferroni's procedure is based on the two sample Student t-test with significance levels adjusted to account for simultaneity.

Let X_1, X_2, ...X_k be k sample means based on N_1, N_2, ...N_k observations respectively. Let M_1, M_2, ...M_k be the corresponding population means. These sample averages might originate as the average values in k levels of a factor under study.

Let s^2 = error SS/error df denote the error mean square from an analysis of variance, based on ν degrees of freedom.

Suppose we wish to make r pairwise comparisons among M_1, M_2, ...M_k. For example, to test $H_0{:}M_i = M_j \quad i \neq j = 1, ..., k$ we must make $r = \frac{k\ (k-1)}{2}$ pairwise comparisons.

H_o will be rejected at significance level if

$$\frac{\left|\bar{x}_i - \bar{x}_j\right|}{\sqrt{\frac{1}{n_i} + \frac{1}{n_j}}} \longrightarrow t\,(\nu;\ 1 - \alpha/2r)$$

for any pair i, j where $t\,(\nu;\ 1 - \alpha/r)$ is the upper $\alpha/2r$ point of the student t distribution with ν d.f.

This procedure leads to the confidence intervals

$$\bar{x}_i - \bar{x}_j - t\,(\nu;\ \underline{1}\ ^{\alpha}/2r)s\sqrt{\frac{1}{n_i} + \frac{1}{n_j}} \leq M_i - M_j \leq \bar{x}_i - \bar{x}_j + t\,(\nu;\ 1 - {}^{\alpha}/2r)s\sqrt{\frac{1}{n_i} + \frac{1}{n_j}}$$

with overall probability 1-a that all r confidence intervals calculated are correct. The means M_i, M_j are significantly different if the confidence interval does not contain zero.

Student Newman Keuls (SNK) Multiple Range Test is used to compare the means of treatment levels following an analysis of variance, in order to determine the reasons for significant effects that have been observed. It is based on a succession of tests utilizing Tukey's studentized range statistic.

Let $X_1, X_2, \ldots X_k$ denote the sample averages in groups 1, 2, ... k based on n_1, $n_2, \ldots n_k$ observations respectively. Let $\mu_1, \mu_2, \ldots, \mu_k$, be the corresponding population means. Let s^2 denote the error mean square from an analysis of variance, based on d.f. The SNK procedure assumes $n_1, = n_2 \ldots = n_k$, but minor differences in the n_j's can be tolerated.

We wish to determine which means are statistically significantly different from one another at significance level .

Let $X_{i(1)} \leq X_{i(2)} \leq X_{i(3)} \leq \ldots \leq X_{i(k)}$ denote the ordered mean values, from smallest to largest. Let $\mu_{i(1)}, \mu_{i(2)}, \ldots, \mu_{i(k)}$ denote the corresponding population means. Let $q\ (1-\alpha;\ \nu,\ r)$ denote the upper point of Tukey's studentized range statistic with degrees ν of freedom and based on r groups.

$$\text{If } \frac{\bar{X}_{i(k)} - \bar{X}_{i(1)}}{s/\sqrt{n}} \leq q\,(1-\alpha;\ \nu;\ k)$$

then all the means $\mu_i, \mu_2, \ldots, {}_k$ are declared to be equal.

The procedure we use accommodates slightly unequal n_j's by comparing

$$\frac{\bar{X}_{i(k)} - \bar{X}_{i(1)}}{s/\sqrt{1/2\left(\frac{1}{n_{i(k)}} + \frac{1}{n_{i(1)}}\right)}} \quad \text{with } q\ (1-\alpha;\ \nu,\ k)$$

$$\frac{\bar{X}_{i(k)} - \bar{X}_{i(1)}}{s/\sqrt{1/2\left(\frac{1}{n_{i(k)}} + \frac{1}{n_{i(1)}}\right)}} \geq q\ (1-\alpha;\ \ ,\ k)$$

then compare

$$\frac{\bar{X}_{i(k-1)} - \bar{X}_{i(1)}}{s/\sqrt{1/2\ \frac{1}{n_{i(k)}} + \frac{1}{n_{i(2)}}}} \quad \text{with } q\ (1-\alpha;\ \nu,\ k-1)$$

and compare

$$\frac{\bar{X}_{i(k)} - \bar{X}_{i(2)}}{s/\sqrt{2\left(\frac{1}{n_{i(k)}} + \frac{1}{n_{i(2)}}\right)}} \quad \text{with } q\ (1-\alpha;\quad , k-1)$$

If, for example, $X_{i(k-1)} - X_{i(1)}$ is not significantly large, then $i(1)$, $i(2)$, ... $i_{i(k-1)}$ are considered to be not significantly different.

This process is continued with subsets of size k-2 within significant subsets of size k-1; subsets of size k-3 within significant subsets of size k-2, etc. At each stage

$$\frac{\bar{X}_{i(p+h)} - \bar{X}_{i(p)}}{s/\sqrt{\frac{1}{2}\left(\frac{1}{n_{i(p+h)}} + \frac{1}{n_{i(p)}}\right)}} \quad \text{is compared with } q\ (1-\alpha;\ \nu\ , h+1)$$

At the conclusion of this process, the means i, j are declared significantly different at level if X_i, X_j did not fall within any nonsignificant subset.

An unweighted least squares regression fit of the destruction data on species abundance data was made. The percent destruction data were transformed into logits, where percent values of 0-100 were assigned values of P = 0-1 to denote proportion. The

logit (proportion destruction) = $\log_{e_1}$Pp.

This transformation converts the (0,1) scale into a (- , +-) scale, and stretches out the extreme values at both ends, allowing greater resolution. Abundance data were transformed into $\log_e$ (1 + abundance).

The regression model used was:

Y = logit(prop. destr.) = $\beta_0 + \beta_1 \ln(1 +$ T. navalis$) + \beta_2 \ln(1 +$ B. gouldi$) + \beta_3 \ln$ (1 + Teredo spp.) + $\beta_4 (1 +$ T. bartschi$) + \beta_5 \ln(1 +$ Teredinidae$) + E$.

where β = the unknown regression coefficient

and E = error or unexplained variability.

This regression analysis was carried out using the SPSS and subprogram Regression. Analysis of variance was carried out on residuals of the regression fit.

Results and Discussion

Modifications to Panel Exposure

During the present reporting period, it became necessary to change the locations of some of the panel racks. The changes in location were very slight, so that in effect the racks remained in the same basic location. These changes are described below.

In December, 1982, the rack at Station 15 was moved from Pier 14 a distance of 40 feet west to Pier 15 because Pier 14 was to be dismantled.

In July, 1983, the rack at Station 4A was moved 25 feet east because of deterioration of the dock.

Several changes were made in November, 1983. At Station 1, the rack was moved to the opposite side of the bulkhead and about 40 feet closer to shore. The rack at Station 7 was moved to deeper water at the end of the dock. At Station 8, the rack was moved to a company-owned dock approximately 2000 feet toward the mouth of Oyster Creek. At Station 9, the rack was moved about 2000 feet toward the plant to company-owned property.

In February, the creosoted panels at Stations 9 and 13 were missing. In April, creosote panel number 2 was replaced at Station 13; creosote panel number 1 was replaced at Station 9 in June.

Species Identified

Only two species of molluscan woodborers, the teredinids Teredo navalis and Bankia gouldi, were identified from either short-term or long-term panels. Teredo bartschi, a key species in previous reports has not been recovered from any panels since February, 1982. A fourth species, T. furcifera, which was of concern during the early years of the program, has not been identified from any panel since March, 1977.

Crustacean woodborers, identified as Limnoria cf. tuberculata (see Maciolek-Blake et al., 1982), were again found at several stations.

Short-Term (1-Month) Panels

Short-term panels, those exposed for a one-month period, provide data on the annual occurrence of shipworm larval settlement, the stations at which settlement occurs, survival of the juveniles, and the amount of growth that can take place in one month. Since the panels are retrieved near the beginning of each month, the results reflect activity during the previous month.

The number and species of Teredinidae found in short-term panels during this report period are shown in Table A-3. Settlement took place as late as December, 1982 at Station 1. The shipworms were too small to identify to species but were probably T. navalis. Short-term panels removed from January through June, 1983 were free of teredinids. Settlement began again in July and persisted through November at Station 1. At the other stations where teredinids were recovered from short-term panels (2, 8, 11, 12, 13, 14, 15 and 17), the principal period of settlement was July through September. Some settlement also occurred as late as November at Station 17.

For the second consecutive year, no settlement occurred on short-term panels at Station 7, formerly a site where considerable settlement could be expected during the summer months.

Settlement on the short-term panels was increased somewhat over last year, but the amount of destruction to short-term panels generally remained at less than 1 percent, except at Station 1, where it was 5 percent (Table A-4). This is considerably lower than the 15 percent recorded during last year's reporting period (Hillman et al., 1983), and a great deal lower than the 75 percent recorded during the 1981-1982 season (Maciolek-Blake et al., 1982).

A comparison of the total number of Teredinidae settling on short-term panels each year from 1975 through November, 1983 is shown in Table A-5. Total set during the present reporting period was the highest since 1979, increased by over 1000 individuals since last year's reporting period (Hillman et al., 1983). Most of the settlement (96 percent) was at Station 1. By contrast, most of the settlement in short-term panels during 1978 and 1979, the two previous years of high settlement (except for the first year of the program) was at Station 7, where no settlement has occurred for the last two reporting periods. Settlement on short-term panels was down somewhat from last year's

TABLE A-3. NUMBERS OF TEREDINIDS IN SHORT-TERM PANELS REMOVED MONTHLY FROM DECEMBER, 1982 THROUGH NOVEMBER, 1983*

T = Teredinidae; Tn = Teredo navalis; Ts = Teredo spp; Bg = Bankia gouldi

Site	Dec	Jul	Aug	Sep	Oct	Nov
1	90 T	26 T	1100 T	1040 Tn, T	85 T	42 T
2			1 T			
3						
4						
4A						
5						
6						
7						
8			1 T			
9						
10						
10A						
10B						
11		6 T				
12			1 T	1 Bg		
13		13 T	2 T			
14		37 T	28 T			
15				1 T		
16B						
17				8 Ts, T		5 T

* Short-term panels removed January through June, 1983 were free of teredinid borers.

TABLE A-4. PERCENT DESTRUCTION OF SHORT-TERM PANELS REMOVED MONTHLY FROM DECEMBER, 1982 THROUGH NOVEMBER, 1983*

Site	Dec	Jul	Aug	Sep	Oct	Nov
1	<1	<1	4	5	<1	<1
2			<1			
3						
4						
4A						
5						
6						
7						
8			<1			
9						
10						
10A						
10B						
11		<1				
12			<1	<1		
13		<1	<1			
14		<1	<1			
15				<1		
16B				<1		<1
17						

* Teredinids were not present in short-term panels removed from January through June, 1983.

TABLE A-5. TOTAL AMOUNT OF TEREDINID SETTLEMENT IN SHORT-TERM PANELS FROM JULY, 1975 THROUGH NOVEMBER, 1983

Site	1975	1976	1977	1978	1979	1980	1981	1982	1983
1	8199	1090	654	1015	535	88	1396	1335	2293
2	17	2		1	8				1
3	9				2				
4	6	2	3		4				
4A					6				
5	4562	2	4	75	754	4	9	2	
6	2886		1	15	171	2			
7	4	3	241	2983	3698	10	301		
8	1	4							1
9			1		1				
10	2	2			5				
10A				1	54	1	3	1	
10B					6	1			
11	375	71	28	5	378	14	6	33	6
12	34	1	5	1	13	4	1		2
13	142	10	9	4	16		1*		15
14	308	20	8	8	69	2	12		65
15	3				5	1		3	1
16	2								
17	117		3		6			19	13
Totals	16667	1207	957	4108	5731	127	1729	1393	2397

* No panels examined in October and November.

totals at Station 11, but up considerably at Station 14, where no settlement took place last year and where it was relatively light in 1980 and 1981.

Destruction. The average percent destruction of short-term panels for each year from 1975 through 1983 is shown in Table A-6. Destruction at Station 1 continued to be greater than at the other stations, but overall, destruction is still quite low.

Identifications. Individuals are only infrequently identified to species from short-term panels because the size of each one is usually less than 10 mm. During this reporting period Teredo navalis was identified only from September panels at Station 1, and Bankia gouldi was identified at Station 12 in September (Table A-3). The remaining identifications were either at the generic (Teredo spp.) or family (Teredinidae) level.

Over 1800 short-term panels have been examined since the beginning of this program in 1975. Table A-7 presents summaries for family, generic and specific identifications made from these collections. Teredo furcifera, not collected since March, 1977, has been excluded.

The number of Teredo navalis identified during this reporting period (40) was down somewhat from last year's 61, but the overall number of Teredinidae reported for 1983 (2487) was almost double last year's 1393, and constituted about 43 percent of all Teredinidae reported since the program began. This is due in part to the relatively large number of Teredinidae occurring in the fall setting period.

Teredo bartschi was absent from short-term panels for the second consecutive year. Only one Bankia gouldi was identified from the short-term panels during the present reporting period.

The pattern of occurrence of teredinids on short-term panels during the 1982/1983 reporting period was generally similar to what it has been in previous years, except perhaps for the increase in settlement during the fall. Most of that settlement was in Region 3, an area well outside the zone of thermal influence, and in part probably represents some recruitment of larvae from outside the Barnegat Bay area.

Long-term (6-month) Panels

Regular long-term panels are those exposed for a six-month period. The results obtained from these panels give an integrated view of woodborer activity,

TABLE A-6. MEAN PERCENT DESTRUCTION OF SHORT-TERM PANELS REMOVED DURING THE JULY THROUGH NOVEMBER PERIOD, 1975 THROUGH 1983*

Site	1975	1976	1977	1978	1979	1980	1981	1982	1983
1	13.0	3.6	2.8	1.6	4.4	0.8	16.0	3.4	2.4
2	1.0	0.4		0.2	0.6				0.2
3	0.4				0.4				
4	0.4	0.2	0.4		0.4				
4A	-	-			0.4				
5	14.0**	0.2	0.4	0.6	2.8	0.4	0.4	0.4	
6	11.6		0.2	0.8	1.4	0.4			
7	1.0**	0.4	3.2	3.0	3.2	0.8	0.8		
8	0.3**	0.2							0.2
9	**		0.2		0.2				
10	0.4	0.2			0.4				
10A	-	-	-	0.2	1.0	0.2	0.4	0.2	
10B	-	-	-		0.4	0.2			
11	9.2	1.0	0.4	0.2	5.4	0.6	0.6	0.4	0.2
12	2.0	0.2	0.4	0.2	1.6	0.4	0.2		0.4
13	3.6	0.6	0.4	0.2	0.6		0.2**		0.4
14	11.2	0.6	0.4	0.4	2.4	0.4	0.4		0.4
15	0.6				0.4	0.2		0.2	0.2
16/16B	0.2							0.2	
17	3.8		0.4		0.6			0.4	0.4

Station 4A established April, 1977.
Station 10A and 10B established April, 1978.
Station 16B established June, 1982.
* <1% destruction treated as 1% in averages.
** Incomplete data.

TABLE A-7. SUMMARY OF NUMBER OF OCCURRENCES OF *Teredo navalis*, *Teredo bartschi*, ALL *Teredo*, *Bankia gouldi* AND TEREDINIDAE ON SHORT-TERM PANELS IN BARNEGAT BAY

Months are Grouped by Season (Winter = Jan, Feb, Mar; Spring = Apr, May, June; Summer = Jul, Aug, Sep; Fall = Oct, Nov, Dec), and Stations are grouped by Region: Region 1 (near OCNGS): Stas. 5, 6, 7, 8; Region 2 (south): Stas. 2, 3, 4, 4A; Region 3 (east): Stas. 1, 16, 17; Region 4 (near north): Stas. 9, 10, 10A, 10B, 11; Region 5 (north): Stas. 12, 13, 14, 15.

Teredo navalis: Identified a Total of 1484 Times

Year	No.	Season	No.	Region	No.
1975	0	Winter		1	0
1976	2	Spring	0	2	2
1977	1	Summer	1484	3	1476
1978	1	Fall	0	4	6
1979	10			5	0
1980	0				
1981	1369				
1982	61				
1983	40				

Teredo bartschi: Identified a Total of 21 Times

Year	No.	Season	No.	Region	No.
1975	0	Winter	0	1	20
1976	0	Spring	0	2	0
1977	2	Summer	17	3	0
1978	4	Fall	4	4	1
1979	6			5	0
1980	1				
1981	8				
1982	0				
1983	0				

All *Teredo**: Identified a Total of 1553 Times

Year	No.	Season	No.	Region	No.
1975	7	Winter	0	1	41
1976	6	Spring	0	2	7
1977	4	Summer	1547	3	1495
1978	7	Fall	6	4	9
1979	21			5	1
1980	2				
1981	1391				
1982	74				
1983	41				

TABLE A-7. (continued)

	Year	No.	Season	No.	Region	No.
All Bankia**: Identified a Total of 77 Times						
	1975	17	Winter	0	1	13
	1976	6	Spring	0	2	5
	1977	8	Summer	77	3	3
	1978	4	Fall	0	4	23
	1979	13			5	33
	1980	9				
	1981	16				
	1982	3				
	1983	1				
Teredinidae***: Identified a Total of 5800 Times						
	1975	47	Winter	1	1	373
	1976	21	Spring	0	2	22
	1977	26	Summer	5297	3	5182
	1978	23	Fall	502	4	79
	1979	52			5	144
	1980	22				
	1981	1729				
	1982	1393				
	1983	2487				

* Includes T. navalis, T. bartschi and Teredo spp.

** Includes Bankia gouldi and Bankia sp.

*** Includes T. navalis, T. bartschi, Teredo spp., Bankia gouldi, Bankia sp. and Teredinidae including reproduction, settlement, and survival, over the entire period for which the panel has been exposed. Numbers and species of teredinids found in long-term panels during the present reporting period are shown in Tables A-8 (December, 1982) through A-19 (November, 1983).

Panels submerged in June, July and August, 1982, and examined in December 1982, and January and February, 1983 respectively, contained specimens ranging from less than 1 mm up to 290 mm. The 290 mm specimens occurred in December at Station 10A. As during last year's reporting period, there was a slight decline through January and February in the upper length reached by any specimen collected over that period. The largest specimen found in January was 240 mm at Station 10, and in February it was 155 mm at Station 11. The smallest size range in December was 10 to 48 mm (only two individuals represented) at Station 15. Otherwise the minimum size ranges were similar to those shown last year, with a range of less than 1 to 70 mm in December, 4 to 60 mm in January, and only 1 individual of less than 1 mm length in February, all at Station 1. The smallest individuals could have set as late as late October and ceased to grow as the water cooled, similar to what was described over the same period last year (Hillman et al., 1983).

Teredinids were collected in March only from Stations 1, 7 and 11 (Table A-11), and they were very small, the largest specimen being 24 mm at Station 7. They were probably also from the fall-spawned set, and grew very little as the water cooled.

In sharp contrast to what was seen last year when no specimens were collected during April, May and June, the April and May panels (Tables A-12 and A-13) contained some very small specimens. Most were less than 1 mm in length, with the longest one being only 10 mm. Most (494) of the young shipworms were collected at Station 1, but panels from Stations 4, 5, 7, 8, 9, 10A, 11, 13 and 17 also contained young teredinids, probably also from the fall set. No teredinids were present in the long-term panels removed in early June (Table A-14).

As expected, the July panels contained young teredinids ranging in length from less than 1 mm at the four stations (1, 11, 13 and 14) where they occurred to 5 mm at Station 11. These specimens would most likely have been from a late May to early June spawn.

TABLE A-8. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED DECEMBER 6-7, 1982

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm	Species Identification	Remarks
1	P	650	99	<1-70	150 T. navalis, 500 Teredinidae*	75% of specimens dead
	C	90	<1	<1	90 Teredinidae*	
5	P	1	2	125	1 T. navalis	
	C	0				
7	P	6	9	14-200	5 T. navalis, 1 Teredinidae*	4 live, 2 dead
	C	0				
9	P	3	10	170-200	1 B. gouldi, 2 T. navalis	
	C	0				
10A	P	4	14	85-290	2 B. gouldi, 2 T. navalis	
	C	0				
10B	P	1	4	250	1 B. gouldi	
	C	0				
11	P	77	90	30-205	2 B. gouldi, 60 T. navalis, 15 Teredinidae*	15 specimens dead
	C	0				
13	P	3	13	210-235	3 B. gouldi	
	C	0				
15	P	2	<1	10-48	2 T. navalis	1 specimen dead
	C	0				
16B	P	1	3	190	1 B. gouldi	
	C	0				
17	P	9	10	9-130	6 T. navalis	
	C	0				

Stations 2-4A, 6, 8, 10, 12, and 14 - No Teredinidae present

P = Long-term panel submerged June 1-2, 1982.
C = Short-term panel submerged November 1-2, 1982.
* = Not speciated due to size or condition.

TABLE A-9. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED JANUARY 3-4, 1983

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm	Species Identification	Remarks
1	P	700	99	4-60	100 T. navalis 600 Teredinidae*	85% of specimens dead
	C	0				
3	P	2	5	145-200	2 B. gouldi	
	C	0				
7	P	4	2	<1-155	1 T. navalis, 3 Teredinidae*	
	C	0				
10	P	1	4	240	1 T. navalis	
	C	0				
10A	P	2	5	140-160	2 T. navalis	
	C	0				
10B	P	2	8	210-215	2 B. gouldi	1 dead
	C	0				
11	P	62	95	25-190	1 B. gouldi, 57 T. navalis, 4 Teredinidae*	4 Teredinidae dead
	C	0				
12	P	1	2	155	1 B. gouldi	
	C	0				
13	P	1	2	150	1 B. gouldi	
	C	0				
15	P	7	15	40-190	4 B. gouldi, 2 T. navalis, 1 Teredinidae*	1 T. navalis and 1 Teredinidae dead
	C	0				
17	P	20	20	2-120	19 T. navalis, 1 Teredinidae*	
	C	0				

Stations 2, 4-6, 8, 9, 14 and 16B - No Teredinidae present.

P = Long-term panel submerged July 6-7, 1982.
C = Short-term panel submerged December 6-7, 1982.
* = Not speciated due to size or condition.

TABLE A-10. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED FEBRUARY 8-9, 1983

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
5	P	1	<1	<1	1 Teredinidae*	
	C	0				
7	P	16	<1	<1-1	16 Teredinidae*	
	C	0				
11	P	10	7	<1-155	4 *T. navalis*, 6 Teredinidae*	
	C	0				
15	P	4	<1	<1-1	4 Teredinidae*	
	C	0				
17	P	27	10	10-75	27 *T. navalis*	
	C	0				

Stations 2-4A, 6, 8-10B, 12-14, and 16B - No Teredinidae present.
Station 1 - Long-term exposure panel missing from rack.

P = Long-term panel submerged August 3-4, 1982.
C = Short-term panel submerged January 3-4, 1983.
* = Not speciated due to size.

TABLE A-11. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED MARCH 7-8, 1983

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	P	68	1	<1-5	68 Teredinidae*	
	C	0				
7	P	4	<1	<1-24	1 T. navalis, 3 Teredinidae*	
	C	0				
11	P	10	<1	<1-1	10 Teredinidae*	
	C	0				

Stations 2-6, 8-10B, 12-17 - No Teredinidae present.

P = Long-term panel submerged September 7-8, 1982.
C = Short-term panel submerged February 8-9, 1983.
* = Not speciated due to size.

TABLE A-12. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED APRIL 5-6, 1983

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	P	327	<1	<1-8	10 T. navalis, 5 Teredo spp., 312 Teredinidae*	
	C	0				
4	P	2	<1	<1	2 Teredinidae*	empty pits
	C	0				
5	P	4	<1	1-10	2 T. navalis, 1 Teredo spp., 1 Teredinidae*	
	C	0				
7	P	84	<1	<1-2	17 Teredo, spp., 67 Teredinidae*	
	C	0				
8	P	3	<1	<1	3 Teredinidae*	
	C	0				
9	P	1	<1	<1	1 Teredinidae*	empty pit
	C	0				
10A	P	3	<1	<1	3 Teredinidae*	
	C	0				
11	P	45	<1	<1-1	45 Teredinidae*	
	C	0				
13	P	2	<1	<1	2 Teredinidae*	
	C	0				
17	P	4	<1	<1-2	4 Teredinidae*	
	C	0				

Stations 2-3, 4A, 6, 10, 10B, 12, 14-16B - No Teredinidae present.

P = Long-term panel submerged October 5-6, 1982.
C = Short-term panel submerged March 7-8, 1983.
* = Not speciated due to size.

TABLE A-13. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED MAY 2-3, 1983

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	P	167	<1	<1	167 Teredinidae*	90 empty pits, 77 with Teredinid shells
	C	0				
7	P	20	<1-1	<1	20 Teredinidae*	15 empty pits, 5 with Teredinid shells
	C	0				
8	P	1	<1	<1	1 Teredinidae*	1 empty pit
	C	0				
9	P	3	<1	<1	3 Teredinidae *	3 empty pits
	C	0				
11	P	3	<1	<1	3 Teredinidae *	3 empty pits
	C	0				

Stations 2-6, 10-10B, 12-17 - No Teredinidae present.

P = Long-term panel submerged November 1-2, 1982.
C = Short-term panel submerged April 5-6, 1983.
* = Not speciated due to size.

TABLE A-14. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED JUNE 6-7, 1983

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
Stations 1-17 no Teredinidae present.						

TABLE A-15. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED JULY 5-6, 1983

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	P	5	<1	<1	5 Teredinidae*	
	C	26	<1	<1	26 Teredinidae*	
11	P	8	<1	<1-5	1 Teredo spp., 7 Teredinidae*	
	C	6	<1	<1-2	6 Teredinidae*	
13	P	0				
	C	13	<1	<1-1	13 Teredinidae*	
14	P	28	<1	<1-1	28 Teredinidae*	
	C	37	<1	<1-1	37 Teredinidae*	

Stations 2-10B, 12, 15-17 - No Teredinidae present.

P = Long-term panel submerged January 3-4, 1983.
C = Short-term panel submerged June 6-7, 1983.
* = Not speciated due to size.

TABLE A-16. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED AUGUST 1-2, 1983

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	P	900	5	<1-16	10 T. navalis, 890 Teredinidae*	
	C	1100	4	<1-7	1100 Teredinidae*	
2	P	0				
	C	1	<1	2	1 Teredinidae*	
5	P	1	<1	30	1 B. gouldi	
	C	0				
7	P	1	<1	2	1 Teredinidae*	
	C	0				
8	P	2	<1	13-30	2 B. gouldi	
	C	1	<1	1	1 Teredinidae*	
10A	P	2	<1	14-45	2 B. gouldi	
	C	0				
10B	P	2	<1	<1	2 Teredinidae*	
	C	0				
11	P	46	60	35-110	43 B. gouldi, 3 T. navalis	Ripening gonads
	C	0				
12	P	2	<1	13-20	2 B. gouldi	
	C	1	<1	<1	1 Teredinidae*	
13	P	0				
	C	2	<1	<1-3	2 Teredinidae*	
14	P	59	40	20-110	59 B. gouldi	Ripening gonads
	C	28	<1	<1-4	28 Teredinidae*	

Stations 3-4A, 6, 9, 10, 15-17 - No Teredinidae present.

P = Long-term panel submerged February 8-9, 1983.
C = Short-term panel submerged July 5-6, 1983.
* = Not speciated due to size.

TABLE A-17. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED SEPTEMBER 6-7, 1983

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	P	850	98	<1-50	650 T. navalis, 200 Teredinidae*	Ripening gonads
	C	1040	5	<1-18	40 T. navalis, 1000 Teredinidae*	
3	P	1	3	180	1 B. gouldi	
	C	0				
5	P	2	8	230-240	2 B. gouldi	
	C	0				
7	P	3	5	60-220	3 B. gouldi	
	C	0				
8	P	7	8	25-180	6 B. gouldi, 1 T. navalis	Teredo-ripening gonads
	C	0				
10A	P	1	4	250	1 B. gouldi	
	C	0				
11	P	37	95	50-190	36 B. gouldi, 1 T. navalis	Teredo dead
	C	0				
12	P	1	3	160	1 B. gouldi	
	C	1	<1	28	1 B. gouldi	
13	P	6	17	140-250	6 B. gouldi	
	C	0				
14	P	47	90	20-190	47 B. gouldi	
	C	0				
15	P	1	2	130	1 B. gouldi	
	C	1	<1	4	1 Teredinidae*	
17	P	7	1	<1-27	4 T. navalis, 3 Teredinidae*	
	C	8	<1	<1-3	1 Teredo spp., 7 Teredinidae*	

Stations 2, 4, 4A, 6, 9, 10, 10B, and 16B - No Teredinidae present.

P = Long-term panel submerged March 7-8, 1983.
C = Short-term panel submerged August 1-2, 1983.
* = Not speciated due to size.

TABLE A-18. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED OCTOBER 4-5, 1983

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	P	400	99		30 T. navalis, 370 Teredinidae*	None live
	C	85	<1	<1-3	85 Teredinidae*	
6	P	1	2	140	1 B. gouldi	
	C	0				
7	P	4	8	95-200	4 B. gouldi	3 live, 1 dead
	C	0				
8	P	3	7	130-170	3 B. gouldi	
	C	0				
10A	P	1	7	360	1 B. gouldi	
	C	0				
10B	P	2	5	140-180	2 B. gouldi	1 live, 1 dead
	C	0				
11	P	48	98	25-190	11 B. gouldi, 37 Teredinidae*	37 empty tubes
	C	0				
12	P	1	2	165	1 B. gouldi	
	C	0				
13	P	23	95	75-225	23 B. gouldi	
	C	0				
14	P	120	98	<1-120	1 T. navalis, 46 B. gouldi 73 Teredinidae*	65% of specimens dead
	C	0				
15	P	1	5	285	1 B. gouldi	
	C	0				
17	P	24	5	<1-140	1 B. gouldi, 6 T. navalis, 9 Teredo spp.*, 8 Teredinidae*	
	C	0				

Stations 2-5, 9-10, 16B - No Teredinidae present

P = Long-term panel submerged April 5-6, 1983.
C = Short-term panel submerged September 6-7, 1983.
* = Not speciated due to size or condition.

TABLE A-19. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED NOVEMBER 7-8, 1983.

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	P	400	99		25 T. navalis, 375 Teredinidae*	Only 1 live
	C	42	<1	<1	42 Teredinidae*	
2	P	1	3	255	1 Teredo spp.	
	C	0				
5	P	1	6	355	1 B. gouldi	
	C	0				
7	P	4	20	170-330	4 B. gouldi	
	C	0				
8	P	3	10	75-265	3 B. gouldi	1 of 3 dead
	C	0				
9	P	1	<1	4	1 B. gouldi	
	C	0				
10A	P	2	5	55-290	1 B. gouldi, 1 Teredinidae*	1 of 2 dead
	C	0				
11	P	52	97	25-200	44 B. gouldi, 8 T. navalis	
	C	0				
12	P	1	1	130	1 B. gouldi	
	C	0				

TABLE A-19 (Continued)

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
13	P	18	75	110-340	17 B. gouldi, 1 T. navalis	
	C	0				
14	P	80	98	15-230	18 B. gouldi, 62 Teredinidae*	62 dead
	C	0				
15	P	5	25	120-280	4 B. gouldi, 1 T. navalis	
	C	0				
16B	P	1	3	220	1 B. gouldi	
	C	0				
17	P	17	12	<1-115	1 B. gouldi, 10 T. navalis, 6 Teredinidae*	
	C	5	<1	<1		

Stations 3-4A, 6, 10 and 10B No Teredinidae present.

P = Long-term panel submerged May 2-3, 1983.
C = Short-term panel submerged October 4-5, 1983.
* = Not speciated due to size or condition.

The numbers of shipworms collected in long-term panels at Station 1 increased sharply by August, as did the number of stations at which shipworms were collected (Table A-16). Specimens up to 110 mm were collected from Stations 11 and 14. This pattern is consistent with what has been reported in previous years (e.g., Hillman et al., 1983). Spawning occurs by late May or early June in the region, and settlement from this spawn is seen on the July and August panels. Much of the set at Station 1 could have come from individuals spawned outside of Barnegat Bay, and swept into the area on incoming tides.

The pattern of setting in the panels recovered in September was similar to that shown in the August panels, except that the sizes of the individuals collected had increased extensively. Specimens of Bankia gouldi 250 mm long were found at Station 13, and 240 mm-long specimens were collected at Station 5 (Table A-17). Teredo navalis specimens up to 50 mm long were collected at Station 1, which was also the station where the greatest number of shipworms were collected in September. By September, 98 percent of the long-term panel recovered at Station 1 was filled with T. navalis, while the long-term panels from Stations 11 and 14 were 95 and 90 percent filled with B. gouldi respectively.

The number and maximum size of shipworms in the October panels decreased from what was found in the September panels, but the panels at Stations 1, 11 and 14 were 99, 98 and 98 percent filled with shipworms (Table A-16). Specimens up to 225 mm in length were collected from Station 13.

The decrease in the maximum length of shipworms found in October was not part of a trend, since by November a specimen of B. gouldi 355 mm long was found at Station 5, and specimens over 325 mm were collected at Stations 7 and 13. Specimens over 250 mm in length were collected at Stations 2, 8, 10A and 15. The panels at Stations 1, 11 and 14 remained almost 100 percent filled, while the panel at Station 13 had decreased to 75 percent filled. Bankia gouldi was the species responsible for filling the panels at Stations 11 and 14, while at Station 1, it was primarily T. navalis.

Species Distribution and Dominance. Tables A-20 through A-22 present a summary of the abundance of Teredo navalis, T. bartschi and Bankia gouldi, respectively, recorded from long-term panels since July, 1975. Dominant species at each station are indicated in Table A-23. A discussion of each species follows.

Teredo navalis. Teredo navalis was recorded from six-month panels from 9 of the 20 stations between December, 1982 and April, 1983, and at only 7 stations between

TABLE A-20. NUMBER OF <u>Teredo navalis</u> IN 6-MONTH PANELS REMOVED JULY, 1975 THROUGH NOVEMBER, 1983

Year	Station	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						4
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
	Dec	400	3												8						

TABLE A-20. (Continued)

	Station	1	2	3	4	4A	5	6	7*	8	9	10	10A	10B	11	12	13	14	15	16**	17
1979	Jan	400	6																		
	Feb	400	4																1		
	Mar	30													1						
	Apr																				
	May																				
	Jun																				
	Jul														19						
	Aug	47	1				1								160			2			1
	Sep	450	20						1		2	1	2		80		2	12	3		
	Oct	500	23								1		2	1	20	2	1	13			3
	Nov	500	17	1		1				—		3	2		1			1	3		4
	Dec	100	23	1		1					3	1		2					1		3
1980	Jan	220	13	1		2						1	1	1	110	1			7		7
	Feb	300	12		3	2		1		1			1	1	139			3	1		4
	Mar	2																			
	Apr																				
	May																				
	Jun																				
	Jul														5						
	Aug	1	6						1						29	1		1			
	Sep	35	7				1		1	1					4			1		1	
	Oct	200	11		1				3						8			1			2
	Nov	300	11												11						6
	Dec	300	1											1	8						
1981	Jan	350																			
	Feb	72											1		8			2			6
	Mar	3											1								
	Apr								1	1											
	May																				
	Jun																				
	Jul									1								2			
	Aug	135													7			3			
	Sep	800													5			4	1		
	Oct	100								1	1				5		--	3			1
	Nov	190								2					2		--		1		
	Dec	65							1						2					--	4
1982	Jan	45													1						3
	Feb	60													8			1	2		2
	Mar	23																			
	Apr																				
	May																				
	Jun																			--	
	Jul									1											
	Aug								1	1					3			1			
	Sep	400							4						55			1	1		3
	Oct	150							2	1				1	48				1		5
	Nov	--					1			1	1		4		82				4		5
	Dec	150					1		5		2		2		60				2		9

TABLE A-20. (Continued)

	Station	1	2	3	4	4A	5	6	7*	8	9	10	10A	10B	11	12	13	14	15	16**	17
	Jan	100							1			1	2		57				2		19
	Feb														4						27
	Mar								1												
	Apr	10																			
	May																				
1983	Jun																				
	Jul																				
	Aug	10													3						
	Sep	650								1					1						4
	Oct	30																1			6
	Nov	25													8		1		1		10

* = New rack submerged September, 1975.
\- = Panel station not in operation.
— = Panel missing.
** = See Table A-1.

TABLE A-21. NUMBER OF Teredo bartschi IN 6-MONTH PANELS REMOVED JULY, 1975 THROUGH NOVEMBER, 1983

Year	Station	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												
	Dec						190	35	400												

TABLE A-21. (continued)

Year	Station	1	2	3	4	4A	5	6	7*	8	9	10	10A	10B	11	12	13	14	15	16**	17
1979	Jan						73	11	300												
	Feb						7	18	70												
	Mar																				
	Apr																				
	May																				
	Jun																				
	Jul																				
	Aug						17		160												
	Sep						240		500				17								
	Oct						35	64	100				20								
	Nov						1	160	38	-			29								
	Dec						10	170	14				47								
1980	Jan						390	39	200				34	1							
	Feb						449	21	55				31		1						
	Mar						22	12	40				1								
	Apr																			-	
	May																				
	Jun																				
	Jul																				
	Aug																				
	Sep																				
	Oct								2												
	Nov								1												
	Dec							1	6												
1981	Jan							2	63												
	Feb								5												
	Mar							4	19												
	Apr																				
	May																				
	Jun																				
	Jul																				
	Aug								5												
	Sep								130												
	Oct						9		130												
	Nov						90		250												
	Dec						3	1	200												

TABLE A-21. (continued)

	Station	1	2	3	4	4A	5	6	7*	8	9	10	10A	10B	11	12	13	14	15	16**	17
1982	Jan						3	1	150												
	Feb						2		100												
	Mar						1														
	Apr																				
	May																				
	Jun																				
	Jul																				
	Aug																				
	Sep																				
	Oct																				
	Nov	-																			
	Dec																				
1983	Jan																				
	Feb																				
	Mar																				
	Apr																				
	May																				
	Jun																				
	Jul																				
	Aug																				
	Sep																				
	Oct																				
	Nov																				

* = New rack submerged September, 1975; location changed to present site, December, 1975.
- = Panel station not in operation.
-- = Panel missing.
** = See Table A-1.

TABLE A-22. NUMBER OF Bankia gouldi IN 6-MONTH PANELS REMOVED JULY, 1975 THROUGH NOVEMBER, 1983

	Station	1	2	3	4	4A	5	6	7*	8	9	10	10A	10B	11	12	13	14	15	16**	17
	Jul									-	-										
	Aug			2	13	-	2	42	14	-	-	4	-	-	387	16	100	335	1	5	
1975	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	
	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					-							-	-							
1976	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		
	Jan					-		1	2				-	-	42	6	5	2			
	Feb				2	-	1	1	1				-	-	31	2	2				
	Mar					-							-	-							
	Apr					-							-	-							
	May												-	-							
	Jun												-	-							
	Jul												-	-							
1977	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			
	Jan			2	1	1	1		2	2	2	1	-	-	34	5	4	6			
	Feb												-	-	1			1	1		
	Mar												-	-							
	Apr												-	-							
1978	May																				
	Jun																				

TABLE A-22. (Continued)

Year	Station	1	2	3	4	4A	5	6	7*	8	9	10	10A	10B	11	12	13	14	15	16**	17
1978	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
	Dec				1	1	2			2	1		5	2	8	1	13	5			
1979	Jan				3		2					1	1		8		3	17	1		
	Feb														1		2	17			
	Mar																				
	Apr																				
	May																				
	Jun																				
	Jul												1		28						
	Aug				1		2					1	4	1	130	5	11	29			
	Sep				3	3	3				1		23	2	100	17	28	66	1		
	Oct				2	2	1						28	5	150	16	31	36			
	Nov			1	3	1				—		2	33	3	6	20	36	41			
	Dec			1	6	4				3		2	23	7	7	21	57	64	1		
1980	Jan			4	2	4	3		5				23	3	4	28	12	12	3		
	Feb				2		1			1	1			3		2	2	8			
	Mar																				
	Apr																				
	May																				
	Jun																				
	Jul																				
	Aug												1								
	Sep						3		1	1	3		13	2	29	12		1	1		
	Oct						4		1	1			17		13	10		1	1		
	Nov						2					1	8	1	34	11	3		4		
	Dec						3	4	1				1	2	18	13	2	1	3		
1981	Jan						5		3		1		17		13	17	1	1	2		
	Feb						1								1	2	1				
	Mar																				
	Apr																				
	May																				
	Jun																				
	Jul																				
	Aug													1		3	2	3	2		
	Sep											1	3		4		3	9			
	Oct						1		2				1		4	2	--	8	1		
	Nov														1	2	--	1			
	Dec								2	1		3	5		1	3	3	8	2	--	

TABLE A-22. (Continued)

	Station	1	2	3	4	4A	5	6	7*	8	9	10	10A	10B	11	12	13	14	15	16**	17
1982	Jan						1					1		1	5		2	8			
	Feb										1										
	Mar																				
	Apr																				
	May																				
	Jun																			--	
	Jul																				
	Aug																				
	Sep						1								1		3	3	3	1	
	Oct			1										2			1	3	1	1	
	Nov																5	2	1	2	
	Dec										1		2	1	2		3			1	
1983	Jan			2										2	1	1	1		4		
	Feb																				
	Mar																				
	Apr																				
	May																				
	Jun																				
	Jul																				
	Aug						1			2			2		43	2		59			
	Sep			1			2		3	6			1		36	1	6	47	1		
	Oct							1	4	3			1	2	11	1	23	46	1		1
	Nov						1		4	3	1		1		44	1	17	18	4	1	1

* = New rack submerged September, 1975.
\- = Panel station not in operation.
-- = Panel missing.
** = See Table A-1.

TABLE A-23. PRESENCE AND DOMINANCE OF SPECIES OF TEREDINIDAE IN LONG-TERM PANELS REMOVED FROM DECEMBER, 1982 THROUGH NOVEMBER, 1983.

Station	Dec., 1982 - April, 1983		July, 1983 - Nov., 1983	
	Bankia gouldi	Teredo navalis	Bankia gouldi	Teredo navalis
1		xdominant		xdominant
2				
3	xdominant		xdominant	
4				
4A				
5		xdominant	xdominant	
6			xdominant	
7		xdominant	xdominant	
8			xdominant	
9	x	xdominant	xdominant	
10		xdominant		
10A	x	xdominant	xdominant	
10B	xdominant		xdominant	
11	x	xdominant	xdominant	x
12	x	xdominant	xdominant	
13	xdominant		xdominant	x
14		xdominant	xdominant	x
15	xco-dominant	x	xdominant	x
16B	xdominant		xdominant	
17		xdominant	x	xdominant

xSpecies present

August and November, 1983. This is a different occurrence pattern than was seen during the last two reporting periods when there was an increase in the number of stations at which T. navalis occurred during the warmer months of the annual cycle (Hillman et al., 1983). No T. navalis were collected from Station 2, a site where they were formerly quite abundant, but have not been collected since December, 1980. They remain, however, dominant at Station 1 (Table A-23). During the first part of the reporting period, from December, 1982 through April, 1983, T. navalis was also dominant at Stations 5, 7, 9, 10, 10A, 11, 12, 14 and 17, and co-dominant at Station 15. This was an increase over what was reported last year, when a significant decline in Bankia gouldi, and the subsequent dominance of T. navalis was reported (Hillman et al., 1983). During the second portion of the reporting period, however, T. navalis remained dominant at only Stations 1 and 17 due to an increase in abundance of B. gouldi over that period.

The results of the analysis of variance of Teredo navalis are given in Table A-24 (based on $\log_e$ (1 + abundance)) and Table A-25 (based on presence/absence). As described in previous reports, the results of both ANOVAs indicate month, station, and bioyear main effects are all highly significant, with station effects appearing the strongest (based on the mean square value). Further discussion of the ANOVA results is based on the ANOVA carried out on $\log_e$ (1 + abundance) values.

In the annual report for the period December, 1980 - November, 1981 (Maciolek-Blake et al., 1982), we initiated a system of grouping the data which corresponded to the breeding season of the Teredinidae rather than to the calendar year. Grouping by calendar year had appeared to artificially enhance the two-way interactions in the analysis of variance and the new grouping has been extremely useful in explaining the underlying causes of variation in the data. We have continued grouping data on the basis of bioyear (i.e. July, Year A to June, Year B) in the present report and thus the most recent data added during this calendar year comprise the last six months of bioyear 82/83 and the first six months of bioyear 83/84.

For the data on Teredo navalis abundance (Table A-24), the results of the ANOVA were similar to those presented in previous reports. All main effects were found to be highly significant for both grouped (region, season, bioyear) and ungrouped (station, month, bioyear) factors. Higher order interactions were calculated for grouped factors only and also indicated a pattern of significance similar to that reported previously. The

TABLE A-24. ANALYSIS OF VARIANCE OF LOG_e (1 + ABUNDANCE) OF *Teredo navalis* BASED ON LONG-TERM (6-MONTH) PANELS REMOVED JANUARY, 1976 THROUGH NOVEMBER, 1983, WITH THE EXCEPTION OF PANELS REMOVED IN APRIL, MAY OR JUNE

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F	Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
MAIN EFFECTS	559.025	12	46.585	51.691	0.000	MAIN EFFECTS	1049.145	33	31.792	609.74	0.000
Region	515.555	4	128.889	143.015	0.000	Station	966.425	19	50.864	97.552	0.000
Season	15.771	2	7.886	8.750	0.000	Month	57.034	8	7.129	13.673	0.000
Bioyear	28.844	6	4.807	5.334	0.000	Bioyear	29.495	6	4.916	9.428	0.000
2-WAY INTERACTIONS	96.062	44	2.183	2.423	0.000					5.222	0.000
Region/Season	64.676	8	8.085	8.971	0.000					19.334	0.000
Region/Bioyear	24.352	24	1.015	1.126	0.306					2.427	0.000
Season/Bioyear	4.976	12	0.415	0.460	0.938					0.991	0.455
3-WAY INTERACTIONS	14.037	48	0.292	0.324	1.000					0.698	0.941
Region/Season/Bioyear	14.037	48	0.292	0.324	1.000						
EXPLAINED	669.124	104	6.434	7.139	0.000	EXPLAINED	1159.24	125	9.274	19.999	
RESIDUAL	989.548	1098	0.901			RESIDUAL	499.433	1077	0.464		
TOTAL	1658.673	1202	1.380								

TABLE A-25. ANALYSIS OF VARIANCE OF PRESENCE/ABSENCE OF Teredo navalis BASED ON LONG-TERM (6-MONTH) PANELS REMOVED JANUARY, 1976 THROUGH NOVEMBER, 1983, WITH THE EXCEPTION OF PANELS REMOVED IN APRIL, MAY OR JUNE

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
MAIN EFFECTS	40.374	12	3.365	26.118	0.000
Region	27.917	4	6.979	54.180	0.000
Season	2.576	2	1.288	9.999	0.000
Bioyear	10.126	6	1.688	13.101	0.000
2-WAY INTERACTIONS	12.889	44	0.293	2.274	0.000
Region/Season	4.341	8	0.543	4.212	0.000
Region/Bioyear	6.136	24	0.256	1.985	0.003
Season/Bioyear	1.911	12	0.159	1.236	0.252
3-WAY INTERACTIONS	3.924	48	0.082	0.635	0.976
Region/Season/Bioyear	3.924	48	0.082	0.635	0.976
EXPLAINED	57.188	104	0.550	4.269	0.000
RESIDUAL	141.443	1098	0.129		
TOTAL	178.630	1202	0.165		

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
MAIN EFFECTS	78.269	33	2.372	23.036	0.000
Station	58.544	19	3.081	29.927	0.000
Month	10.013	8	1.252	12.156	0.000
Bioyear	10.200	6	1.700	16.510	0.000
				3.052	0.000
				5.656	0.000
				2.667	0.000
				1.656	0.071
				0.854	0.750
EXPLAINED	95.082	125	0.761	7.915	
RESIDUAL	103.548	1077	0.096		

interaction of region and season was highly significant, meaning that the pattern of seasonal change in T. navalis densities differs among regions. The region-bioyear interaction was also significant, but season-bioyear interactions were not significant. The interaction of all three main factors was also not significant.

Formal multiple comparison procedures were carried out based on the results of the ANOVA calculations of $\log_e$ (1 + abundance). The Student-Newman-Keuls multiple range test was carried out at the $\alpha = 0.05$ level. The specific ways in which stations, months, and years were compared were chosen on the basis of the results of the interaction plots. Thus, the following comparisons were made:

1) Stations

   a) all data
   b) summer months only
   c) fall and winter months only

2) Bioyears

   a) all data
   b) Region 3 only
   c) Region 1 (impacted) only

3) Months

   a) all data
   b) complete bioyears only (7/76 - 6/82)
   c) Region 3 only

Comparisons among station means for T. navalis log abundances, using all available data produced the following grouping (stations connected by an underline were not significantly different at $p = .05$):

16B 6 12 13 4 5 3 10 4A 10B 9 8 7 10A 14 15 2 17 11 1

This pattern was repeated in the results based on fall and winter data only:

16B 5 6 13 12 4 10 3 8 4A 10B 9 7 14 10A 15 2 17 11 1

and was only slightly different using data from only the summer months:

3 4 6 16B 14A 10 12 10B 13 9 5 10A 7 8 15 2 17 14 11 1.

These observations are generally similar to those described in recent reports (Maciolek-Blake et al., 1982; Hillman et al., 1983) and continue to indicate significantly elevated densities of T. navalis near Barnegat Inlet (Stations 1 and 17) and at Stations 2 and 11. As in previous years, densities of T. navalis at stations in Oyster Creek (Stations 5, 6, 7, 8) were not significantly different from the majority of stations on the western side of Barnegat Bay.

The results of the Student-Newman-Keuls procedure on ANOVA results using bioyears did not indicate as many significant differences as were found among stations. When all data were included in the analysis, a broadly overlapping pattern resulted:

83/84 77/78 78/79 81/82 80/81 82/83 76/77 75/76 79/80

The overall pattern is similar to that described in our previous report, with the obvious exception of Bioyear 83/84 which is included for the first time. This most recent bioyear had the lowest T. navalis densities, but this is not necessarily indicative of any trend in this direction because the difference is not significant, and data for the current bioyear are incomplete. Overall, the pattern continues to provide no evidence for either a decrease or increase in T. navalis densities throughout the sampling area as a whole.

When only data from Region 3 (Stations 1 and 17), near Barnegat Inlet, are considered, a considerably different pattern is evident although, again, the differences among bioyears are generally too small to be significant:

75/76 79/80 77/78 80/81 78/79 81/82 82/83 76/77 83/84

Based on data from Region 1 (impacted stations) only, 82/83 remained the bioyear of greatest recorded T. navalis densities, but was no longer significantly different from several other years (see Hillman et al., 1983; p. A-43). Data from the current bioyear (83/84) did not appear to support a hypothesis of recent increases in T. navalis densities.

As presented and described in previous reports (Hillman et al., 1983), the results of SNK comparisons among months were generally similar for all data, complete bioyears only, and Region 3 only. These results clearly indicated a seasonal cycle for T. navalis populations in Barnegat Bay with lowest numbers in the spring and summer followed by greatest densities during fall and winter.

Teredo bartschi. One of the more significant aspects of last year's program was the virtual disappearance of T. bartschi from the panels (Hillman et al., 1983). Again, no T. bartschi were collected at any site in the study area during this reporting period. The reason or reasons for the disappearance of this species from the study area are still not defined.

Bankia gouldi. Bankia gouldi was recorded from 6-month panels from 9 of the 20 stations during December, 1982 and January, 1983 (Table A-22). No additional B. gouldi were collected until August, 1983, but between August and November, they were collected at 15 of the 20 sites, a sharp increase over what has been observed for the past several seasons. A significant decline in abundance was reported for B. gouldi in the previous report (Hillman et al., 1983). It would appear from the data shown in Table A-22, that this trend may have been reversed.

Table A-23 shows B. gouldi dominant only at Stations 3, 10B, 13 and 16B, and co-dominant at Station 15 during the period from December, 1982 through April, 1983. From July, 1983 through November, it became dominant at 14 of the 20 collecting sites. This is due more to an increase in numbers of B. gouldi than to a decrease in numbers of T. navalis.

As has been the case in previous years, analysis of both the presence/absence and abundance data produced similar results. All main effects were highly significant for both the grouped (region, season, bioyear) and ungrouped (station, month, bioyear) analysis. Comparison of the mean squares attributable to each of the main factors indicated results identical with those reported last year (Hillman et al., 1983). Using $\log_e$

(1 + abundance) data, station was the most important main effect for ungrouped factors and region was most important for grouped factors. Using presence/absence data, however, month was the most important ungrouped factor and season the most important grouped factor. In all cases, however, the relative importance of all factors (except bioyear) was quite similar. Although the effect of bioyear was significant, its magnitude was consistently lower than spatial (station/region) and shorter-term temporal (month/season) factors.

The results of the analyses of variance of Bankia gouldi are given in Tables A-26 (based on $\log_e$ (1 + abundance)) and Table A-27 (based on presence/absence).

Based on the abundance data, both the region-season and region-bioyear interactions were highly significant and the season-bioyear interaction was not significant. Only the region-bioyear interaction was significant for the presence/absence data. For both types of data the three-way interaction was not significant. These results are essentially similar to those reported last year (Hillman et al., 1983).

Interaction plots were prepared based on the ANOVA results for $\log_e$ (1 + abundance) and formal multiple comparison procedures were carried out in order to understand the significance of the ANOVA results. The Student-Newman-Keuls multiple range test was carried out at the $p = 0.05$ level. The specific way in which stations, months, and years were compared were chosen on the basis of the results of the interaction plots. The following comparisons were therefore made:

1) Stations

   a) all data
   b) fall months only
   c) winter and summer months only

2) Bioyears

   a) all data

3) Months

   a) all data
   b) complete bioyears only (7/76 - 6/83)

TABLE A-26. ANALYSIS OF VARIANCE OF LOG_e (1 + ABUNDANCE) OF *Bankia gouldi* BASED ON LONG-TERM (6-MONTH) PANELS REMOVED JANUARY, 1976, THROUGH NOVEMBER, 1983, WITH THE EXCEPTION OF PANELS REMOVED IN APRIL, MAY OR JUNE

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F	Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
MAIN EFFECTS	210.064	12	17.505	27.957	0.000	MAIN EFFECTS	470.780	33	14.266	33.148	0.000
Region	99.804	4	24.951	39.848	0.000	Station	302.414	19	15.917	36.942	0.000
Season	44.492	2	22.246	35.527	0.000	Month	103.568	8	12.946	30.080	0.000
Bioyear	57.700	6	9.617	15.358	0.000	Bioyear	69.948	6	11.658	27.088	0.000
2-WAY INTERACTIONS	57.902	44	1.316	2.102	0.000					3.323	0.000
Region/Season	19.108	8	2.389	3.815	0.000					6.033	0.000
Region/Bioyear	29.020	24	1.209	1.931	0.005					3.053	0.000
Season/Bioyear	7.730	12	0.644	1.029	0.419					1.626	0.079
3-WAY INTERACTIONS	18.405	48	0.383	0.612	0.983					0.967	0.538
Region/Season/Bioyear	18.405	48	0.383	0.612	0.983						
EXPLAINED	286.371	104	2.754	4.398	0.000	EXPLAINED	547.087	125	4.377	11.053	
RESIDUAL	687.524	1098	0.626			RESIDUAL	426.807	1077	0.396		
TOTAL	973.894	1202	0.810								

TABLE A-27. ANALYSIS OF VARIANCE OF PRESENCE/ABSENCE OF Bankia gouldi BASED ON LONG-TERM (6-MONTH) PANELS REMOVED JANUARY, 1976, THROUGH NOVEMBER, 1983 WITH THE EXCEPTION OF PANELS REMOVED IN APRIL, MAY OR JUNE

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
MAIN EFFECTS	49.522	12	4.127	24.217	0.000
Region	23.749	4	5.937	34.841	0.000
Season	13.137	2	6.569	38.546	0.000
Bioyear	10.677	6	1.780	10.443	0.000
2-WAY INTERACTIONS	12.610	44	0.287	1.682	0.004
Region/Season	1.901	8	0.238	1.395	0.194
Region/Bioyear	8.387	24	0.349	2.051	0.002
Season/Bioyear	2.119	12	0.177	1.036	0.412
3-WAY INTERACTIONS	6.573	48	0.137	0.804	0.829
Season/Region/Bioyear	6.573	48	0.137	0.804	0.829
EXPLAINED	68.706	104	0.661	3.877	0.000
RESIDUAL	187.110	1098	0.170		
TOTAL	255.816	1202	0.213		

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
MAIN EFFECTS	106.882	33	3.239	25.422	0.000
Station	58.205	19	3.063	24.045	0.000
Month	36.266	8	4.533	35.582	0.000
Bioyear	14.315	6	2.386	18.727	0.000
				2.392	0.000
				1.983	0.045
				2.908	0.000
				1.475	0.127
				1.142	0.238
EXPLAINED	126.065	125	1.009	8.408	
RESIDUAL	129.751	1077	0.120		

Comparisons among stations using all available data indicated the following groupings (groups of stations connected by an underline were not significantly different at p = 0.5):

2 17 16B 1 3 9 6 4A 10 8 15 4 10B 7 5 10A 12 13 14 11

These results are generally similar to those presented in the previous two reports (Maciolek-Blake, et al., 1982: Hillman et al., 1983) and continue to indicate the unique nature of Station 11. Once again, stations within the area of influence of the generating station (Stations 5, 6, 7, 8) do not tend to group together with respect to B. gouldi densities and are not significantly different from most stations in the study area.

Repeating this analysis on data from the fall season only produced the following pattern of significant differences:

2 1 16B 3 9 17 6 4A 10 15 8 4 10B 5 7 12 19 14 13 11

This result is very similar to that described for all data and again underscores the uniquely high densities of B. gouldi at Station 11. Both analyses also indicate that Stations 13 and 14 have significantly higher densities of B. gouldi than the remainder of the Bay though not as high as densities at Station 11.

Analysis of data grouped by bioyear, using all available data, produced a pattern of overlapping significantly different groups similar to that reported last year (Hillman et al., 1983):

82/83 81/82 78/79 80/81 83/84 77/78 76/77 79/80 75/76

The trend of decreasing densities of B. gouldi throughout the Bay remained evident through the 82/83 bioyear, for which data are now complete. Partial data from the current bioyear (83/84), however, tentatively indicate that this trend may be reversing. Because of the overlapping pattern of significance and incomplete 83/84 data, however, this observation is only speculative at this time.

Analysis of monthly patterns of change in B. gouldi densities repeated the clear seasonal trends discussed last year (Hillman et al., 1983). The Student-Newman-Keuls multiple range procedure produced the following pattern of significance, using all data or data from complete bioyears only:

MAR JUL FEB AUG NOV SEP OCT DEC JAN

Significantly lower densities were evident during the months bracketing the spring period (APR, MAY, JUN), a time during which no teredinids are found in the samples. Significantly elevated densities occur during the fall and winter months.

Destruction. Percent destruction (= percent filled) of panels was recorded for both short-term (Table A-4) and long-term panels (Tables A-8 through A-19). The average percent destruction to long-term panels (Figure A-5) over each breeding season (July, Year A, through April, Year B) is given in Table A-28, and in Table A-29 the stations are ranked in descending order of amount of attack. The first and second place rankings for Stations 11 and 14, respectively, are a manifestation of the increase in Bankia gouldi abundance at those stations over the reporting period. Station 1 dropped to a third place ranking this year after having been ranked first for the two previous reporting periods. This does not necessarily represent a decrease in attack at that site, but, again, an increase in B. gouldi attack at Stations 11 and 14.

Over the years of the study, Station 1 has probably had more consistent attack than any other station. This statement is based on a ranking by "relative attack", determined by assigning 10 points to a station each time it was ranked first (Table A-28), 9 points for a second place ranking, 8 points for a third place ranking, down to 1 point for a tenth place ranking. The number of times each station was ranked in each of the ten top places is shown in Table A-30, and the relative ranking after assigning the various points is shown in Table A-31. Station 1 was ranked first five times, and was in the top four stations each year of the study (Table A-30). Station 11, with two first place rankings, is the only other station to have placed in the top four each year.

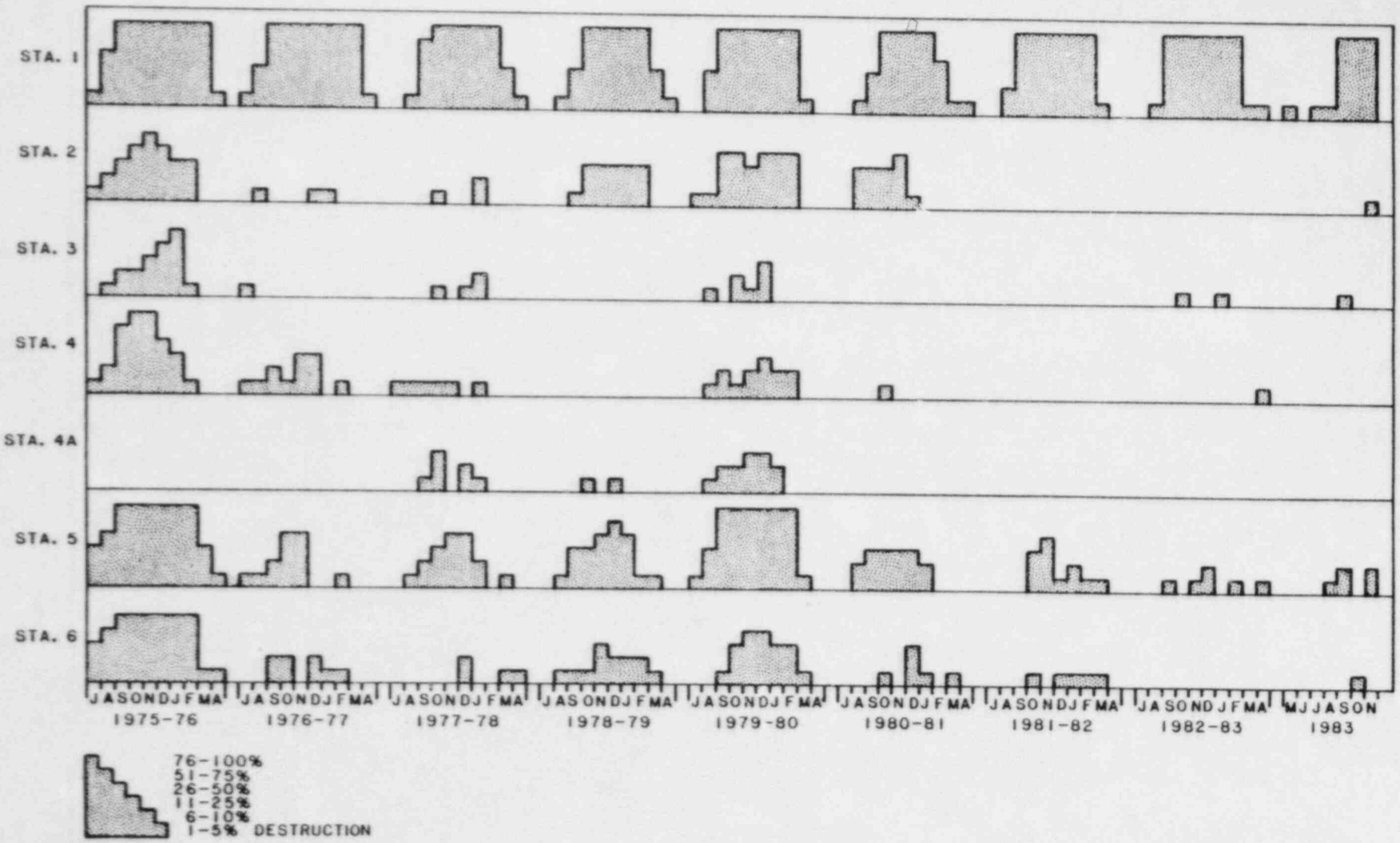

FIGURE A-5. PERCENT DESTRUCTION BY TEREDINIDS TO LONG-TERM (6-MONTH) EXPOSURE PANELS FROM JULY, 1975 THROUGH NOVEMBER, 1983.

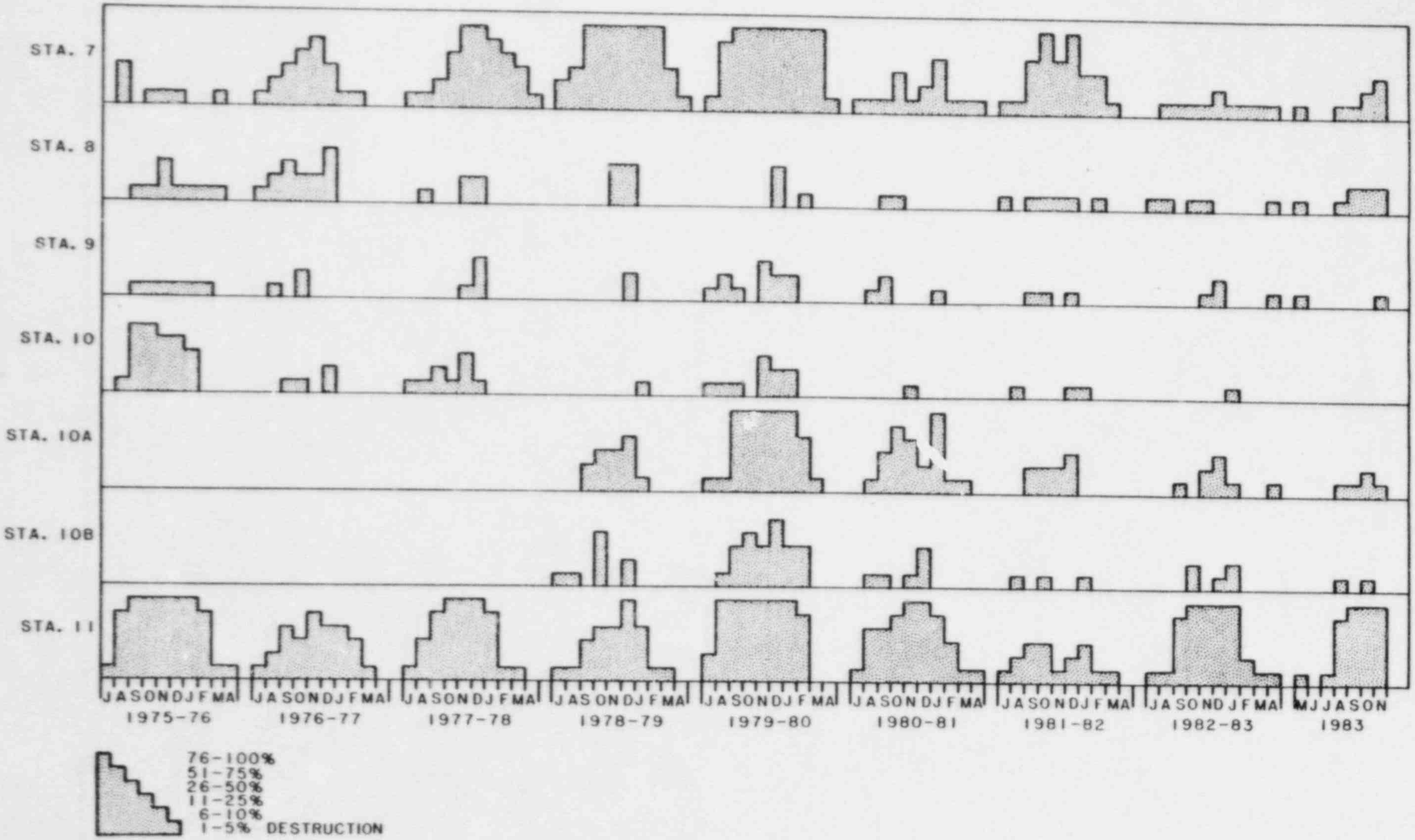

FIGURE A-5. (Continued)

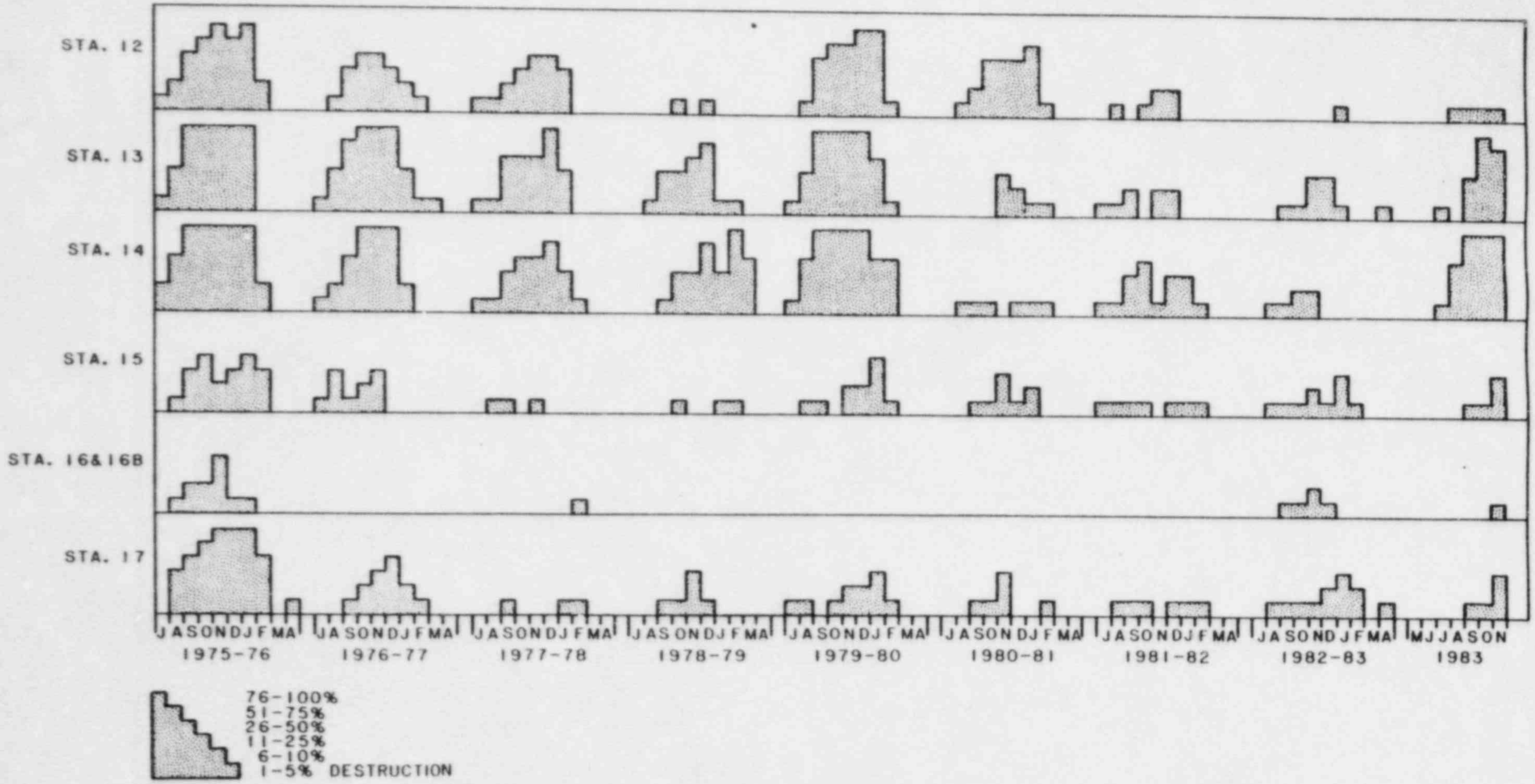

FIGURE A-5. (Continued)

TABLE A-28. AVERAGE PERCENT DESTRUCTION TO LONG-TERM PANELS OVER BREEDING SEASONS

Station	Breeding Season* 1975	1976	1977	1978	1979	1980	1981	1982	1983
1	72.7**	61.1	58.8	52.7	60.7	40.2	60.6	49.5	60.4
2	23.7	0.4	1.1	8.8	19.4	8.4	0.0	0.0	0.6
3	15.4	0.1	0.9	0.0	2.7	0.0	0.0	0.5	0.6
4	33.0	5.1	1.3	2.6	4.8	0.2	0.0	0.1	0.0
4A	-	-	3.1	0.6	8.2	0.0	0.0	0.0	0.0
5	67.9	7.2	9.9	21.9	61.1	8.5	6.5	0.8	3.0
6	65.1	3.1	0.9	4.7	14.9	2.3	0.5	0.0	0.4
7	2.1**	18.1	36.5	53.0	67.5	6.9	29.9	2.0	6.8
8	3.5**	7.4	2.1	3.3	2.5**	1.1	0.7	0.8	5.2
9	2.3**	1.1	1.4	0.8	4.2	1.3	0.3	1.2	0.2
10	23.7	1.6	3.3	0.2	3.9	0.2	0.5	0.4	0.0
10A	-	-	-	8.0	49.6	22.4	3.2	3.0	3.4
10B	-	-	-	2.4	14.4	2.1	0.4	2.0	1.2
11	64.5	24.5	43.1	24.7	66.6	40.5	7.7	42.8	70.2
12	39.6	15.7	12.4	0.8	35.6	18.3	2.0	0.2	1.4
13	57.2**	38.2	24.9	13.7	42.2	2.8	3.1**	4.4	37.4
14	56.3	32.4	19.2	24.3	48.5	2.2	10.2	2.0	65.4
15	15.4	5.1	0.5	0.7	5.6	2.9	1.2	2.9	6.4
16/16B	6.6	0	0.1	0.0	0.0	0.0	0.0**	1.8	0.6
17	44.4	8.5	0.8	1.8	3.5	2.0	0.8	5.0	3.6

* 1975: July, 1975-April, 1976
1976: July, 1976-April, 1977
1977: July, 1977-April, 1978
1978: July, 1978-April, 1979
1979: July, 1979-April, 1980
1980: July, 1980-April, 1981
1981: July, 1981-April, 1982
1982: July, 1982-April, 1983
1983: July, 1983-November, 1983

** = Incomplete data.
\- = Panel not exposed.

TABLE A-29. RANK OF STATIONS IN DESCENDING ORDER OF TEREDINID ATTACK*

1975	1976	1977	1978	1979	1980	1981	1982	1983**
1	1	1	7	7	11	1	1	11
5	13	11	1	11	1	7	11	14
6	14	7	11	5	10A	14	17	1
11	11	13	14	1	12	11	13	13
14	7	14	5	10A	5	5	10A	7
13	12	12	13	14	2	10A	15	15
17	17	5	2	13	7	13	7	8
12	8	10	10A	12	15	12	10B	17
4	5	4A	6	2	13	15	14	10A
10	4	8	8	6	6	17	16B	5
2	15	9	4	10B	14	8	9	12
3	6	4	10B	4A	10B	6	5	10B
		2	17	15	17	10	8	2
15	10	3	9	4	9	10B	3	3
16	9	6	12	9	8	9	10	16B
8	2	17	15	10	4	2	12	6
9	3	15	4A	17	10	3	4	9
7	16	16	10	3	3	4	2	4
			3	8	4A	4A	4A	4A
			16	16	16	16	6	10

* = From mean percentages, Table A-28.
** = Half season.

TABLE A-30. NUMBER OF TIMES EACH STATION WAS RANKED IN EACH OF THE FIRST TEN PLACES IN TERMS OF PERCENT TEREDINID ATTACK.

Station	Ranking									
	1	2	3	4	5	6	7	8	9	10
1	5	2	1	1						
2						1	1		1	
3										
4									1	1
4A										
5		1	1		3		1		1	1
6			1						1	2
7	2	1	1		2		2			
8								1		2
9										
10								1		1
10A			1		2	1		1	1	
10B								1		
11	2	3	1	3						
12				1		2		2		
13		1		3						
14		1	2	1	2	1			1	
15						2		1	1	
16										1
17			1				2	1		1

TABLE A-31. RELATIVE RANKING OF STATIONS IN TERMS OF PERCENT TEREDINID ATTACK FROM 1975 THROUGH 1983.

Rank	Station	Points
1	1	83
2	11	76
3	7	57
4	14	51
5	5	42
6	10A	30
6	13	30
7	12	23
8	17	20
9	15	15
10	6	12
11	2	11
12	8	5
13	10	4
14	4	3
15	16	1
16	3	0
16	4A	0
16	9	0

Analysis of destruction data in previous reports (Maciolek-Blake et al., 1981; 1982; Hillman et al., 1983) has indicated that woodborer abundance is the most important variable (factor) in determining the amount of destruction of the test substrata. Of the remaining variables, temporal factors were found to be more important than spatial factors. That is, variation over time is more important in determining amount of destruction than is location of the panels among the various station sites in the study area. Addition of data from the current year continues to support these conclusions.

An unweighted least squares multiple regression model of logit (proportion destruction) was fitted to the abundance data and solved for the regression coefficient for each species. Data outliers which had been omitted in previous years (see Hillman et al., 1983, p. A-64) were also eliminated in the current analysis. Calculated regression coefficients were:

	Unstandardized	Standardized
B_0 (Constant)	-5.08	
B_1 Teredinidae	0.25	0.13
B_2 Bankia gouldi	1.43	0.57
B_3 Teredo navalis	1.20	0.48
B_4 Teredo bartschi	0.66	0.24
B_5 Teredo spp.	0.48	0.11

The magnitude of the regression coefficient for each taxon is proportional to relative amount of damage done per individual of the taxon. For this analysis, as in previous years, Bankia gouldi has the largest coefficient, indicating that B. gouldi does the most destruction per individual. Similarly, the small regression coefficient for the taxon Teredinidae indicates that individuals of that taxon perform the least damage; that is apparently related to their small size. The multiple coefficient of determination (r^2) for this fit was 0.76, indicating that approximately 75% of the variation in the destruction data was explainable in terms of the Teredinidae densities.

In order to investigate the effect, if any, of spatial or temporal factors (other than abundance of teredinids) on the amount of destruction, an analysis of variance (ANOVA) model was fitted to the regression residuals using station, month, and bioyear as main effects. The results of this ANOVA are presented in Table A-32. All main effects and two-way interactions were significant with month (or season) being the most important factor. The season/bioyear interaction was the most important of the three interactions examined.

Long-term (12-Month) Panels

Beginning in August, 1976, two "special panels" were placed on the exposure racks at every station. These panels are removed and replaced in May and June each year, after a 12-month exposure. The purpose of these additional panels is to provide specimens of teredinids for histological analyses of gonad development (see Appendix B), particularly during the critical spring months when no borers are usually found in the 6-month panels. Additional information on species present in these 12-month panels, their size range and the percent of panel filled has also been recorded. These data are not as extensive, however, as those collected from the regular 1- and 6-month panels.

The incidence of teredinids in 12-month panels was first reported in 1982 (Maciolek-Blake et al., 1982). The incidence of teredinids in panels submerged in May, 1982 and retrieved in May, 1983 is shown in Table A-33. Table A-34 shows incidence in the panels submerged in June, 1982 and retrieved in June, 1983.

The teredinid distribution and abundance patterns from the 12-month panels conform to what was shown by the 6-month panels. This is consistent with what was reported for the previous reporting period (Hillman et al., 1983).

Limnoria

Table A-35 shows the incidence of the crustacean woodborer Limnoria in 6-month and 1-month panels removed December, 1982 through November, 1983.

During the present report period, Limnoria was present at Stations 1, 2, 3, 4, 4A, and 5. Attack was up at Stations 2 and 4A (Figure A-6). At Station 2, it was higher

TABLE A-32. ANALYSIS OF VARIANCE OF RESIDUALS OF LEAST SQUARES REGRESSION MODEL OF LOGIT (PROPORTION DESTRUCTION).

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	163.463	13	12.574	15.874	0.000
Region	11.723	4	2.931	3.700	0.005
Season	68.088	2	34.044	42.977	0.000
Bioyear	80.959	7	11.566	14.600	0.000
2-Way Interactions	190.292	50	3.806	4.805	0.000
Region/Season	13.844	8	1.736	2.191	0.026
Region/Bioyear	101.643	28	3.630	4.583	0.000
Season/Bioyear	75.134	14	5.367	6.775	0.000
3-Way Interactions	47.493	56	0.848	1.071	0.339
Region/Season/Bioyear	47.493	56	0.848	1.071	0.339
Explained	401.248	119	3.372	4.257	0.000
Residual	973.538	1229	0.792		
Total	1374.786	1348	1.020		

Source of Variation	Sum of Squares	DF	Mean Sqaure	F	Significance of F
Main Effects	277.340	34	8.157	9.767	0.000
Station	61.964	19	3.261	3.905	0.000
Month	131.990	8	16.499	19.754	0.000
Bioyear	83.550	7	11.936	14.291	0.000
				5.346	0.000
				2.438	0.013
				5.098	0.000
				7.538	0.000
				1.191	0.162
Explained	515.130	140	3.679	5.167	
Residual	859.656	1208	0.712		

TABLE A-33. INCIDENCE OF TEREDINIDAE IN 12-MONTH PANELS SUBMERGED MAY 4-5, 1982 AND REMOVED MAY 2-3, 1983

Station	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	500	99	3-65	150 T. navalis, 350 Teredinidae	20% of panel missing 90% of shipworms dead. Several with ripening gonads.
7	11	13	<1-305	1 B. gouldi, 1 T. navalis, 9 Teredinidae	All dead except for B. gouldi
10A	2	4	18-210	2 B. gouldi	
11	8	18	30-200	7 T. navalis 1 Teredinidae	Ripening gonads, 2 Dead.
13	1	3	190	1 B. gouldi	
14	3	10	163-217	3 B. gouldi,	
15	6	2	<1-75	2 T. navalis, 4 Teredinidae	

No Teredinidae in panels from Stations 2-6, 8-10, 10B, 12, 16B-17.

TABLE A-34. INCIDENCE OF TEREDINIDAE IN 12-MONTH PANELS SUBMERGED JUNE 1-2, 1982 AND REMOVED JUNE 6-7, 1983

Station	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	400	99	3-35	3 T. navalis 397 Teredinidae	1/3 of panel missing. All dead except for 3. Ripening gonads and larvae.
7	34	1	<1-55	7 T. navalis, 27 Teredinidae	
9	1	2	140	1 T. navalis	Dead
10A	2	7	165-180	2 T. navalis	Ripening gonads.
10B	1	5	230	1 B. gouldi	Ripening gonads.
11	4	18	185-330	3 B. gouldi 1 T. navalis	Ripening gonads.
13	1	5	295	1 B. gouldi	Ripening gonads.
14	1	6	315	1 B. gouldi	Ripening gonads.
15	5	3	<1-150	1 B. gouldi, 1 T. navalis, 3 Teredinidae	Ripening gonad.
17	5	2	<1-77	3 T. navalis, 2 Teredinidae	All dead.

No Teredinidae in panels from Stations 2-6, 8, 10, 12, 16B.

TABLE A-35. INCIDENCE OF LIMNORIA IN 6-MONTH (P) AND 1-MONTH (C) EXPOSURE PANELS REMOVED DECEMBER, 1982 THROUGH NOVEMBER, 1983

Station	Panel	Dec 1982 Tunnels/* Specimens	Jan 1983 Tunnels/* Specimens	Feb 1983 Tunnels/* Specimens	Mar 1983 Tunnel/ Specimens	Apr 1983 Tunnels/** Specimens	May 1983 Tunnels/ Specimens	Jun 1983 Tunnels/** Specimens	Jul 1983 Tunnels/*** Specimens	Aug 1983 Tunnels/*** Specimens	Sep 1983 Tunnels/*** Specimens	Oct 1983 Tunnels/*** Specimens	Nov 1983 Tunnels/*** Specimens
1	P	4/0	7/0	-	6/4	5/3	3/2	2/3	2/0	7/12	26/12	19/3	0/0
	C	0/0	0/0	0/0	0/0	0/0	0/0	0/0	1/2	7/8	10/12	10/7	2/0
2	P	360/390	345/300	80/86	1[illegible]/10	5/5	4/2	96/130	670/800	1600/1500	4000/3800	2000/1500	2400/2010
	C	0/0	0/0	0/0	0/0	0/0	0/0	15/17	34/57	31/23	38/47	2/0	2/2
3	P	1/1	0/0	1/0	0/0	0/0	0/0	1/2	19/12	20/16	155/170	150/130	80/70
	C	0/0	0/0	0/0	0/0	0/0	0/0	1/1	3/4	0/0	0/0	0/0	0/0
4	P	425/390	132/110	71/66	0/0	1/0	0/0	54/66	54/80	14/19	290/375	205/205	610/510
	C	0/0	0/0	0/0	0/0	0/0	0/0	16/11	1/2	0/0	1/0	0/0	0/0
4A	P	6800/5000	500/450	800/700	126/72	27/23	21/10	2200/3504	3500/6000	4500/6000	7200/6000	7500/5500	7800/5000
	C	1/1	0/0	0/0	0/0	0/0	8/3	900/1500	990/1500	260/380	59/73	15/10	1/0
5	P	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	2/2	0/0	0/0
	C	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
6-17 No Limnoria present													

* Juveniles present
** Gravid females present
*** Gravid females and juveniles present
\- No panel examined

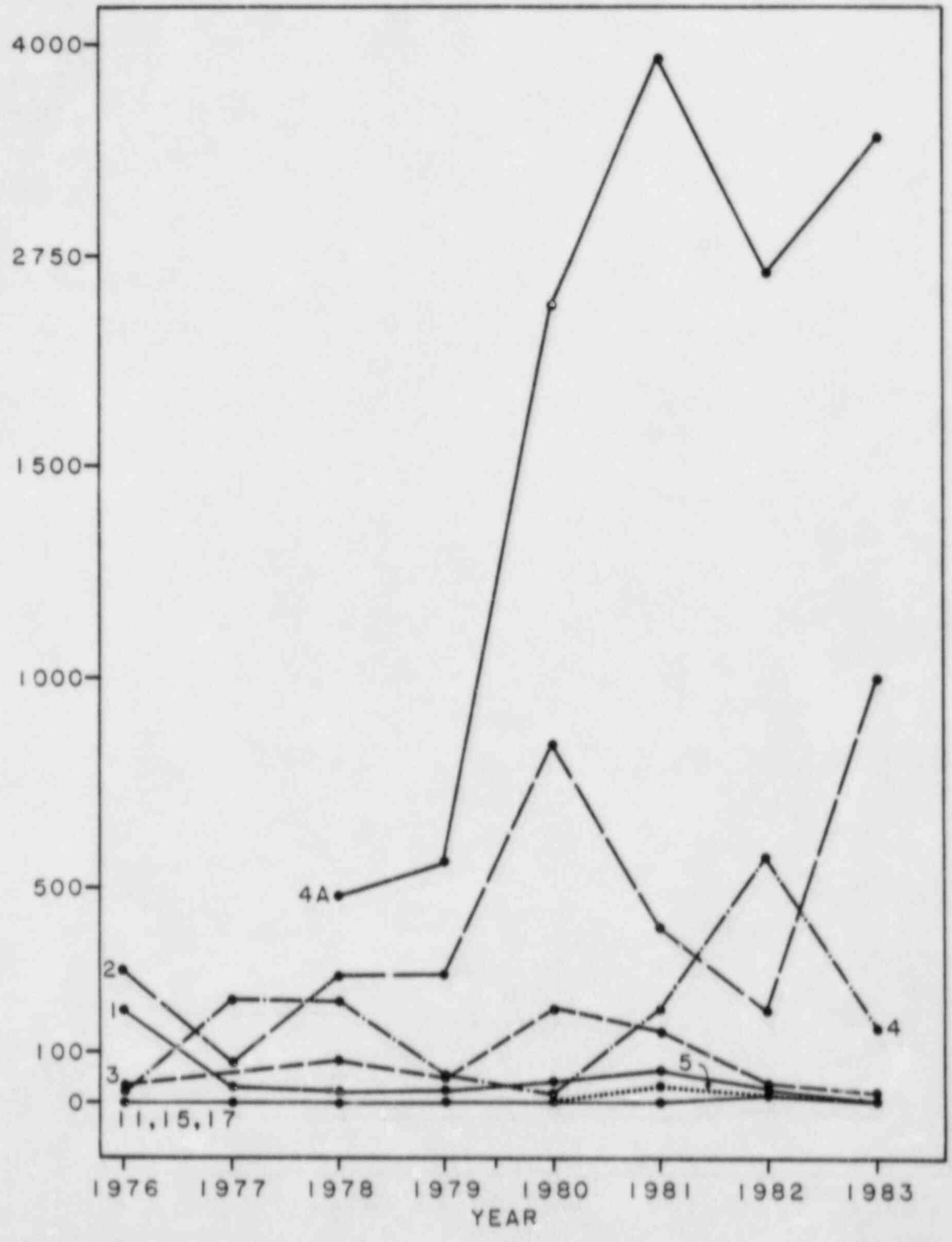

FIGURE A-6. AVERAGE NUMBER OF Limnoria TUNNELS IN LONG-TERM (6-MONTH) PANELS FROM 1976 THROUGH 1983.

than at any other time during the study, but considerably less than what was recorded at Station 4A. Attack was down sharply at Station 4 after a two-year increase.

The mode of destruction of the surface of wood by crustacean borers such as Limnoria can prevent teredinid larvae from finding a suitable surface on which to settle. The presence of Limnoria at Station 2 could perhaps be a contributing factor in the decline of teredinids at that site.

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APPENDIX B

APPENDIX B

BORER DEVELOPMENTAL STATUS

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BORER DEVELOPMENTAL STATUS

Introduction

Temperature may be the most important factor in the regulation of reproductive cycles in marine invertebrates (Hedgpeth and Gonor, 1969). For this reason, studies of the reproductive cycles of the teredine borers in Barnegat Bay have been an integral part of the program designed to assess the effects of the Oyster Creek Nuclear Generating Station on woodborers in the Bay.

Alteration of the normal cycles theoretically could occur in one or more ways. Initiation of gonad development could be earlier than expected in 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 the surrounding areas not affected by the thermal plume, the breeding period might be extended well into the fall.

The developmental stages of gonads from borers in areas affected by the thermal plume were assessed histologically and compared to stages of gonad development in borers from non-affected areas. Data through November, 1982 did not suggest any major alterations in breeding patterns of indigenous shipworm species within the study area. The studies have continued and the data reported here summarize the results of observations made from August, 1975 through November, 1983.

In previous reports (e.g., Maciolek-Blake et al., 1982) the possibility of an extended breeding season for Teredo bartschi in the discharge area was discussed. Since February, 1982, however, no T. bartschi have been recovered for examination of gonad developmental patterns. A sub-tropical species, T. bartschi could have been expected to have breeding individuals year-round in the warmer discharge water, even though their larvae would not have been expected to survive the colder winter water temperatures outside the discharge areas.

Materials and Methods

Teredine borers were removed in the laboratory from exposure panels retrieved from Barnegat Bay. Details of the retrieval schedule for standard panels are given in Appendix A. With the six-month retrieval schedule, there were three months of the year (April through June) when no borers were recovered from the panels because the panels were immersed when no larvae were settling. 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 enabled us to obtain some information on the early spring gonadal patterns. In addition, separate racks were installed at Stations 2, 7, 11, 12 and 17 to provide additional information on the parasites of Teredo. The panels on these racks are exposed for a 12 month cycle.

Upon removal from the exposure panels, the shipworms were placed in one of a variety of fixatives. During the initial portion of the study, when specimens were being shipped to Battelle's Columbus, Ohio, facility for sectioning, they were fixed in Bouin's fixative. Since processing was begun at the Duxbury facility in May, 1977 the specimens have been fixed in Zenker's, Helly's and most recently, Davidson's fixative.

The specimens were fixed for 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 methylbenzoate and cleared in three changes of xylene. They were then embedded in Paraplast and sectioned at six microns. From January, 1978 through November, 1981, at least two slides of each specimen were prepared. One slide was stained in hematoxylin and eosin for gonad analysis; the second slide was stained with Masson's trichrome or Whipf's polychrome stain and used with the hematoxylin and eosin stained slides for pathological analysis.

The slides were examined microscopically to determine the stage of gonad development at the time the specimens were removed from the water. Because 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 - Oogonia occurred at the periphery and within the alveolar walls; nuclei of oogonia contained basophilic nucleoli. The alveolar walls were not completely contracted and lumina were evident in most gonads.

2. Late active phase - Large oocytes were attached to the alveloar wall and protruded into the alveolar lumen. The oocyte nucleus was large and contained a basophilic nucleolus.

3. Ripe phase - The shipworm was considered ripe when the number of oocytes 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 oocytes 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 oocytes and those that remained were undergoing cytolysis.

Male Gonads

1. Early active phase - Shipworms in the early active phase contained darkly staining spermatogonia in the thickened alveolar wall.

2. Late active phase - This phase was characterized by the proliferation and maturation of spermatocytes, most of which have 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 conditions of both the oocytes 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 species and station designations only after the gonads were characterized. This tended to eliminate any possible bias for station or season.

Results and Discussion

From August, 1975 through November, 1982, a total of 4171 teredinid borers was examined histologically for gonad condition. This included 1607 Teredo navalis, 534 T. bartschi, 24 T. furcifera, 59 immature Teredo too small to be identified to species, and 1947 Bankia gouldi. The data from those observations were included in the annual report to GPU Nuclear Corporation for the period December 1, 1981 through November 30, 1982. From December 1, 1982 through November 1983, an additional 379 T. navalis, 3 immature Teredinidae, and 282 B. gouldi were examined. The results of these examinations are tabulated in Tables B-1 through B-3.

As in past years (Hillman et al., 1983) no effect of plant operations on gonadal development was observed. In previous reports (e.g., Maciolek-Blake et al., 1982) an extended breeding season for Teredo bartschi in the discharge canal was discussed. No T. bartschi have been recovered since March, 1982, so it is not possible to comment any further at this time on gonadal cycles in that species.

The reproductive patterns of the various species of teredinid borers occurring within the study area are discussed below.

Teredo navalis. During the present study, Teredo navalis occurred at 12 of the 20 stations at which panels are exposed (Table B-1), a decrease of one station from the previous year's collection.

Ripe gonads were found at Station 1 in January, 1983, and at Station 11 in February, March and April. The histological appearance of these gonads indicated that they were not newly ripe, but were possibly in that condition in late fall, 1982, and remained that way as the water cooled.

Newly ripe specimens were found at Station 1 in May and June, and again in September. They also occurred at Stations 5, 7, 8, 14 and 17 at some point between May

TABLE B-1. NUMBERS OF SPECIMENS AND STAGE OF GONAD DEVELOPMENT OF Teredo navalis IN EXPOSURE PANELS AT STATIONS IN BARNEGAT BAY, NEW JERSEY, FROM DECEMBER, 1982 THROUGH NOVEMBER, 1983.

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

Gonad Stage	1982 Dec	Jan	Feb	Mar	Apr	May	1983 June	Jul	Aug	Sep	Oct	Nov	Station
EA													
LA		1				2							
R		1				1	1			13			1
PS	7	3				5							
S	8	12				9	2					1	
NG		1							2	3			
EA													
LA													
R													
PS													5
S	1												
NG													
EA		1		1			3						
LA		1											
R								5					7
PS													
S	3												
NG	1					1							
EA													
LA													
R										1			8
PS													
S													
NG													
EA													
LA													
R													9
PS													
S	2												
NG													

TABLE B-1. (continued)

Gonad Stage	1982 Dec	Jan	Feb	Mar	Apr	May	1983 June	Jul	Aug	Sep	Oct	Nov	Station
EA													
LA													
R													10
PS													
S	1												
NG													
EA													
LA													
R													10A
PS													
S	2	2					1						
NG													
EA		4	2	1		2							
LA				1			1						
R			1	1	3								11
PS	6	1	3	2	8	6	1	1					
S	11	21	5	17	5	3	3	1				2	
NG			3	1	1	1			1				
EA													
LA													
R													13
PS													
S												1	
NG													
EA													
LA													
R											1		14
PS													
S	1												
NG													

TABLE B-1. (continued)

Gonad Stage	1982 Dec	Jan	Feb	Mar	Apr	May	1983 June	Jul	Aug	Sep	Oct	Nov	Station
EA		1											
LA													
R												1	15
PS													
S	1					2	1						
NG													
EA		11	10	1		1						10	
LA		1	2				2					7	
R							4	1		1		1	17
PS					4	14	2	3		1		1	
S	7	14	12	3	2	4	1			8	8	4	
NG		1	1	1	2				1	2	4		

TABLE B-2. NUMBERS OF SPECIMENS AND STAGE OF GONAD DEVELOPMENT OF IMMATURE TEREDINIDS IN EXPOSURE PANELS AT STATIONS IN BARNEGAT BAY, NEW JERSEY, FROM DECEMBER, 1982 THROUGH NOVEMBER, 1983

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

Gonad	1982						1983						
Stage	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Station
EA													
LA													
R													2
PS													
S												1	
NG													
EA													
LA													
R								1					11
PS													
S													
NG										1			
EA													
LA													
R										1			17
PS													
S													
NG										1			

TABLE B-3. NUMBERS OF SPECIMENS AND STAGE OF GONAD DEVELOPMENT OF Bankia gouldi IN EXPOSURE PANELS AT STATIONS IN BARNEGAT BAY, NEW JERSEY, FROM DECEMBER, 1982 THROUGH NOVEMBER, 1983

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

Gonad Stage	1982 Dec	Jan	Feb	Mar	Apr	May	1983 June	Jul	Aug	Sep	Oct	Nov	Station
EA													
LA													
R													3
PS													
S		2								1			
NG													
EA													
LA													
R									1				5
PS													
S										2		1	
NG													
EA													
LA													
R													6
PS													
S													
NG											1		
EA													
LA													
R										3			7
PS													
S	1										4	2	
NG						1				1		4	

TABLE B-3. (Continued)

Gonad	1982						1983						
Stage	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Station
EA													
LA													
R										1			8
PS										3			
S										1	3	2	
NG									1	1			
EA													
LA													
R													9
PS													
S	1												
NG													
EA													
LA									1	1			
R									1				10A
PS													
S	2					1						1	
NG						1					1		
EA													
LA													
R													10B
PS							1						
S	1	1									1		
NG													
EA													
LA									3	2		3	
R								1	6	3			11
PS							3		11	7		1	
S	1	2	1				1			9	14	11	
NG	1	1			1				2		5	7	

TABLE B-3. (Continued)

Gonad Stage	1982 Dec	Jan	Feb	Mar	Apr	May	1983 June	Jul	Aug	Sep	Oct	Nov	Station
EA										1			
LA													
R													12
PS										1		1	
S	1	1				1					1	1	
NG				1					2	1			
EA													
LA													
R										2			13
PS							1			3	3		
S		1				1					15	11	
NG	3									1		1	
EA											2		
LA									2			1	
R									1	2			14
PS									11	3	1		
S						2				8	13	8	
NG						1	1		1				
EA													
LA													
R													15
PS							1						
S		4										3	
NG										1	1	1	
EA													
LA													
R													16B
PS													
S												1	
NG	1												

TABLE B-3. (Continued)

Gonad	1982						1983						
Stage	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Station
EA										1			
LA													
R													17
PS													
S											4	3	
NG										3	1		

and October. Ripe gonads in November at Stations 15 and 17 were probably ripe in October and remained that way as the water cooled and spawning was inhibited.

In general, gonad developmental patterns exhibited by T. navalis were not unusually different from those described in previous reports (e.g., Hillman et al., 1983). The two spawning peaks described for the 1980-1981 and 1981-1982 reporting periods were not as conspicuous during the present reporting period (Figure B-1), but it would be expected that shipworms spawned in June could set, ripen and spawn by late summer. The immature teredinids reported in Table B-2 were probably the result of a late spring spawn. They were too young to identify to species, yet two were ripe and one already spent.

Teredo bartschi. T. bartschi have previously been found in Barnegat Bay only within the thermally-affected area. Since February, 1982, however, no T. bartschi have been recovered from exposure panels in the Barnegat Bay area (Figure B-2).

Bankia gouldi. B. gouldi was collected for gonad observations during the present report period from 15 of the 20 exposure panel stations, an increase of 3 sites since the previous reporting period. Most of the specimens (approximately 70%) occurred at Stations 11, 13 and 14. Gonad developmental patterns did not differ appreciably from what has been reported in previous years (e.g., Hillman et al., 1983).

Most specimens recovered for gonad analysis were collected in December and then from June through November. Late active and ripe gonads were found primarily from July through September, with partially spawned and spent gonads occurring throughout the rest of the fall (Table B-3). This pattern is consistent with what has been reported throughout the study (e.g., Hillman et al., 1983).

To determine whether the thermal effluent from the Oyster Creek Nuclear Generating Station might be having an effect on reproductive cycles of B. gouldi, the gonad development pattern found within the thermally-affected area was compared with the pattern shown by specimens from Region 1 (Figure B-3), and with the pattern from Regions 2, 4 and 5 combined (Figure B-4). No differences have been apparent since 1977 when shipworms became available on a year-round basis from the special panels.

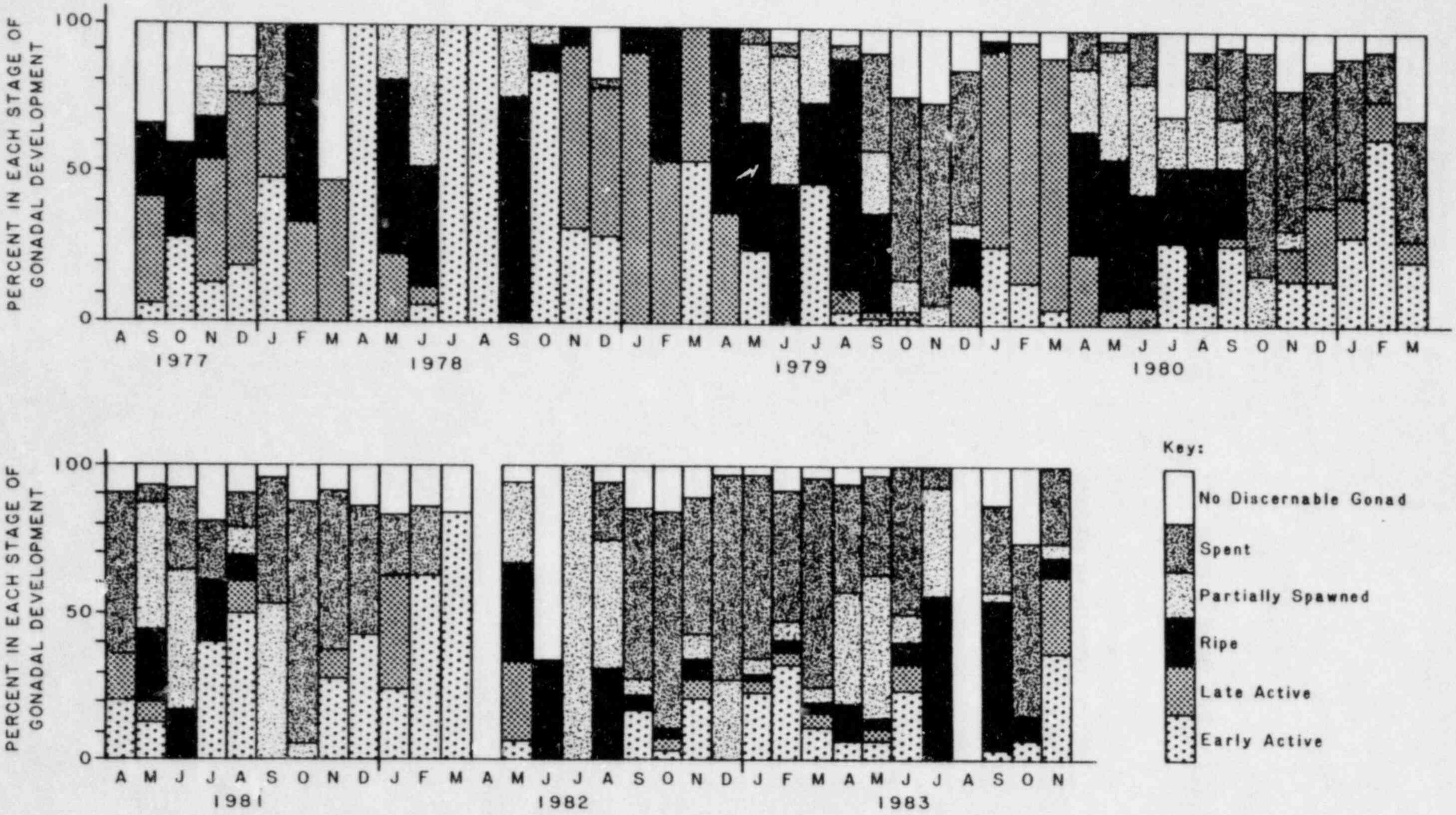

FIGURE B-1. PERCENT OF ALL SPECIMENS OF Teredo navalis IN EACH STAGE OF GONAD DEVELOPMENT FROM AUGUST, 1977 THROUGH NOVEMBER, 1983.

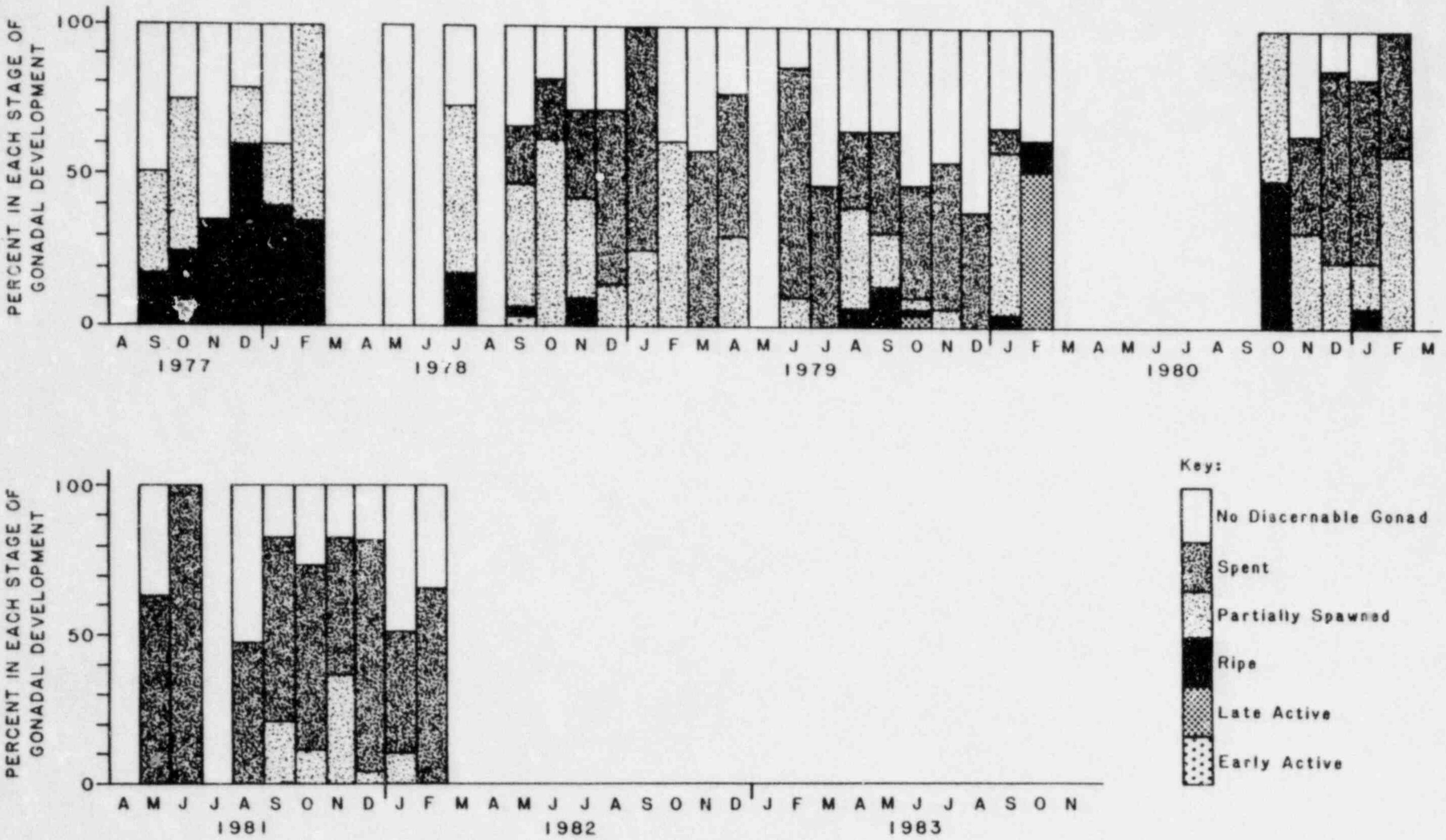

FIGURE B-2. PERCENT OF ALL SPECIMENS OF Teredo bartschi IN EACH STAGE OF GONAD DEVELOPMENT FROM AUGUST, 1977 THROUGH NOVEMBER, 1983.

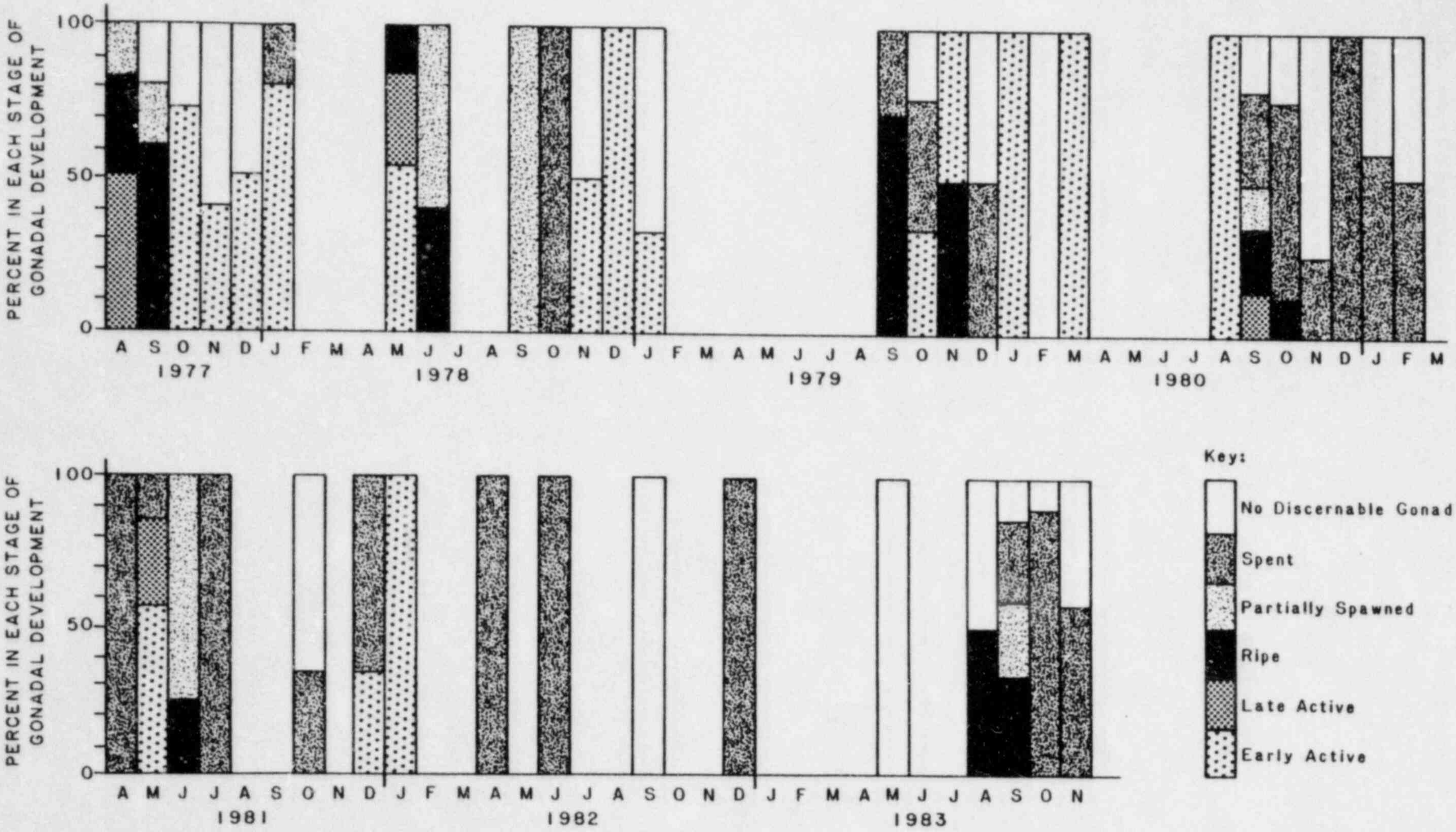

FIGURE B-3. PERCENT OF SPECIMENS OF Bankia gouldi FROM REGION I IN EACH STAGE OF GONAD DEVELOPMENT FROM AUGUST, 1977 THROUGH NOVEMBER, 1983.

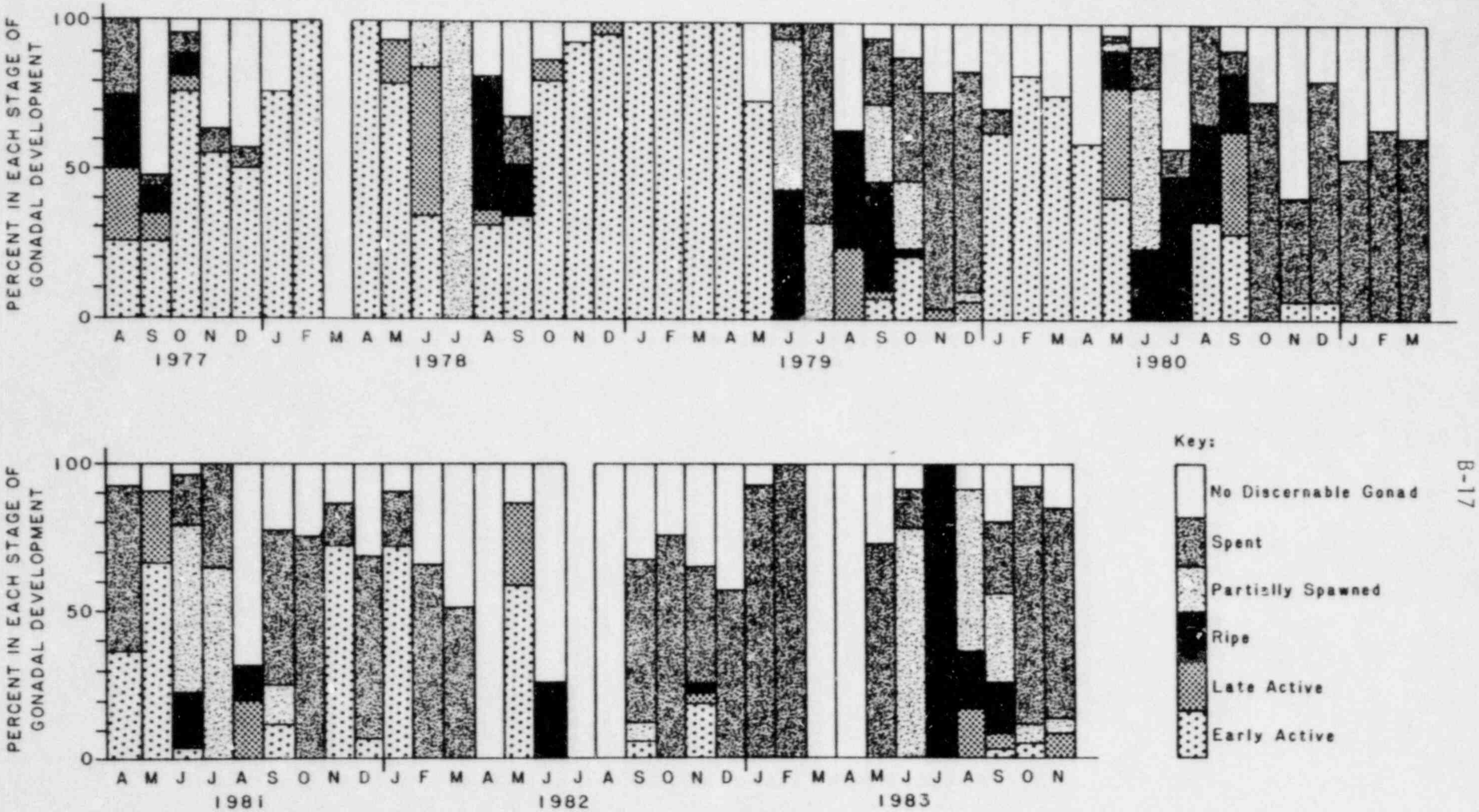

FIGURE B-4. PERCENT OF SPECIMENS OF Bankia gouldi FROM REGIONS 2, 4, AND 5 IN EACH STAGE OF GONAD DEVELOPMENT FROM AUGUST, 1977 THROUGH NOVEMBER, 1983.

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APPENDIX C

APPENDIX C

WATER QUALITY

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APPENDIX C

WATER QUALITY

Introduction

Several water quality parameters were measured at each of the exposure panel stations at the time of panel removal and replacement. These values, recorded monthly, are used to document the physico-chemical environment in Barnegat Bay at the time of the field collections. This portion of the report includes data collected from December, 1982 through November, 1983, and a synthesis of the data collected since the initiation of the study in June, 1975.

Materials and Methods

Field

Water quality measurements were taken monthly at the 20 exposure panel stations (Figure C-1) by the field personnel exchanging exposure panels (see Appendix A), and supplied to Battelle.

Analysis

Several descriptive summaries of water quality values have been prepared. More emphasis is placed on temperature and salinity than on pH and dissolved oxygen because these parameters are considered to be the more important when considering teredinid distribution and abundance.

A). The mean value + one standard deviation was calculated for all parameters for each month in this report period.

B). For temperature and salinity, average values for each biological year from July, 1975 through June, 1983 were calculated and plotted for each station. A biological

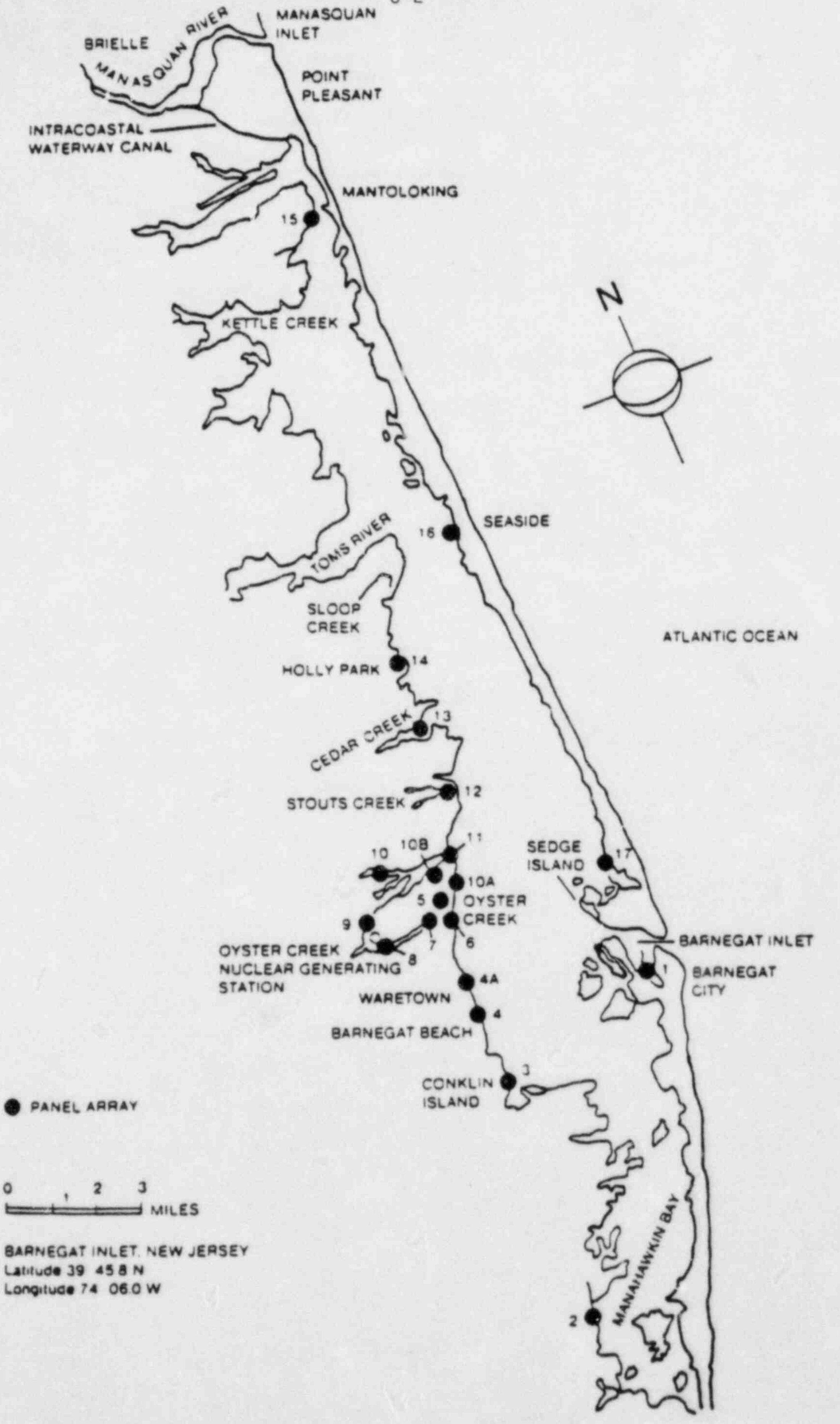

FIGURE C-1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHIC LOCATIONS OF EXPOSURE PANELS year is defined as July, Year A through June, Year B, and corresponds to the breeding season of the teredinids. The period of July, 1983 through November, 1983 was not included because it represents only 5 months of a 12 month period, and average values over this period are not comparable to the other averages calculated.

C). Stations were grouped into regions, and average values of temperature and salinity were calculated and plotted for each biological year since July, 1975. Regions are as follows: Region 1 (near OCNGS discharge), Stations 5, 6, 7, and 8; Region 2 (south of OCNGS), Stations 2, 3, 4, and 4A; Region 3 (east side of bay). Stations 1 and 17; Region 4 (near north), Stations 9, 10, 10A, 10B, and 11; Region 5 (north of OCNGS), Stations 12, 13, 14, 15, and 16B.

D). The differences in temperature values recorded at Station 8 and at Stations 2, 9, 12, 15, and 17 were calculated for each month since July, 1975.

Analyses of variance were carried out on each of the four water quality parameters measured since July, 1975. Calculations were made first by fitting main effects of station, month and biological year (referred to as "bioyear"), and then by fitting main effects, 2-factor and 3-factor interactions of the summary factors region, season and bioyear. The results of the two ANOVA's were then combined by adding the main effect sums of squares for the full factors and the interaction sums of squares for the summary factors. The residual mean square based on the combined fit was used as the error variance estimate and is considered to be more appropriate than the error estimate based on the summary factors. The program used for this calculation is that given in Statistical Package for the Social Sciences (Nie, Hull, Jenkins, Steinbrenner and Bent, 1975).

Multiple classification analyses (MCA) were then used to quantify the systematic variations detected by the analysis of variance procedures (Nie et al., 1975).

This output, which is a display rather than a particular test, provides information about the patterns of effects of each factor, and therefore about the reasons underlying significant effects observed in the analysis of variance calculations. It is appropriate only if the interactions among factors are not practically or statistically significant.

The MCA output provides the grand mean of all the responses. "Unadjusted deviations" are deviations from the grand mean of the sample averages in each level of each factor, not accounting for the effects of any of the other factors. "Adjusted for independent deviation" are deviations from the grand mean of the effects of each category when the other factors are adjusted for in an additive manner. These adjustments are made by fitting an additive analysis of variance model in the factors (i.e., main effects only, and not interactions) and estimating the effects of the levels of each factor from the coefficients in the model. For nearly balanced data, the adjusted and unadjusted deviations should be similar.

Bonferroni t-statistic (Miller, 1966) was used to compare means of treatment levels in a pairwise fashion to determine the sources of significant effects that have been observed in analysis of variance tests. Bonferroni's procedure is based on the two sample Student t-test with significance levels adjusted to account for simultaneity.

Let X_1, X_2, ...X_k be k sample means based on N_1, N_2, ...N_k observations respectively. Let M_1, M_2, ...,M_k be the corresponding population means. These sample averages might originate as the average values in k levels of a factor under study.

Let s^2 = error SS/error df denote the error mean square from ana analysis of variance, based on ν degrees of freedom.

Suppose we wish to make ν pairwise comparisons among M_1, M_2, ...,M_k. For example, to test H_0: M_i i ≠ j = 1, ...,k we must make r = k (k-1) pairwise comparisons.

H_0 will be rejected at significance level α if

$$\frac{[\bar{x}_i - \bar{x}_j]}{\sqrt{\frac{1}{n_i} + \frac{1}{n_j}}} > t(\nu; 1 - \alpha/2r)$$

for any pair i, j, where $t(\nu; 1 - \alpha/r)$ is the upper $\alpha/2r$ point of the student distribution with νd.f.

This procedure leads to the condidence intervals

$$\bar{x}_i - \bar{x}_j - t(\nu; 1 \, ^{\alpha}/2r)s\sqrt{\frac{1}{n_i} + \frac{1}{n_j}} \leq M_i - M_j \leq \bar{X}_i - \bar{X}_j + t(\nu; 1 - {}^{\alpha}/2r)s\sqrt{\frac{1}{n_i} + \frac{1}{n_j}}$$

with overall probability $1-\alpha$ that all r confidence intervals calculated are correct. The means M_i M_j are significantly different if the confidence interval does not contain zero.

Results and Discussion

The water quality values recorded each month at each of the exposure panel stations from December, 1982, through November, 1983 are given in Tables C-1 through C-12. Table C-13 gives the monthly minimum, maximum and mean ± one standard deviation for each parameter measured.

Temperature

Water temperatures in December, 1982 (Table C-1) were very much higher than during December, 1981. The highest temperature recorded in December, 1982 was 18.0°C at Station 8, and the lowest was 11.8°C at Station 17. Last year, the highest December temperature was only 9.0°C at Station 7, almost 3°C lower than this year's lowest temperature. The mean temperature in the area during December, 1982 was 14.4°C (Table C-13) as compared to 4.8°C last year.

By January, 1983 water temperatures had dropped sharply, with a mean temperature of 4.4°C being calculated for the area. This was in line with last year's January mean water temperature of 4.6°C.

The lowest water temperatures over the study area are usually recorded in February, and this held true during the present reporting period, with a mean of 1.9°C calculated for the various sites.

Through March, April and May, 1983 temperatures rose sharply. The mean water temperature in April, 1983 was 10.6°C, in contrast with last year's April mean water temperature of only 3.5°C. This year's mean water temperature is more consistent with previous years' April mean water temperature.

The mean May water temperature of 17.6°C is somewhat lower than last year's mean of 20°C. The highest water temperature in May, 1983 was 19.0°C at Station 9, while Stations 4A, 5, 6, 7, 8, 10A, 10B, 11 and 13 had temperatures in excess of 18°C. Lows of 15.0°C at Station 1, and 15.1°C at Station 17, were also recorded in May.

The warmest mean water temperature in 1983 occurred during the months of July, August and September, when means of 27.8°C, 28.1°C and 28.2°C, respectively, were calculated. They declined sharply through October and by November, the mean water temperature was calculated at 10.9°C, about 7°C lower than the previous year.

TABLE C-1. WATER QUALITY AT EXPOSURE PANEL STATIONS DECEMBER, 1982

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (oC)	O_2** (mg/l)	pH*
1	12/6/82	0950	3.0	23.5	13.8	8.0	8.0
2	12/6/82	1045	2.5	20.4	14.1	7.5	7.9
3	12/6/82	1125	0.5	20.6	14.8	8.2	8.2
4	12/6/82	1150	2.5	21.9	14.6	8.9	-
4A	12/6/82	1220	0.5	19.8	14.2	8.9	-
5	12/6/82	1340	0.8	20.5	16.8	8.5	-
6	12/6/82	1355	1.0	20.5	16.6	8.5	-
7	12/6/82	1410	0.8	20.5	17.5	8.1	-
8	12/6/82	1430	3.0	20.7	18.0	8.2	-
9	12/6/82	1505	3.0	20.9	15.7	9.5	-
10	12/7/82	1430	2.5	19.8	13.3	9.9	-
10A	12/6/82	1530	0.8	21.0	15.4	9.3	-
10B	12/6/82	1550	2.0	21.0	16.0	-	-
11	12/6/82	1605	0.8	22.3	14.5	-	-
12	12/7/82	1350	1.0	16.7	12.0	9.5	-
13	12/7/82	1330	1.2	15.0	12.2	9.2	-
14	12/7/82	1300	1.5	15.2	12.9	9.1	-
15	12/7/82	0940	1.0	16.8	12.1	8.9	-
16B	12/7/82	1030	2.0	14.6	11.9	9.5	-
17	12/7/82	1120	0.2	22.2	11.8	10.4	-

- No reading taken.

* pH meter not working properly after Station 3.

** DO readings questionable, meter erratic at Stations 4 through 7.
YSI DO meter temperature reading incorrect at Stations 8, 9 and 10A, therefore DO reading may be invalid at these stations.

TABLE C-2. WATER QUALITY AT EXPOSURE PANEL STATIONS JANUARY, 1983

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	1/3/83	1020	3.5	28.5	4.9	12.6	8.3
2	1/3/83	1110	0.7	23.4	3.9	12.6	8.2
3	1/3/83	1150	1.0	25.9	4.2	12.0	8.3
4	1/3/83	1215	1.0	26.1	4.5	12.1	8.3
4A	1/3/83	1230	1.0	26.7	4.7	11.6	8.3
5	1/3/83	1400	0.7	23.9	6.7	10.4	8.2
6	1/3/83	1415	1.0	23.1	5.9	10.7	8.1
7	1/3/82	1435	0.7	23.8	6.7	11.1	8.2
8	1/3/83	1505	3.5	22.7	6.4	11.6	8.3
9	1/3/83	1540	3.0	23.8	4.6	11.7	8.3
10	1/4/83	1412	2.5	21.5	5.5	11.2	8.1
10A	1/3/83	1608	1.0	24.0	4.6	11.9	8.2
10B	1/3/83	1622	2.5	24.4	4.5	12.0	8.3
11	1/4/83	1440	0.8	24.1	3.1	11.8	8.3
12	1/4/83	1308	1.5	23.7	4.3	11.7	8.2
13	1/4/83	1235	1.5	21.0	3.9	12.1	8.2
14	1/4/83	1208	2.0	22.1	3.3	12.4	8.3
15	1/4/83	1040	2.0	22.8	3.1	13.2	8.2
16B	1/4/83	1110	2.5	18.6	2.0	13.1	8.1
17	1/4/83	1145	0.5	27.1	1.6	13.9	8.2

TABLE C-3. WATER QUALITY AT EXPOSURE PANEL STATIONS FEBRUARY, 1983

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	2/8/83	1020	2.5	27.1	2.5	14.1	8.1
2	2/8/83	1102	1.0	22.7	1.7	13.0	8.0
3	2/8/83	1145	1.0	24.9	1.9	12.2	8.1
4	2/8/83	1220	1.0	27.8	2.7	11.1	8.1
4A	2/8/83	1245	1.5	27.7	3.2	10.2	8.1
5	2/8/83	1345	0.5	20.9	3.8	12.0	7.7
6	2/8/83	1408	0.5	19.0	2.7	12.6	7.7
7	2/8/83	1430	0.5	22.0	3.8	12.3	7.8
8	2/8/83	1507	2.5	21.7	3.5	13.3	7.9
9	2/8/83	1530	2.5	23.3	1.9	13.9	8.0
10	2/8/83	1710	2.5	16.9	1.8	13.2	7.7
10A	2/8/83	1558	0.8	23.5	1.8	14.1	8.1
10B	2/8/83	1617	2.5	23.5	1.6	14.2	8.0
11	2/8/83	1638	1.0	23.9	1.6	13.5	8.0
12	2/9/83	1232	1.5	19.2	1.2	12.8	7.7
13	2/9/83	1201	1.5	12.9	1.7	12.8	7.5
14	2/9/83	1134	1.5	20.1	1.4	13.4	7.9
15	2/9/83	0912	2.0	22.1	0.3	14.5	8.1
16B	2/9/83	0945	3.0	18.7	-0.2	14.9	7.9
17	2/9/83	1028	0.5	25.8	-0.8	14.9	7.9

TABLE C-4. WATER QUALITY AT EXPOSURE PANEL STATIONS MARCH, 1983

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	0_2 (mg/l)	pH
1	3/7/83	1025	3.5	24.8	6.7	10.6	7.8
2	3/7/83	1105	3.5	20.6	9.1	9.8	7.8
3	3/7/83	1150	0.8	18.7	8.9	10.3	7.6
4	3/7/83	1225	2.5	19.8	7.6	9.0	7.8
4A	3/7/83	1250	0.8	19.9	7.2	9.9	7.9
5	3/7/83	1345	0.5	17.3	7.3	10.4	7.5
6	3/7/83	1408	1.0	14.8	7.9	10.0	7.2
7	3/7/83	1430	1.0	16.0	7.6	10.1	7.3
8	3/7/83	1500	2.5	17.9	6.8	10.2	7.7
9	3/7/83	1530	3.5	18.9	6.7	10.0	7.7
10	3/8/83	1328	2.5	16.7	6.7	8.9	7.5
10A	3/7/83	1605	1.0	20.0	6.8	9.9	7.3
10B	3/7/83	1628	2.0	21.0	6.7	9.8	7.8
11	3/7/83	1645	1.0	19.9	6.7	9.6	8.1
12	3/8/83	1300	2.0	17.6	6.0	9.8	7.8
13	3/8/83	1231	2.5	5.8	5.9	9.8	7.4
14	3/8/83	1208	2.5	15.0	5.6	10.2	7.9
15	3/8/83	0930	2.0	20.2	5.6	10.2	8.1
16B	3/8/83	1010	3.5	19.1	5.7	10.3	8.0
17	3/8/83	1100	0.8	21.2	5.7	10.3	8.1

TABLE C-5. WATER QUALITY AT EXPOSURE PANEL STATIONS APRIL, 1983

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (oC)	0_2 (mg/l)	pH
1	4/5/83	0920	4.5	22.8	10.0	10.2	8.4
2	4/5/83	0955	0.5	21.8	10.5	9.0	8.1
3	4/5/83	1030	0.8	21.0	10.7	10.6	8.4
4	4/5/83	1050	0.8	22.0	9.7	10.8	8.3
4A	4/5/83	1110	0.8	21.9	9.7	10.9	8.4
5	4/5/83	1130	0.5	10.9	10.2	10.3	7.3
6	4/5/83	1145	0.5	6.0	10.0	10.2	7.3
7	4/5/83	1203	0.8	15.1	10.8	10.0	7.7
8	4/5/83	1408	3.5	21.5	9.2	10.0	3.4
9	4/5/83	1335	4.5	9.9	11.0	9.2	7.9
10	4/5/83	1355	2.0	18.3	11.7	10.1	8.3
10A	4/5/83	1430	0.8	21.0	11.5	9.6	8.5
10B	4/5/83	1450	2.0	20.3	11.7	9.8	8.2
11	4/5/83	1508	0.8	15.2	12.0	9.6	8.1
12	4/6/83	1233	1.5	16.0	10.8	11.2	8.2
13	4/6/83	1205	1.5	5.0	10.0	9.2	7.2
14	4/6/83	1135	2.0	13.8	10.2	11.0	8.5
15	4/6/83	0917	2.5	15.1	10.0	10.8	8.4
16B	4/6/83	0950	3.3	15.0	10.7	11.2	8.4
17	4/6/83	1035	0.5	20.3	11.2	9.4	8.2

TABLE C-6. WATER QUALITY AT EXPOSURE PANEL STATIONS MAY, 1983

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	5/2/83	0950	4.5	19.8	15.0	8.2	8.1
2	5/2/83	1035	2.5	20.3	16.1	7.4	7.7
3	5/2/83	1120	0.5	19.1	17.2	7.6	7.7
4	5/2/83	1145	1.0	19.9	17.9	6.8	7.5
4A	5/2/83	1210	1.0	18.1	18.6	7.1	7.8
5	5/2/83	1310	0.5	13.9	18.2	7.7	7.7
6	5/2/83	1330	0.5	14.1	18.1	7.6	7.6
7	5/2/83	1352	0.5	14.2	18.6	7.3	7.5
8	5/2/83	1418	3.0	13.2	18.2	7.4	7.5
9	5/2/83	1448	4.5	13.9	19.0	7.7	7.8
10	5/3/83	1326	3.5	15.0	16.1	6.4	7.3
10A	5/2/83	1533	1.0	14.9	18.8	7.8	7.8
10B	5/2/83	1553	2.5	15.0	18.8	8.2	8.0
11	5/2/83	1615	0.8	15.6	18.1	8.2	7.9
12	5/3/83	1245	2.0	16.0	17.6	7.8	7.8
13	5/3/83	1212	2.0	12.1	18.5	7.6	8.2
14	5/3/83	1140	2.5	14.5	17.6	7.6	8.1
15	5/3/83	0912	3.0	10.2	17.3	7.6	7.6
16B	5/3/83	0950	4.0	10.9	16.9	8.3	8.0
17	5/3/83	1034	0.5	20.9	15.1	8.4	7.8

TABLE C-7. WATER QUALITY AT EXPOSURE PANEL STATIONS
JUNE, 1983

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	6/6/83	0945	4.5	24.0	17.6	7.6	8.0
2	6/6/83	1040	1.0	19.9	22.5	6.6	8.1
3	6/6/83	1120	1.0	17.6	22.7	6.2	7.9
4	6/6/83	1145	1.0	18.8	22.3	7.0	8.0
4A	6/6/83	1210	1.2	18.5	23.0	6.6	7.9
5	6/6/83	1430	0.8	17.0	23.2	6.9	8.1
6	6/6/83	1445	2.0	17.0	22.3	7.4	8.0
7	6/6/83	1505	0.5	4.9	23.7	6.1	7.0
8	6/6/83	1405	3.5	2.0	23.0	6.2	6.2
9	6/6/83	1335	3.5	13.9	23.6	6.3	7.3
10	6/7/83	1425	2.5	12.8	21.7	4.4	7.0
10A	6/6/83	1545	1.0	16.2	23.0	6.4	8.0
10B	6/6/83	1604	2.0	16.0	23.0	6.5	8.0
11	6/7/83	1500	0.7	11.8	24.6	6.4	7.9
12	6/7/83	1355	1.5	14.6	24.3	6.6	7.8
13	6/7/83	1325	2.0	11.8	24.0	5.4	7.3
14	6/7/83	1215	2.5	14.6	22.8	6.1	8.0
15	6/7/83	0905	2.5	11.2	21.7	7.0	7.5
16B	6/7/83	0950	3.5	9.7	21.7	6.3	7.6
17	6/7/83	1040	0.2	21.0	21.6	5.2	7.9

TABLE C-8. WATER QUALITY AT EXPOSURE PANEL STATIONS
JULY, 1983

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	7/5/83	0912	3.5	24.1	22.8	6.1	7.7
2	7/5/83	0955	1.2	20.5	28.5	3.5	7.6
3	7/5/83	1042	1.2	19.9	29.2	4.2	7.4
4	7/5/83	1105	1.0	20.1	29.5	4.4	7.6
4A	7/5/83	1124	1.5	19.9	29.5	5.6	7.9
5	7/5/83	1412	0.5	13.2	29.2	6.5	7.6
6	7/5/83	1425	1.2	15.2	28.7	6.3	7.7
7	7/5/83	1705	0.8	13.2	27.5	7.2	7.5
8	7/5/83	1326	3.5	18.0	27.8	4.6*	7.6
9	7/5/83	1345	3.5	14.8	29.5	6.8	7.7
10	7/5/83	1506	3.5	11.0	28.0	3.8**	6.4**
10A	7/5/83	1632	1.0	18.6	28.0	7.2	7.8
10B	7/5/83	1610	2.5	17.0	28.8	6.7	7.7
11***	7/5/83	1600	1.0	15.0	28.8	5.6	7.4
12	7/5/83	1225	1.5	16.6	27.5	6.6	7.7
13	7/6/83	1200	2.0	12.5	27.5	5.6	7.0
14	7/6/83	1130	2.5	14.4	26.8	5.6	7.5
15	7/6/83	0850	3.0	15.9	25.6	4.5	7.2
16B	7/6/83	0925	3.5	10.8	26.4	5.1	7.1
17	7/6/83	1015	0.5	23.5	26.3	3.2	7.8

*Value may be too low, DO meter may have needed to be recalibrated.
**Readings erratic: pH and DO meters became slightly wet during a heavy thundershower.
***Meters changed at Station 11.

TABLE C-9. WATER QUALITY AT EXPOSURE PANEL STATIONS
AUGUST, 1983

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	8/1/83	0905	4.0	25.2	21.7	6.1	7.7
2	8/1/83	0950	3.0	23.4	27.0	5.0	7.6
3	8/1/83	1025	1.0	21.1	28.2	4.4	7.5
4	8/1/83	1048	1.5	21.8	29.0	5.2	7.7
4A	8/1/83	1106	1.0	21.8	28.8	5.6	7.8
5	8/1/83	1125	0.8	15.2	28.7	6.2	7.8
6	8/1/83	1140	2.0	16.8	27.5	6.2	7.8
7	8/1/83	1206	1.5	19.0	30.0	6.2	7.9
8	8/1/83	1356	4.0	17.8	28.5	6.5	7.8
9	8/1/83	1325	4.0	17.8	28.8	6.0	7.4
10	8/1/83	1521	3.0	12.5	28.9	5.8	7.5
10A	8/1/83	1425	1.5	19.3	29.6	5.2	7.8
10B	8/1/83	1443	3.0	18.9	29.5	6.0	7.9
11	8/1/83	1500	2.0	17.8	29.2	5.6	7.9
12	8/2/83	1250	2.0	18.3	28.7	6.0	7.6
13	8/2/83	1220	2.5	13.0	28.5	6.3	7.4
14	8/2/83	1152	3.0	17.8	28.2	5.6	7.7
15	8/2/83	0908	3.5	13.0	26.5	5.8	7.2
16B	8/2/83	0942	4.0	12.3	26.8	5.0	7.2
17	8/2/83	1030	1.0	23.3	27.0	7.6	8.0

TABLE C-10. WATER QUALITY AT EXPOSURE PANEL STATIONS
SEPTEMBER, 1983

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	9/6/83	0910	6.0	24.8	23.7	5.6	7.4
2	9/6/83	0955	1.5	24.5	27.7	5.0	7.5
3	9/6/83	1028	1.5	22.8	27.9	4.4	7.3
4	9/6/83	1102	3.0	22.6	28.0	3.2	7.2
4A	9/6/83	1123	2.0	22.3	29.0	5.6	7.6
5	9/6/83	1142	2.0	18.1	28.7	6.3	7.5
6	9/6/83	1155	2.0	19.1	28.0	5.0	7.3
7	9/6/83	1213	1.2	17.5	29.0	6.0	7.3
8	9/6/83	1340	4.0	20.2	27.9	5.4	7.3
9	9/6/83	1323	4.0	19.0	28.7	6.0	7.2
10	9/6/83	1512	4.0	16.0	28.7	5.7	7.3
10A	9/6/83	1406	2.2	20.2	28.9	5.8	7.6
10B	9/6/83	1425	3.0	20.0	29.0	6.0	7.6
11	9/6/83	1442	1.5	19.0	29.2	6.0	7.6
12	9/7/83	1324	2.5	19.4	28.8	5.2	7.5
13	9/7/83	1256	3.0	16.1	28.8	5.3	7.4
14	9/7/83	1220	4.0	17.9	29.0	4.8	7.4
15	9/7/83	0852	3.0	15.2	26.7	6.3	7.3
16B	9/7/83	0930	4.0	13.8	27.6	5.0	7.2
17	9/7/83	1055	1.5	23.9	28.7	3.9	7.6

TABLE C-11. WATER QUALITY AT EXPOSURE PANEL STATIONS OCTOBER, 1983

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	10/4/83	0900	5.5	20.9	19.6	6.6	7.8
2	10/4/83	0938	2.0	20.9	19.8	6.9	7.7
3	10/4/83	1026	2.0	20.5	20.2	6.3	7.6
4	10/4/83	1053	2.2	20.8	19.9	5.8	7.6
4A	10/4/83	1112	2.2	21.1	20.7	6.8	7.8
5	10/4/83	1131	1.2	16.6	20.5	8.8*	7.9
6	10/4/83	1148	2.5	18.0	20.0	7.4	7.8
7	10/4/83	1205	1.6	16.9	21.7	8.4	8.0
8	10/4/83	1401	4.0	20.2	20.6	9.0	8.0
9	10/4/83	1340	4.0	18.8	21.7	7.2	7.4
10	10/4/83	1535	4.0	18.2	21.0	7.3	7.7
10A	10/4/83	1430	1.5	19.0	22.3	7.1	7.7
10B	10/4/83	1450	3.2	19.4	21.6	7.8	7.9
11	10/4/83	1508	2.5	18.5	21.7	7.8	7.9
12	10/5/83	1250	2.5	19.6	21.6	7.6	7.9
13	10/5/83	1225	3.0	19.6	21.6	8.0	8.0
14	10/5/83	1140	4.0	17.9	21.5	7.4	7.8
15	10/5/83	0928	4.0	17.6	20.6	7.3	7.7
16B	10/5/83	1000	5.0	14.0	20.7	7.8	7.9
17	10/5/83	1054	1.5	22.3	21.6	6.2	7.7

*Value may be too low, DO meter may have needed to be recalibrated.

TABLE C-12. WATER QUALITY AT EXPOSURE PANEL STATIONS NOVEMBER, 1983

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	11/7/83	0902	7.5	27.5	9.4	10.0	8.0
2	11/7/83	0942	4.0	25.2	9.2	8.6	8.0
3	11/7/83	1017	2.0	24.2	9.2	8.2	8.0
4	11/7/83	1040	3.0	26.9	10.2	8.0	8.0
4A	11/7/83	1058	2.0	27.0	11.4	8.4	8.1
5	11/7/83	1118	2.0	21.2	10.5	8.2	7.9
6	11/7/83	1130	2.2	21.0	9.7	9.0	7.9
7	11/7/83	1153	4.0	25.8	12.1	8.6	8.0
8	11/7/83	1450	2.2	22.9	12.2	9.3	8.0
9	11/7/83	1335	7.0	24.5	13.2	7.7	7.9
10	11/8/83	1237	4.0	23.8	13.5	7.8	7.8
10A	11/7/83	1510	2.0	24.8	11.0	9.4	8.0
10B	11/7/83	1525	4.0	25.0	11.3	9.0	7.9
11	11/7/83	1537	2.0	22.0	11.0	9.7	8.0
12	11/8/83	1208	3.0	22.1	12.1	9.7	8.0
13	11/8/83	1132	3.0	22.6	12.2	8.6	8.0
14	11/8/83	1108	3.5	17.0	10.5	8.7	7.9
15	11/8/83	0847	3.5	21.0	9.7	9.9	8.0
16B	11/8/83	0915	4.5	17.5	9.5	9.4	8.1
17	11/8/83	1000	1.0	24.5	10.2	8.7	7.8

TABLE C-13. MINIMUM, MAXIMUM, MEAN AND STANDARD DEVIATION OF WATER QUALITY VALUES OBSERVED DURING EACH MONTH OF EXPOSURE PANEL STATIONS IN BARNEGAT BAY, NEW JERSEY, FROM DECEMBER, 1982 THROUGH NOVEMBER, 1983

Parameter	Date	Maximum	Minimum	Mean	+ Standard Deviation
	Dec 1982	18.0	11.8	14.4	1.9
	Jan 1983	6.7	1.6	4.4	1.4
	Feb	3.8	-0.8	1.9	1.2
	Mar	9.1	5.6	6.9	1.0
	Apr	12.0	9.2	10.6	0.8
Temperature	May	19.0	15.0	17.6	1.2
(°C)	Jun	24.6	17.6	22.6	1.5
	Jul	29.5	22.8	27.8	1.6
	Aug	30.0	21.7	28.1	1.8
	Sep	29.2	23.7	28.2	1.2
	Oct	22.3	19.6	20.9	0.8
	Nov	13.5	9.2	10.9	1.3
	Dec 1982	23.5	14.6	19.7	2.6
	Jan 1983	28.5	18.6	23.9	2.3
	Feb	27.8	12.9	22.2	3.7
	Mar	24.8	5.8	18.3	5.2
	Apr	22.8	5.0	17.1	3.1
Salinity	May	20.9	10.2	15.6	5.2
(o/oo)	Jun	24.0	2.0	14.7	3.8
	Jul	24.1	10.8	16.7	3.8
	Aug	25.2	12.3	18.3	3.1
	Sep	24.8	13.8	22.1	1.9
	Oct	22.3	14.0	19.0	2.9
	Nov	27.5	17.0	23.3	2.6
	Dec 1982	8.2	7.9	8.0*	0.2
	Jan 1983	8.3	8.1	8.2	0.1
	Feb	8.1	7.5	7.9	0.2
	Mar	8.1	7.2	7.7	0.3
	Apr	8.5	7.3	8.1	0.4
pH	May	8.2	7.3	7.8	0.2
	Jun	8.1	6.2	7.7	0.5
	Jul	7.9	7.0	7.6*	0.3
	Aug	8.0	7.2	7.7	0.2
	Sep	7.6	7.2	7.4	0.1
	Oct	8.0	7.4	7.8	0.2
	Nov	8.1	7.8	8.0	0.1
	Dec 1982	10.4	7.5	9.0*	0.7
	Jan 1983	13.9	10.4	12.0	0.8
	Feb	14.9	10.2	13.2	0.8
	Mar	10.6	8.9	10.0	0.4
	Apr	11.2	9.0	10.2	0.7
Dissolved Oxygen	May	8.4	6.4	7.6	0.5
(mg/l)	Jun	7.6	4.4	6.4	0.7
	Jul	7.2	3.2	5.6*	1.2
	Aug	7.6	4.4	5.8	0.7
	Sep	6.3	3.2	5.3	0.8
	Oct	9.0	5.8	7.3*	0.8
	Nov	10.0	7.7	8.8	0.7

* Equipment malfunctioning - readings not available for every station.

The only ice cover reported during this year's sampling program occurred during February, 1983 at Stations 12 and 17.

The average temperature at each station for the bioyear July, 1982 through June, 1983 is shown in Figure C-2. A bioyear corresponds to the teredinid breeding season in the Barnegat Bay region (Richards et al., 1979). As in previous years, the stations closest to the discharge from the power station (Stations 5 through 8) showed temperatures somewhat above those at the other stations.

The average temperatures for the various regions (Appendix A) over the most recent bioyear are plotted in Figure C-3. As in previous years (see Hillman et al., 1983), highest temperatures are in Region 1 (near the plant) and the lowest are in Region 3 (outside any thermal effects from the plant).

Table C-14 compares water temperatures recorded at Station 8 in Oyster Creek since July, 1975 with those recorded at Stations 2, 9, 12, 15 and 17 which are outside Oyster Creek. Over that time period, temperatures at Station 8 have been elevated within a range of 74 percent of the time above those at Station 9 to 88 percent of the time above those at Station 2. Elevations have been in the 3.0 to 5.9°C range above ambient at least 50 percent of the time at Stations 2 and 15. At Station 12, they were in that range only 38 percent of the time.

The results of the factorial ANOVA on temperature data are shown in Table C-15. All three main effects of month, station, and bioyear were highly significant, with month obviously the most important main effect (based on a comparison of the relative mean square values). This result is expected considering the known seasonal temperature cycle in temperate estuaries. All three two-factor interactions are also highly significant, with the interaction between season and bioyear being most important. In addition, the three-way interaction of region/season/bioyear was highly significant.

Multiple comparison procedures were used to identify patterns within the temperature data. This was done for stations, months, and bioyears using all available data. Because this procedure does not correct for variation explained by other factors (e.g., seasonal variation), the results of the analysis by station indicated no significant differences. As in previous years, however, stations in Region 1 had generally higher temperatures than the remainder of the Bay.

When the analysis was performed on data grouped by month, each of the nine months examined was found to be significantly different. Analysis of temperature data by bioyear indicated 75/76 to be significantly colder and 83/84 to be significantly warmer

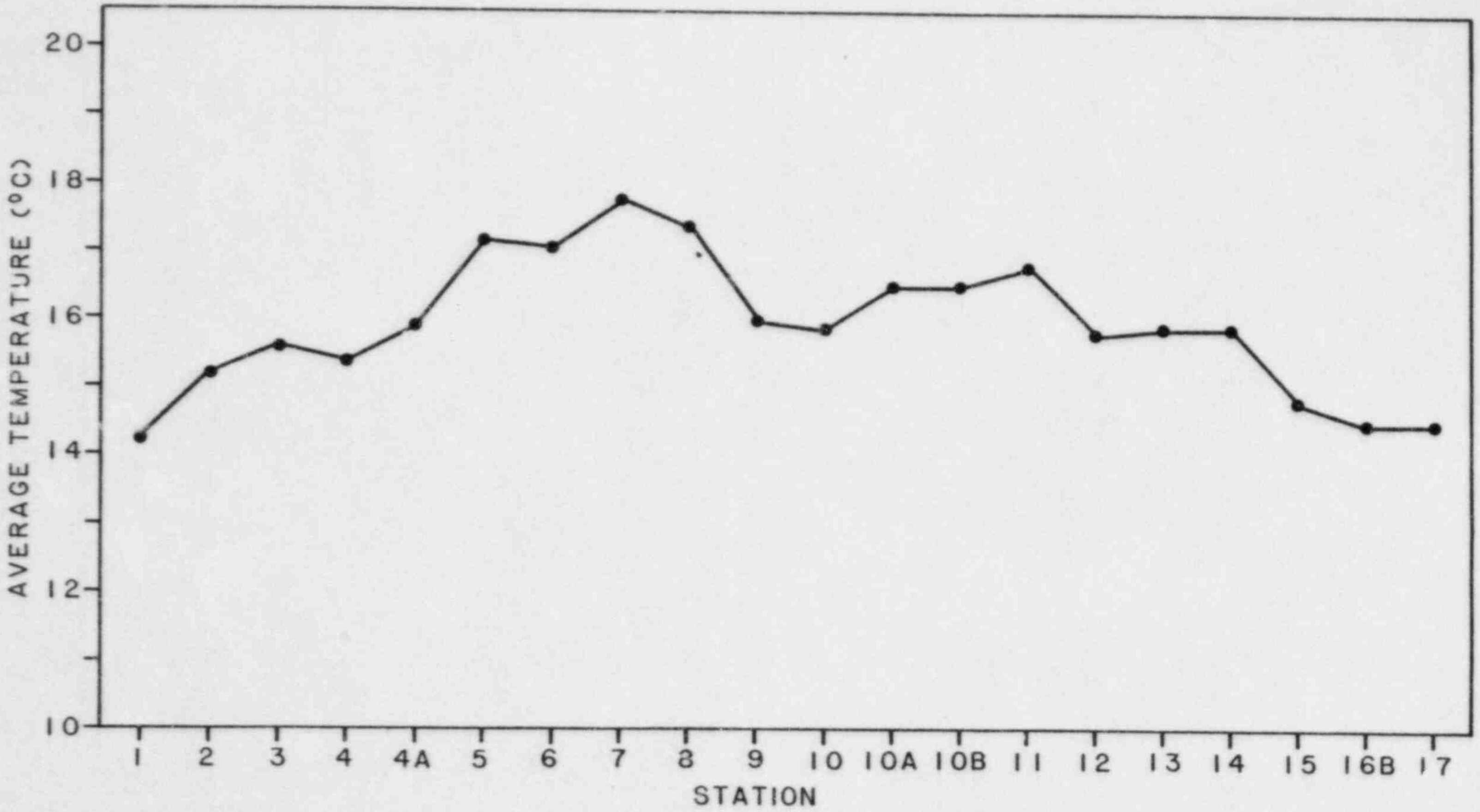

FIGURE C-2. AVERAGE TEMPERATURE AT EACH EXPOSURE PANEL STATION CALCULATED FOR THE BIOLOGICAL YEAR JULY, 1982 THROUGH JUNE, 1983. NUMBER OF OBSERVATIONS IS 12.

TABLE C-14. TEMPERATURES RECORDED AT STATION 8 COMPARED TO FIVE OTHER EXPOSURE PANEL STATIONS IN VARIOUS REGIONS OF BARNEGAT BAY SINCE JULY, 1975.

Station 8 Compared to:	Station 2	Station 9	Station 12	Station 15	Station 17
Number of Observations					
Lower Than	11	15	21	8	13
Equal To	1	11	3	6	2
0.1 to 0.9°C Higher	13	5	7	6	7
1.0 to 1.9°C Higher	8	10	13	10	15
2.0 to 2.9°C Higher	8	16	11	13	13
3.0 to 3.9°C Higher	18	18	21	14	11
4.0 to 4.9°C Higher	21	17	7	20	17
5.0 to 5.9°C Higher	10	5	9	15	10
6.0 to 6.9°C Higher	4	2	5	4	5
7.0 to 8.5°C Higher	4	0	0	2	4
8.5°C Higher	0	0	0	0	1
Missing Pairs	3	2	4	3	3
Summary					
Total Observations	98	99	97	98	98
Number of Times Elevated	86	73	73	84	83
Percent of Times Elevated	88	74	75	86	85
Number of Times 3.0-5.9°C	49	40	37	49	38
Percent of Times 3.0-5.9°C	50	40	38	50	39

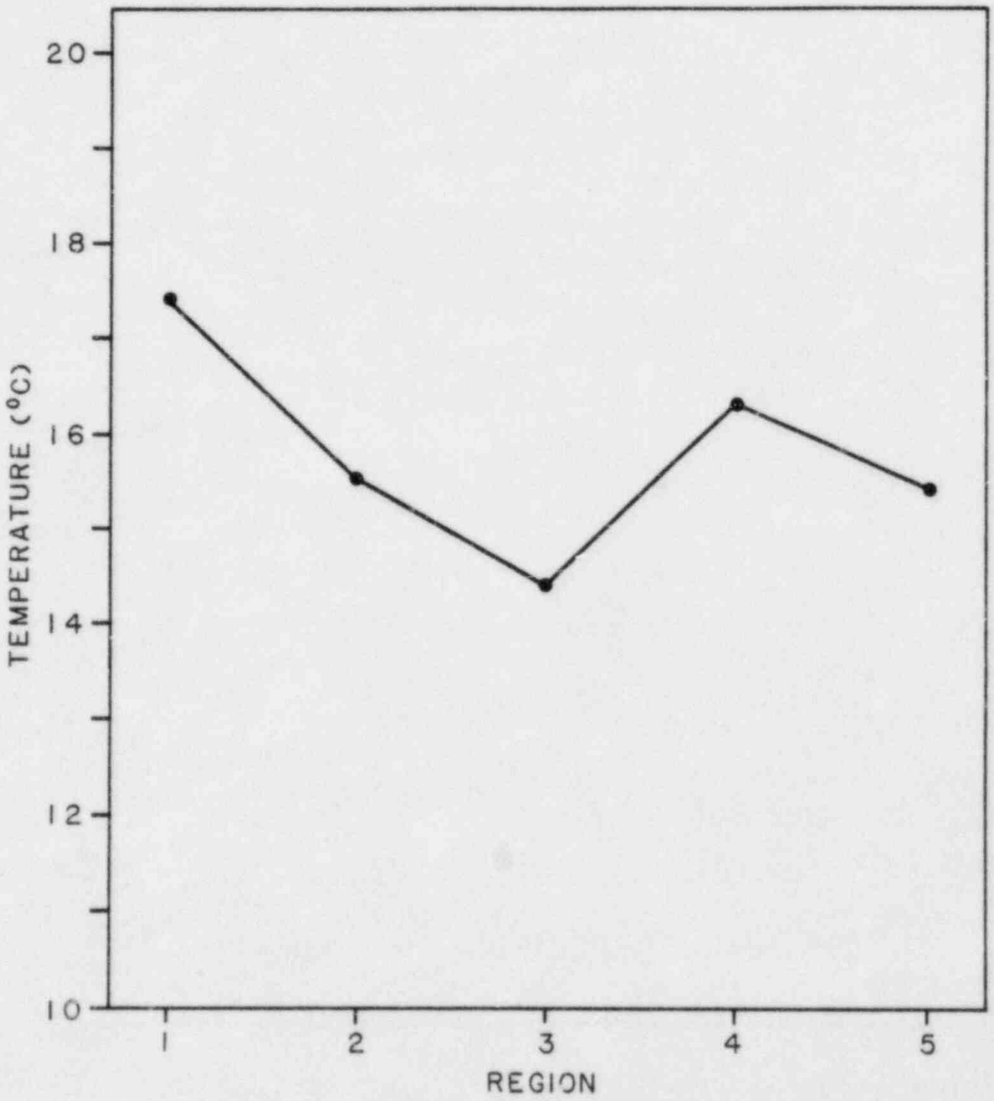

FIGURE C-3. AVERAGE TEMPERATURE FOR STATIONS GROUPED INTO REGIONS FOR BIOLOGICAL YEAR JULY, 1982 THROUGH JUNE, 1983.

REGION 1 = STATIONS 5, 6, 7, 8; REGION 2 = STATIONS 2, 3, 4, 4A; REGION 3 = STATIONS 1, 17; REGION 4 = STATIONS 9, 10, 10A, 10B, 11; REGION 5 = STATIONS 12, 13, 14, 15, 16B.

TABLE C-15. ANALYSIS OF VARIANCE OF TEMPERATURES RECORDED AT EXPOSURE PANEL STATIONS IN BARNEGAT BAY FROM JULY, 1975 THROUGH NOVEMBER, 1983.

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	104170.8	13	8013.1	500.380	0.000
Region	1725.6	4	431.4	26.939	0.000
Season	102035.6	3	34011.9	2123.870	0.000
Bioyear	416.3	6	69.4	4.333	0.000
2-Way Interactions	2782.4	54	51.5	3.218	0.000
Region/Season	149.0	12	12.4	0.775	0.677
Region/Bioyear	181.3	24	7.6	0.472	0.986
Season/Bioyear	2447.3	18	136.0	8.490	0.000
3-Way Interactions	553.6	71	7.8	0.487	1.000
Region/Season/Bioyear	553.6	71	7.8	0.487	1.000
Explained	107506.9	138	779.0	48.647	0.000
Residual	23268.5	1453	16.0		
Total	130775.4	1591	82.2		

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	121134.6	36	3364.8	542.730	0.000
Station	1921.1	19	101.1	16.309	0.000
Month	118805.5	11	10800.5	42.056	0.000
Bioyear	1154.0	6	192.3	31.023	0.000
				11.681	0.000
				2.812	0.001
				1.724	0.016
				30.846	0.000
				1.769	0.000
Explained	124470.6	161	773.1	768.691	0.000
Residual	6304.8	1430	4.409		

than the remaining years. These were both artifacts due to the exclusion of summer and fall data from 75/76 and lack of data from winter and spring of 1984. Complete bioyears (76/77 through 82/83) indicated no significant differences and no suggestion of either a warming or cooling trend over the course of the program.

Salinity

The minimum salinities at which Teredo navalis will grow and reproduce have been reported as 5-10 °/oo (Turner, 1973; Richards et al., 1978), 10-14 °/oo for Bankia gouldi (Allen, 1924; Turner, 1973) and 7-10 °/oo for T. bartschi (Hoagland et al., 1980). During the period December, 1982, through November, 1983, salinities were generally only sporadically recorded below 10 °/oo. At Station 13 in March, salinities were 5.8 and 5.0 °/oo respectively (Tables C-4 and C-5) on the days when readings were taken. If the salinity had been that low consistently throughout those months, it might have had some deleterious effect on the borers. Salinities are generally lower at Station 13 than at most of the other stations anyway.

Other incidences of salinities below 10 °/oo during the present reporting period included values of 6.0 at Station 6 and 9.9 at Station 9 in April (Table C-5); 2.0 at Station 8, 4.9 at Station 7 and 9.7 at Station 16B in June (Table C-7). Mean salinities (Table C-13) were somewhat lower this year than last, particularly through the spring and summer.

Average salinities at each exposure panel station, calculated for the bioyear from July 1982 through June, 1983 are shown in Figure C-4. Stations were grouped into regions, and the average salinity of each region for this bioyear is plotted in Figure C-5.

The results of the ANOVA for salinity are shown in Table C-16. As reported previously (Hillman et al., 1983) all three main effects of station, month, and bioyear were statistically significant. The bioyear effect was strongest, based on relative mean square values. Both the region/season and season/bioyear interactions were significant, with the season/bioyear interaction being most important. The three-way interaction was also highly significant.

Multiple comparison procedures were carried out on the salinity data in a manner analogous to that described previously for temperature. The SNK multiple range procedure identified seven significantly different groups of stations:

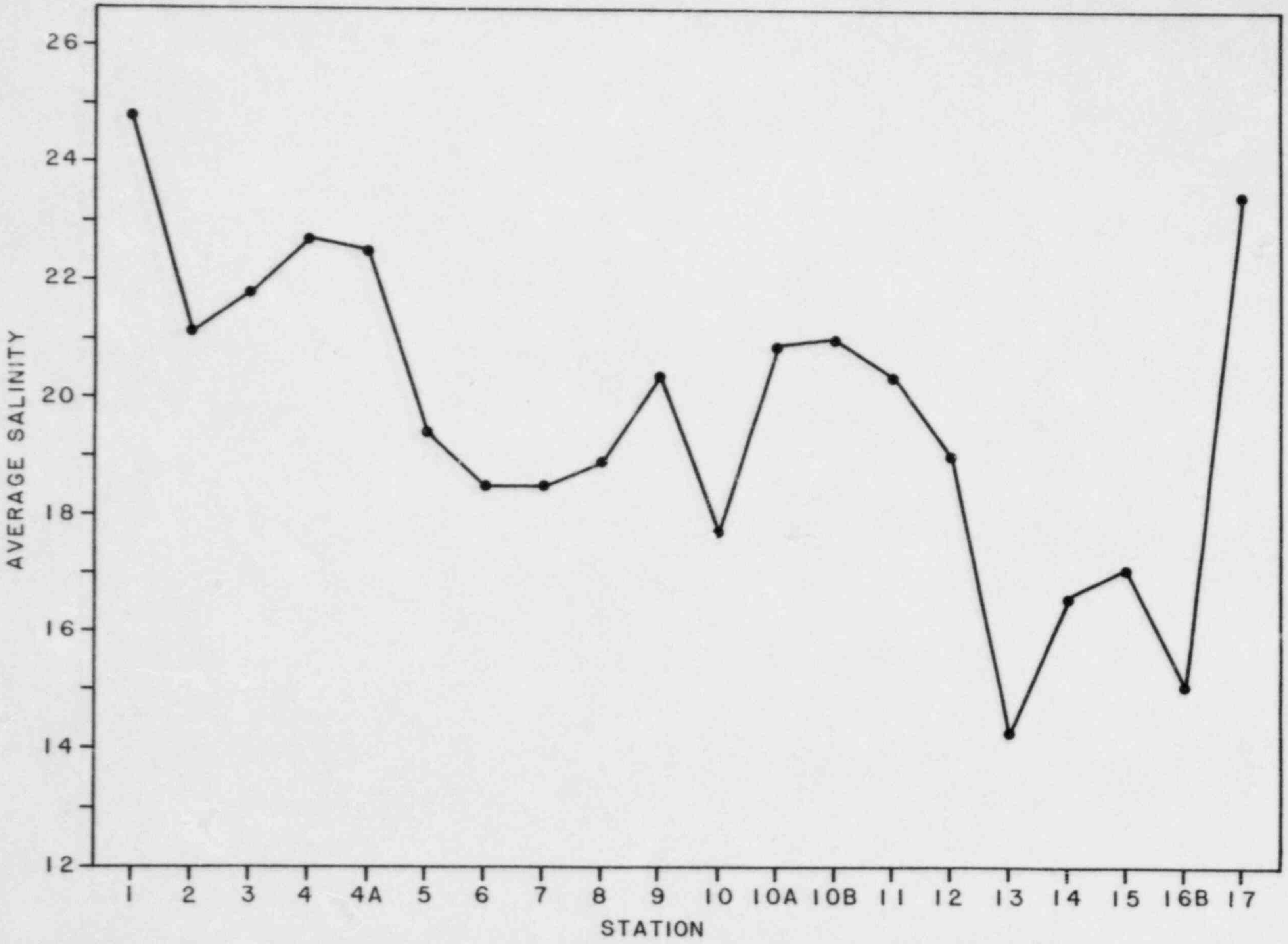

FIGURE C-4. AVERAGE SALINITY AT EACH EXPOSURE PANEL STATION CALCULATED FOR THE BIOLOGICAL YEAR JULY, 1982 THROUGH JUNE, 1983. NUMBER OF OBSERVATIONS IS 12.

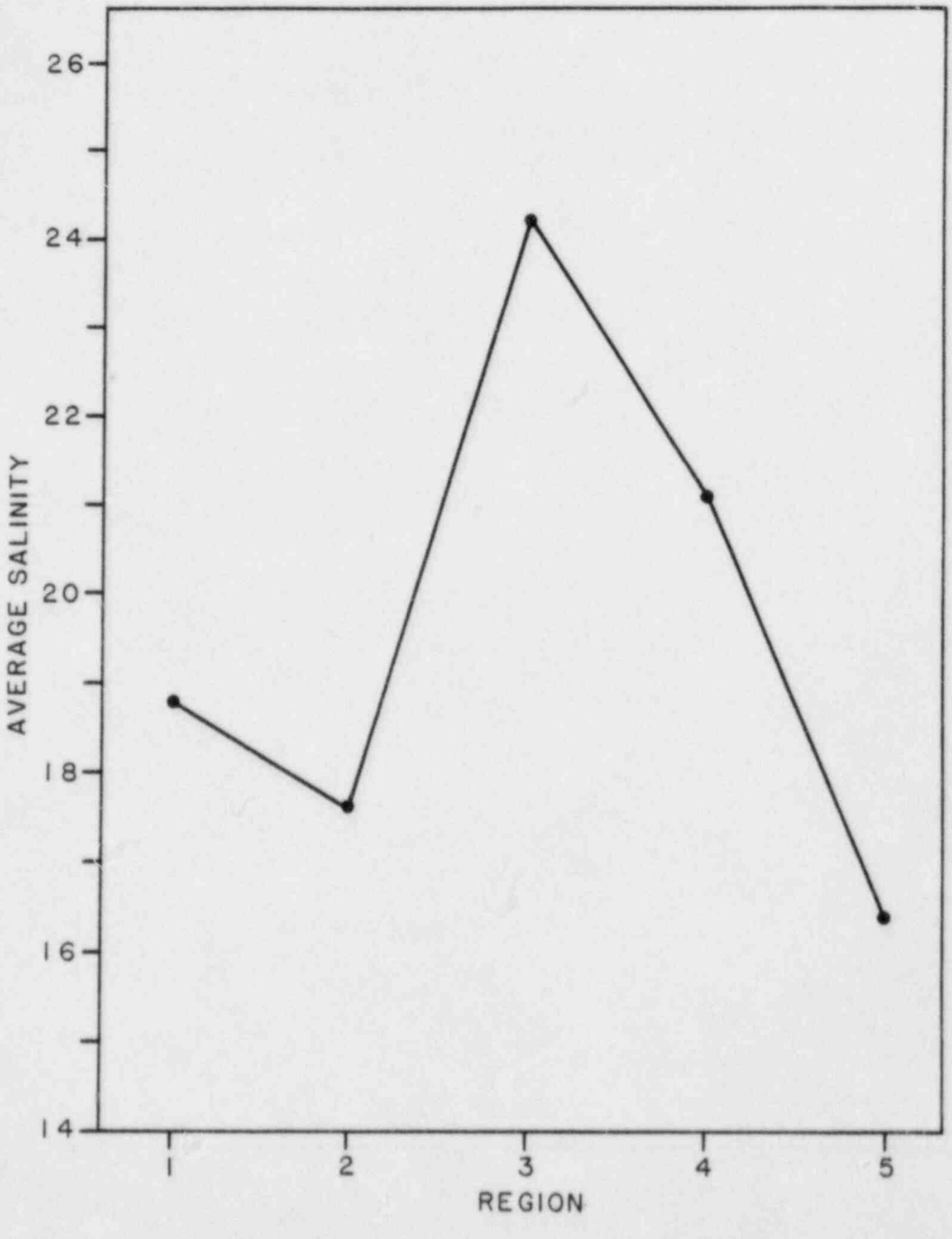

FIGURE C-5. AVERAGE SALINITY FOR STATIONS GROUPED INTO REGIONS FOR BIOLOGICAL YEAR JULY, 1982 THROUGH JUNE, 1983.

REGION 1 = STATIONS 5, 6, 7, 8; REGION 2 = STATIONS 2, 3, 4, 4A; REGION 3 = STATIONS 1, 17; REGION 4 = STATIONS 9, 10, 10A, 10B, 11; REGION 5 = STATIONS 12, 13, 14, 15, 16B.

TABLE C-16. ANALYSIS OF VARIANCE OF SALINITIES RECORDED AT EXPOSURE PANEL STATIONS IN BARNEGAT BAY FROM JULY, 1975 THROUGH NOVEMBER, 1983.

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	23322.4	13	1794.0	121.355	0.000
Region	10048.1	4	2512.0	169.922	0.000
Season	6122.9	3	2041.0	138.058	0.000
Bioyear	6984.9	6	1164.1	78.748	0.000
2-Way Interactions	8984.0	54	166.4	11.254	0.000
Region/Season	257.5	12	21.5	1.452	0.136
Region/Bioyear	338.7	24	14.1	0.955	0.526
Season/Bioyear	8359.1	18	464.4	31.413	0.000
3-Way Interactions	1235.6	71	17.4	1.177	0.153
Region/Season/Bioyear	1235.6	71	17.4	1.177	0.153
Explained	33542.1	138	243.1	16.441	0.000
Residual	21391.6	1447	14.8		
Total	54933.7	1585	34.7		

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	28043.9	36	779.0	44.874	0.000
Station	12886.2	19	678.2	39.069	0.000
Month	7953.6	11	723.1	41.652	0.000
Bioyear	6995.0	6	1165.8	67.159	0.000
				5.670	0.000
				1.838	0.038
				1.204	0.227
				39.658	0.000
				1.487	0.006
Explained	38263.5	161	237.6	20.308	0.000
Residual	16670.2	1424	11.71		

16B 13 10 14 15 12 5 7 6 8 10A 11 9 10B 2 3 4A 4 17 1

These results are similar to those reported last year and are related to the position of the stations within the Bay. The five stations grouped at the right have lower salinities and are located in the northern portion of Barnegat Bay where there is more freshwater input. Station 1, located at Barnegat Inlet, had significantly higher salinities than all other stations.

The multiple comparison of salinities by month produced the following pattern of significance:

FEB JAN MAR DEC JUL AUG NOV OCT SEP

This pattern agrees with that presented in previous reports and is believed to result from increased precipitation and freshwater runoff in the winter months leading to generally lowered salinities in the Bay.

Analysis of salinity data grouped by bioyear indicated no discernable trend over the course of this program:

75/76 78/79 79/80 83/84 82/83 77/78 76/77 80/81 81/82

pH

The results of the factorial analysis of variance for pH data are given in Table C-17. All main effects were very highly significant with bioyear being the first-order effect. As we have noted in previous reports (Maciolek-Blake et al., 1982; Hillman et al., 1983) even though these data are clearly indicative of statistically significant differences in pH both in space and time, we do not believe that the range of pH values occurring in the bay is biologically significant for teredinids.

The one-way analysis of variance indicated no significant differences among stations when the effects of month and bioyear were not accounted for and, subsequently, the Student-Newman-Keuls test indicated no significantly different groups of stations for

TABLE C-17. ANALYSIS OF VARIANCE OF pH RECORDED AT EXPOSURE PANEL STATIONS IN BARNEGAT BAY FROM JULY, 1975 THROUGH NOVEMBER, 1983.

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F	Source of Variation	Sum of Squares	DF	Mean Sqaure	F	Significance of F
Main Effects	78.500	13	6.038	30.626	0.000	**Main Effects**	113.544	36	3.154	15.053	0.000
Region	5.086	4	1.272	6.449	0.000	Station	16.266	19	0.856	4.086	0.000
Season	12.413	3	4.138	20.986	[illegible]	Month	36.214	11	3.292	15.712	0.000
Bioyear	58.497	6	9.750	49.447	[illegible]	Bioyear	58.493	6	9.749	46.528	0.000
2-Way Interactions	57.733	54	1.069	5.422	0.000					6.109	0.000
Region/Season	2.830	12	0.236	1.196	0.280					1.349	0.184
Region/Bioyear	7.178	24	0.299	1.517	0.052					1.709	0.018
Season/Bioyear	48.329	18	2.685	13.617	0.000					15.343	0.000
3-Way Interactions	14.888	67	0.222	1.127	0.229					1.269	0.129
Region/Season/Bioyear	14.888	67	0.222	1.127	0.229						
Explained	151.122	134	1.128	5.720	0.000	**Explained**	186.165	157	1.186	6.777	0.000
Residual	271.897	1379	0.197			**Residual**	236.853	1356	0.175		
Total	423.018	1513	0.280								

this parameter. Analysis of these data by month indicated a pattern described in earlier reports (Hillman et al., 1983):

JAN FEB SEP DEC OCT NOV MAR AUG JUL

When the data were examined by bioyear, the resulting pattern of significance was:

80/81 75/76 81/82 83/84 76/77 79/80 77/78 82/83 78/79

No directed pattern of temporal change in the Bay is indicated by these results.

Dissolved Oxygen

The results of the factorial analysis of variance for dissolved oxygen data are shown in Table C-18. All three main effects were very highly significant with month being the most important based on the mean square values. Station, though still highly significant, was the least important main effect. This is the same pattern described in last year's report (Hillman et al., 1983).

Of the two-way interactions, both region/season and season/bioyear were significant with the latter interaction being much more important than the former. The three-way interaction was not significant.

One-way analysis of variance by station confirmed the lack of differences in dissolved oxygen concentrations among stations, indicating no significant groupings. Analysis of the dissolved oxygen data by month, however, produced the following distinct pattern of significance:

JUL SEP AUG OCT NOV DEC JAN MAR FEB

This pattern is clearly related to temperature changes in the Bay. Lowest dissolved oxygen concentrations are associated with the warmest months of the year and highest dissolved oxygen values with the coldest months.

TABLE C-18. ANALYSIS OF VARIANCE OF DISSOLVED OXYGEN RECORDED AT EXPOSURE PANEL STATIONS IN BARNEGAT BAY FROM JULY, 1975 THROUGH NOVEMBER, 1983.

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	6144.47	13	472.65	216.786	0.000
Region	85.02	4	21.26	9.749	0.000
Season	5463.47	3	1821.16	835.292	0.000
Bioyear	702.05	6	117.009	53.667	0.000
2-Way Interactions	750.08	54	13.89	6.371	0.000
Region/Season	38.87	12	3.24	1.486	0.123
Region/Bioyear	42.05	24	1.75	0.804	0.736
Season/Bioyear	660.29	18	36.68	16.825	0.000
3-Way Interactions	137.27	70	1.96	0.899	0.709
Region/Season/Bioyear	137.27	70	1.96	0.899	0.709
Explained	7031.82	137	51.33	23.542	0.000
Residual	3039.29	1394	2.18		
Total	10071.10	1531	6.58		

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	7059.94	36	196.11	97.365	0.000
Station	123.97	19	6.53	3.239	0.000
Month	6338.70	11	576.25	286.10	0.000
Bioyear	827.43	6	137.90	68.47	0.000
				8.96	0.000
				2.09	0.015
				1.13	0.301
				23.66	0.000
				1.26	0.076
				1.26	0.076
Explained	7947.29	160	49.67	32.06	
Residual	2123.81	1371	1.55		

Multiple comparisons of dissolved oxygen concentrations over the nine "bioyears" of this program indicated the following pattern:

83/84 80/81 82/83 81/82 76/77 78/79 77/78 79/80 75/76

The most recent data appear to support the observation noted last year (Hillman et al., 1983) of decreasing dissolved oxygen levels in the Bay during the course of this study. Because 83/84 data are incomplete at this point and include only data from the seasons typically associated with lower oxygen concentrations (summer and fall), the placement of the current bioyear may be an artifact.

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Battelle
New England
Marine Research Laboratory
397 Washington Street
Duxbury, Massachusetts 02332
Telephone (617) 934-5682