ANNUAL REPORT

For the Period December 1, 1983 to November 30, 1984

on

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

to

GPU Nuclear Corporation

May 15, 1985

by

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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 Jersey Central Power & Light Company, which owns the Oyster Creek Nuclear Generating Station, operated by GPU Nuclear Corporation. This report covers the period from December 1, 1983 through November 30, 1984, and includes a discussion of the pattern of distribution, abundance, and reproductive activity of woodborers observed since the beginning of the program.

During the present report 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 few 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. Both T. bartschi and T. furcifera, of concern during the earlier years of the study, remain absent from the exposure panels.

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

The total abundance of 4756 individual teredinids collected over the present report period represents a decline of 15 percent from the total collected during the previous report period. This is the fifth consecutive report period in which a decline in abundance has occurred. The largest decrease in terms of absolute numbers occurred at Station 1 (Figure 1), but the largest percentage decrease, 92 percent, occurred at Station 7. During the present period, 87 percent of all teredinids were collected at Station 1. Four stations, Stations 1, 11, 14 and 17 account for over 97 percent of all shipworms collected in long-term panels.

Distribution patterns of T. navalis have remained fairly consistent since the program began in 1975. Most T. navalis occur at Stations 1, 11, and 17, with elevated abundances also occurring at Station 2.

Abundances of B. gouldi increased during the present report period over what was reported last year, thereby reversing the pattern of significant decline over the past several years. Most B. gouldi were collected at Stations 10A, 11, 12, 13 and 14.

Analyses of abundance and distribution of teredinids in Barnegat Bay were carried out specifically with the extended plant outage in mind. During the outage, there was a significant decrease in densities of T. navalis. Whether this decrease is related to the outage is questionable, since the largest decline in T. navalis abundance was at Station 1, outside the influence of the OCNGS discharge.

Gonad development patterns of T. navalis and B. gouldi remained consistent with what has been reported previously.

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

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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 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.

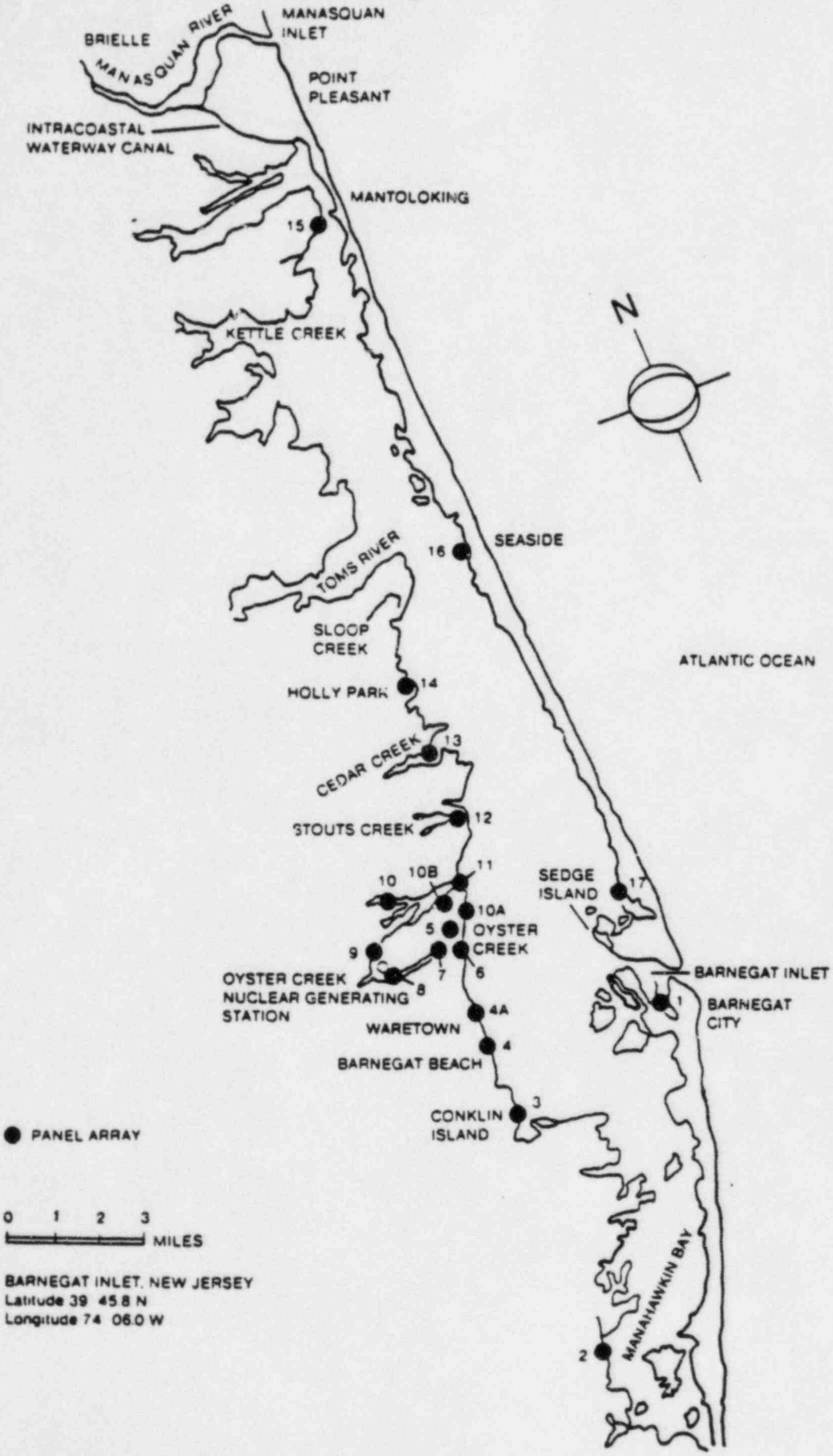

FIGURE 1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHIC LOCATIONS OF EXPOSURE PANELS

This report covers the sampling year from December 1, 1983 through November 30, 1984, 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 is summarized in Table 1. The total abundance of 4756 teredinids collected over the present reporting period represents a decline of 15 percent from the total abundance of 5601 individuals collected during the previous report period (Hillman et al., 1984). This is the fifth consecutive report period in which a decline in abundance in the long-term panels has occurred.

The largest decrease in absolute numbers occurred at Station 1, where there was a decrease of 329 individuals from the 4467 collected during the preceding year. This represented a seven percent decline. The largest percentage drop, however, occurred at Station 7, where the abundance declined from 146 individuals during the previous report period to 12 individuals over the present report period, a drop of 92 percent. Marked decreases also occurred at Stations 11 (34 percent decrease), 13 (51 percent), 14 (58 percent), and 17 (18 percent).

The effect of these declines was to leave Station 1 with 87 percent of the shipworms collected in the long-term panels, an increase of seven percent over last year, and 27 percent more than two years ago (Hillman et al., 1983). Only four stations, Stations 1, 11, 14 and 17 account for over 97 percent of all shipworms collected in long-term panels. Four stations, Stations 3, 6, 10A and 16B, produced no teredinids in long-term panels during the present report period.

The monthly abundance pattern over the present report period differed from that observed during the same period last year. The greatest abundance during the present period came in panels placed in the water monthly from June through October, 1983, and removed six months later (December, 1983 through April, 1984). Last year, most of the shipworms were collected in panels placed in the water monthly from February through May, 1983 and removed monthly from August through November. Thus, the greater abundances recorded this year are part of a cycle which began with the February, 1983 panels.

TABLE I. NUMBERS OF TEREDINIDS IN LONG-TERM (6-month) PANELS SUBMERGED JUNE, 1983 THROUGH MAY, 1984 AND REMOVED SEQUENTIALLY FROM DECEMBER, 1983 THROUGH NOVEMBER, 1984

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		400	400	600	500	680	170			240	351	297	500	4138	87.01
2			1	1								2	3	7	0.15
3														0	0.00
4				3										3	0.06
4A											1			1	0.02
5		5	2	1							1	1		10	0.21
6														0	0.00
7		7	2						1			2		12	0.25
8		10	5									2	2	19	0.40
9												2		2	0.04
10														0	0.00
10A		4	1	1							1			7	0.15
10B		1		1								5	1	8	0.17
11		47	16	9	22				9	44	26	58	31	262	5.51
12		3	1	1					1		3	5	5	19	0.40
13		18	5	2									1	26	0.55
14		90	36	3	4					1	2	2	1	139	2.92
15		7	3	1						1			3	15	0.32
16B														0	0.00
17		23	24	20	16	2						1	2	88	1.85

Teredinids were recovered from short-term (1-month) panels during December, 1983, and from July through November, 1984 (Table 2), a period identical with that reported last year. A total of 2448 teredinids were recovered from short-term panels during the present report period, only 39 fewer than during the previous period. The distribution pattern however, was different this year. There were 2432 teredinids collected at Station 1 as compared to only 2383 collected last year. The largest number collected during any one month was 1400, collected in the panel removed in November. Last year most of the larvae settled during August and September, when the usual peak settlement occurs. The remaining 16 teredinids were collected at only four stations, Stations 2, 8, 11 and 12, with 11 of the 16 being collected at Station 11. This is in sharp contrast to last year's short-term panel collections, which had 104 teredinids being collected at eight stations, in addition to Station 1 (Hillman et al., 1984), with 65 of them coming from Station 14.

Abundance and Distribution of Teredo navalis

Teredo navalis was collected at only nine of the 20 stations during the present report period, with most of them coming from Station 1. Of a total of 628 T. navalis identified from long-term panels (see Table A-20, Appendix A), and 15 from short-term panels (Table 2), 509 were collected at Station 1.

Analysis of spatial variation in T. navalis densities during the present report period produced the following grouping of stations (stations connected by an underline were not significantly different at p = 0.05):

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

Comparisons among station means for T. navalis abundance, using all available data from the entire study, the following grouping was obtained:

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

These observations are essentially identical with those reported in previous years (Maciolek-Blake et al., 1982; Hillman et al., 1983, 1984) and continue to indicate significantly elevated abundances of T. navalis near Barnegat Inlet (Stations 1 and 17) and at Stations 2 and 11.

TABLE 2. NUMBERS OF TEREDINIDS IN SHORT-TERM PANELS REMOVED MONTHLY FROM DECEMBER, 1983 THROUGH NOVEMBER, 1984*

T = Teredinidae; Tn = Teredo navalis; Ts = Teredo spp; Bg = Bankia gouldi, Bs - Bankia spp.

Site	Dec	Jul	Aug	Sep	Oct	Nov
1	60 T	2 T	15 Tn, 485 T	210 T	260 T	1400 T
2			1 T			
3						
4						
4A						
5						
6						
7						
8		1 T				
9						
10						
10A						
10B						
11		1 Bs, 6 T	3 T	1 T		
12				2 Bg, 1 T		
13						
14						
15						
16B						
17						

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

The results of analyses of T. navalis densities by bioyear indicated few significant differences:

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

These results indicate that although there has been a decline in the abundance of T. navalis over the past several years, there has been no overall statistically significant trend in T. navalis densities during the course of the program.

No unusual change in gonad development patterns from what has been reported previously was noted for the present report period (see Appendix B). Early active stages occurred in February and March, 1984, at a time when the shipworms were preparing for the spring spawning period. Spawning and setting occurred throughout the spring, summer and fall. Early and late active stages again predominate into the late fall, the result of development in shipworms that were spawned and set during mid- to late-summer.

Abundance and Distribution of Bankia gouldi

Bankia gouldi occurred in long-term panels at 13 of the 20 stations from December, 1983 through November, 1984, a decrease of two stations over the same period last year. The total of 335 B. gouldi collected in long-term panels represents a decrease of 89 individuals from what was collected during the previous report period (Table A-21, Appendix A). An individual B. gouldi was collected in September and two in October at Station 1, the first time that B. gouldi has been collected at Station 1 since November, 1976.

An analysis of spatial variation of B. gouldi densities during the present report period produced the following station grouping:

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

Comparisons among stations, using all available data, produced the following grouping:

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

This pattern is exactly the same as that presented in the previous report (Hillman et al., 1984), and is generally similar to what has been reported previously (Maciolek-Blake et al., 1982; Hillman et al., 1983).

It can be concluded that B. gouldi densities at stations in the vicinity of the OCNGS discharge (Stations 5, 6, 7 and 8) are not radically different from those at any other site. It is also apparent that Stations 10A, 11 12, 13 and 14 have significantly elevated densities.

Comparison of B. gouldi abundance across bioyears, using data from all complete bioyears (July, 1976 through June, 1984) produced the following pattern:

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

This pattern of overlapping significance is difficult to interpret, but it does appear to reverse somewhat the pattern of decreasing B. gouldi abundance discussed in last year's report (Hillman et al., 1984).

Gonadal development in B. gouldi followed a seasonal pattern similar to that reported throughout the study (e.g., Hillman et al., 1984). Early active stages were found from December through May, with those found in December and January probably in that stage from the previous fall. Spawning began in June and continued through October.

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, a distribution pattern the same as it was during the previous report period.

Attack continued high at Stations 2 and 4A although it was considerably less at Station 4A than during the previous report period. Attack continued to decline at Station 4, and also was down at Station 3.

CONCLUSIONS

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

1. Over the past five report periods, there has been a decline in the overall abundance of teredinids occurring in long-term (6-month) panels. The decline is not yet statistically significant.

2. The significant decline in the abundance of Bankia gouldi, reported in the previous report, may have leveled off during the present report period. The number of stations at which B. gouldi was collected decreased slightly over the present report period.

3. Population dynamics of Teredo navalis continue to remain relatively stable. Most T. navalis are collected at Station 1, and although the numbers of T. navalis collected there this year declined, the overall percentage of T. navalis contributed by Station 1 collections increased from 80 percent last year to 87 percent this year. This is due largely to declines in abundance at Stations 2, 11 and 17. These stations remain, however, as the principal stations at which T. navalis is collected.

4. Reproductive patterns of both Teredo navalis and Bankia gouldi have remained consistent, and apparently unaffected by the OCNGS discharge.

5. Attack by the crustacean woodborer Limnoria moderated somewhat during the present report period. Limnoria continues to be restricted in its distribution in the bay, and has not been collected from any stations in the OCNGS discharge area.

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Maciolek-Blake, N.J., R.E. Hillman, C.I. Belmore, and P.I. Feder. 1981. Study of Woodborer Populations in Relation to the Oyster Creek Generating Station. Annual Report for the period December 1, 1979 to November 30, 1980 to Jersey Central Power and Light Company. Battelle-Columbus Laboratories, William F. Clapp Laboratories, Inc., Duxbury, Massachusetts. Report No. 15040.

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, 1984) presented results of the study for each annual period. The present report discusses data collected from December 1, 1983 through November 30, 1984, 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 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

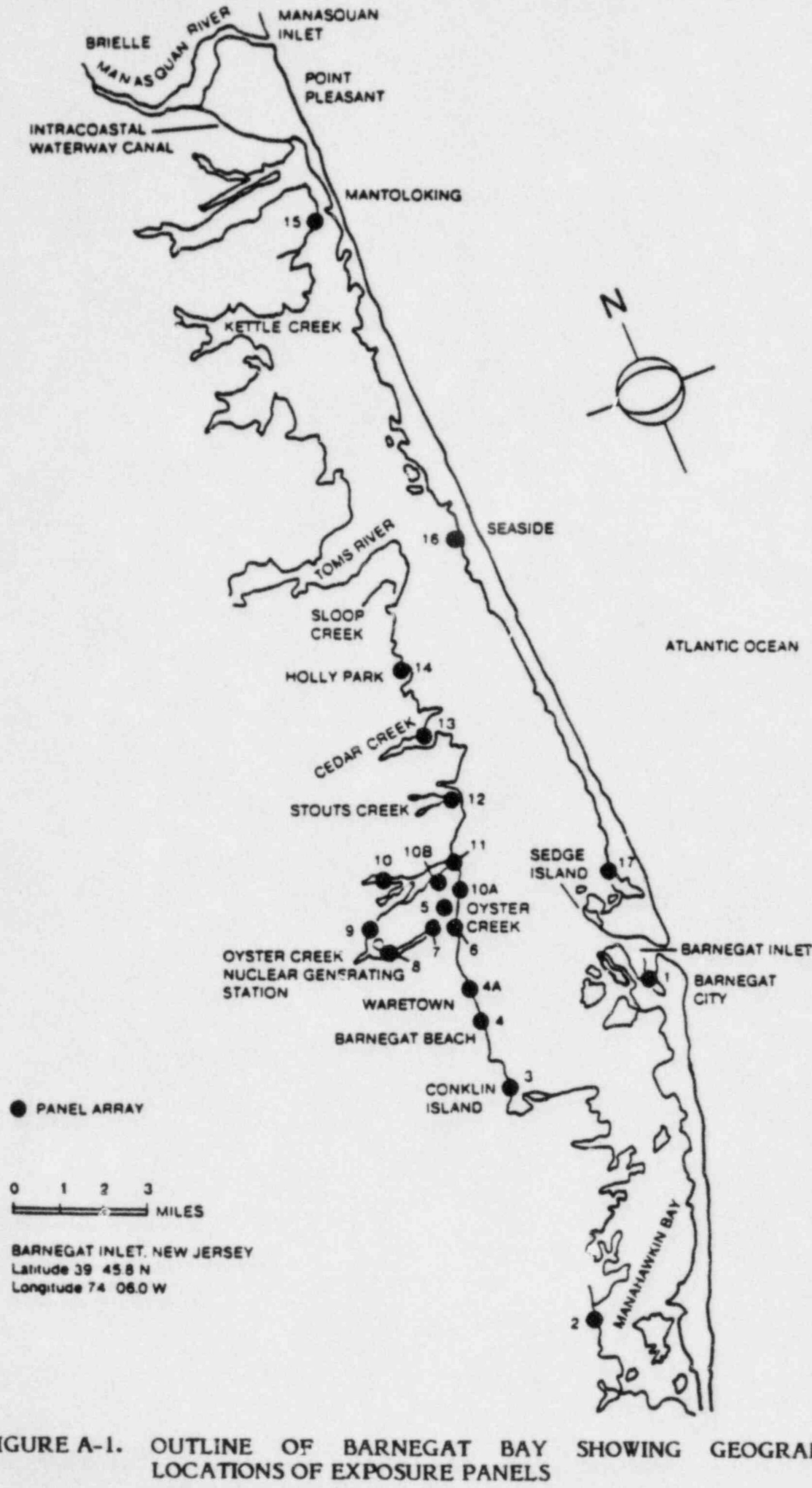

FIGURE A-1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHIC LOCATIONS OF EXPOSURE PANELS

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	WC 21 R. Turner Rutgers U.	Lat. 39° 48'N Long. 74° 11'W
5.	Mouth of Oyster Creek, Lot 4, Compass Road Offshore End	Dock	WC 29, 30 Rutgers U.	Lat. 39° 48.5'N Long. 74° 10.3'W
6.	Oyster Creek 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.

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.
Sites 8 and 9 moved from original locations November, 1983.

relocated into deeper water at the end of the same dock. Station 8 was changed to a company-owned dock about 200 feet nearer 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 those used by Battelle until March, 1982.

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

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 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

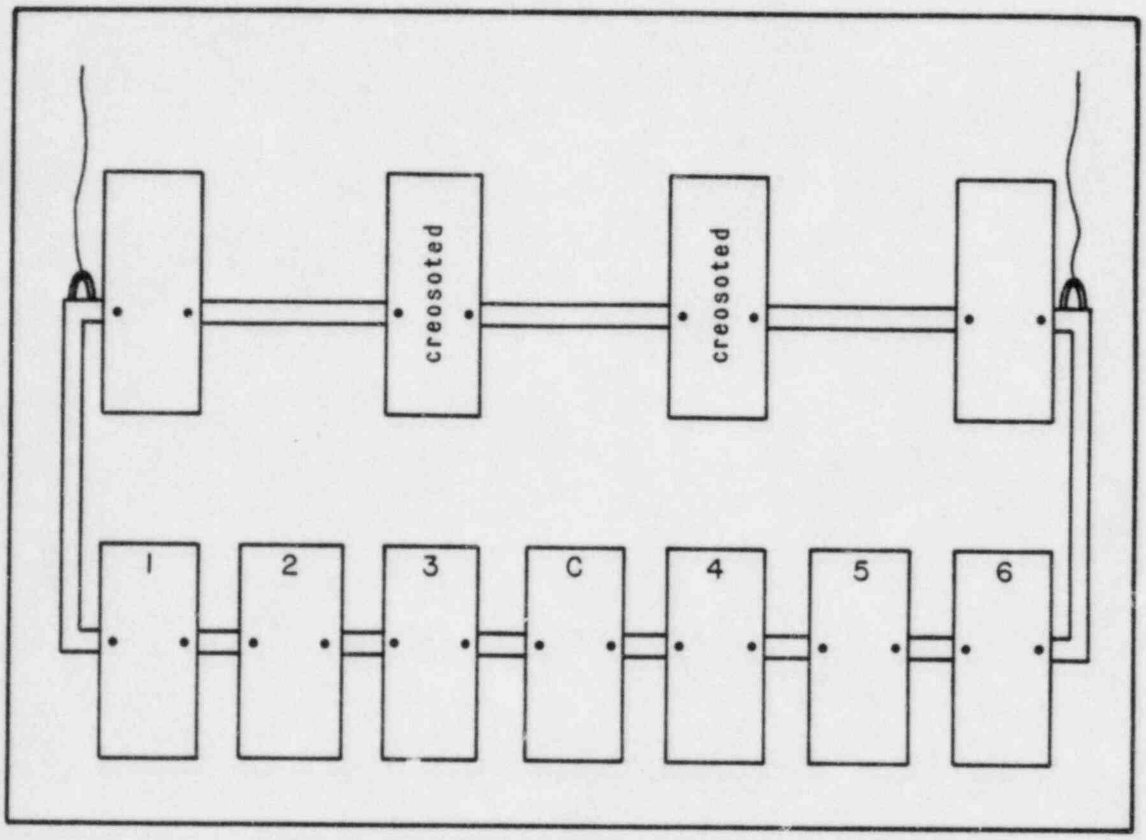

FIGURE A-2. EXPOSURE PANEL ARRAY.

TABLE A-2. RATING SCALE FOR TEREDINID AND LIMNORIA ATTACK

Teredinidae

No. of tubes per panels	Percent filled*	Attack Rating
1-5	5	Trace
6-25	5-10	Slight
26-100	11-25	Moderate
101-250	26-50	Medium heavy
251-400	51-75	Heavy
400+**	76-100	Very heavy

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

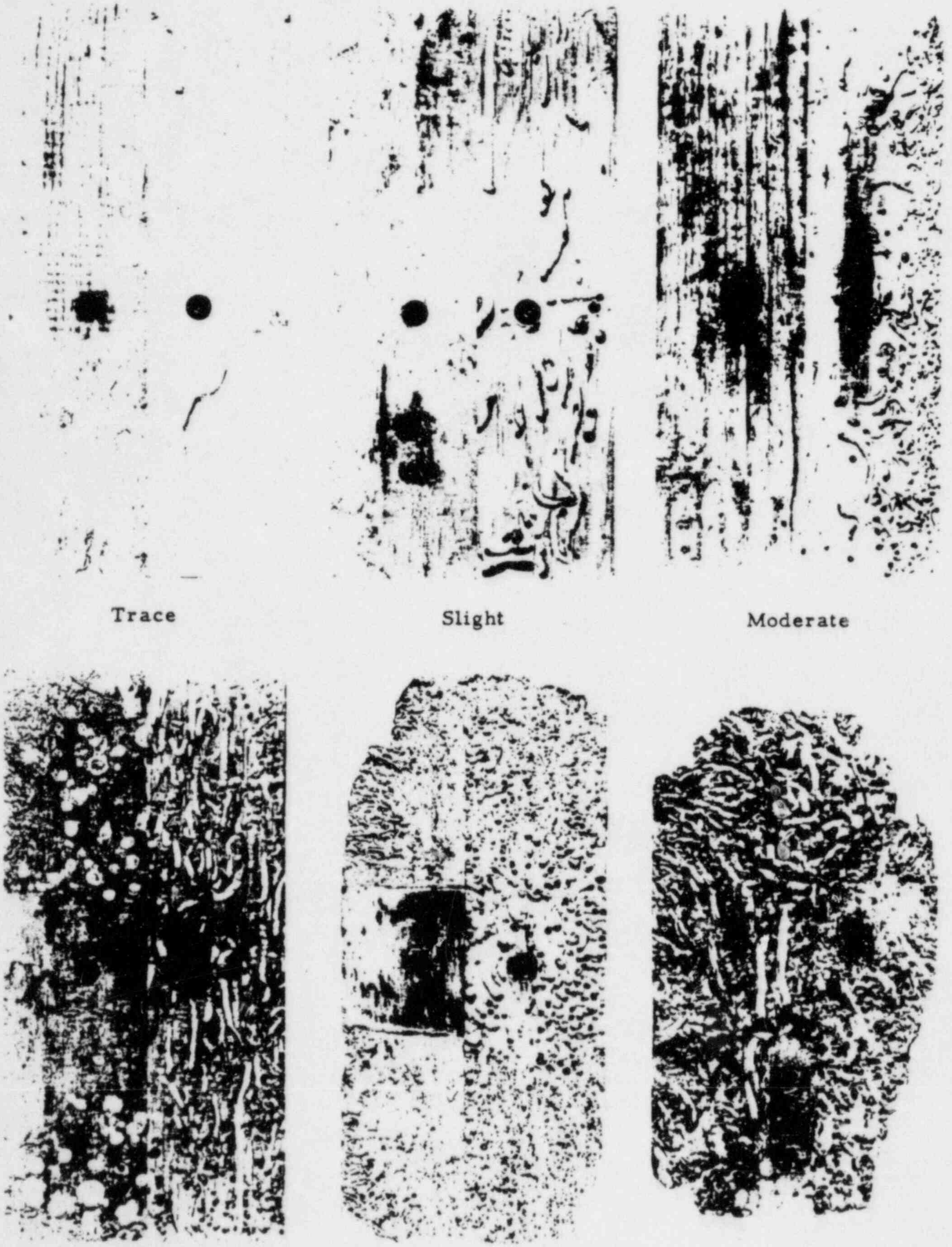

FIGURE A-3. RATING OF TEREDINID ATTACK

LIMNORIDAE

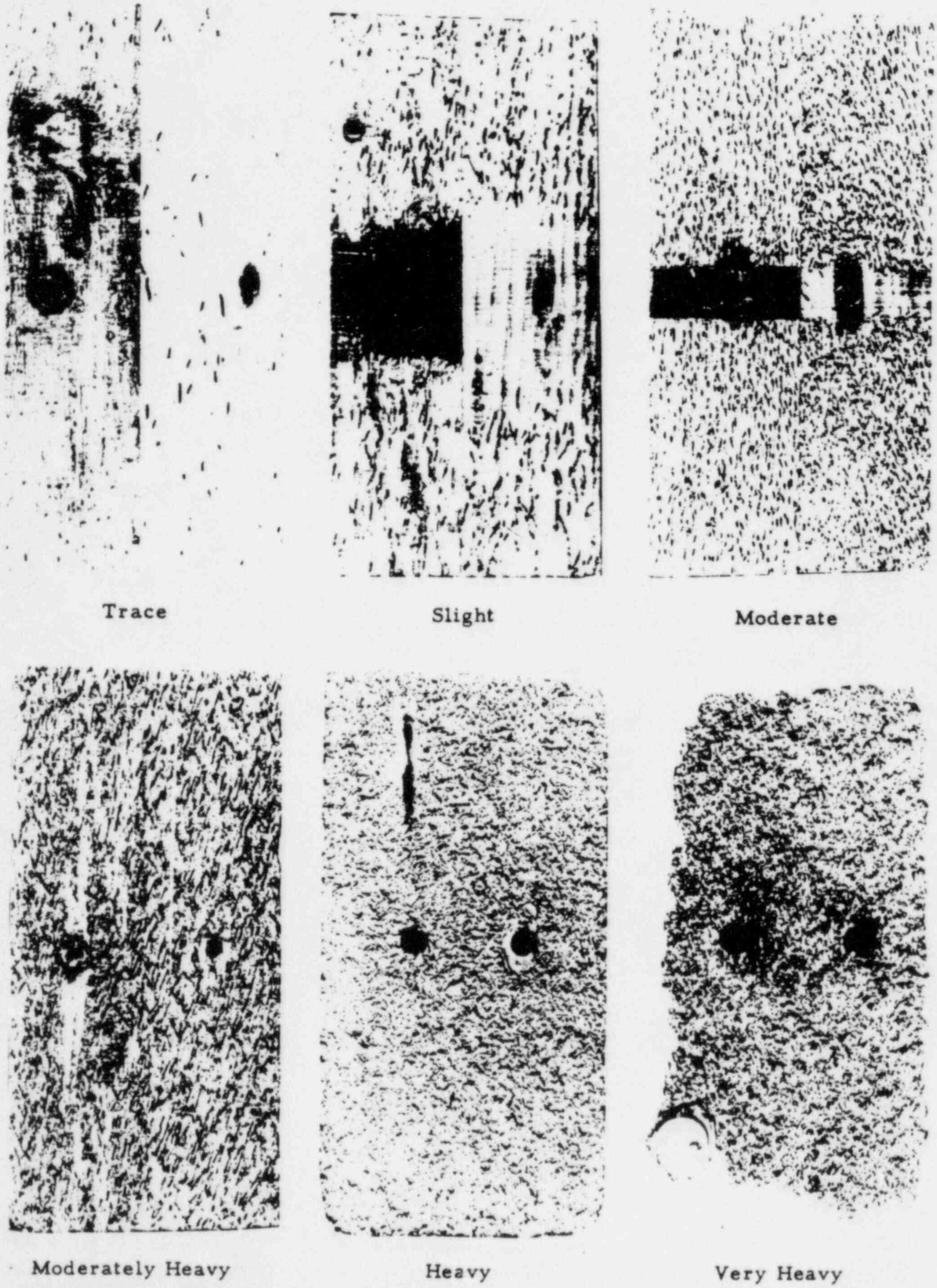

FIGURE A-4. RATING OF LIMNORID ATTACK

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, Philadelphia Academy of Sciences.

Statistical Analysis

Data reduction and analysis for this report followed procedures used for previous reports. Most analyses were conducted using the VAX 11-780 system at Woods Hole Oceanographic Institution and the SPSS-X statistical package. Changes in SPSS since the previous report required complete rewriting of all analytical programs but did not affect either the procedures or their application.

As in previous years, few organisms were found on the short-term panels and statistical analyses were carried out on data from long-term (6-month) panels only. Parameters analyzed included presence/absence and abundance of Bankia gouldi and Teredo navalis, percent destruction, and various physical parameters.

Analyses of variance were carried out on presence/absence data and $\log_e$ (abundance + 1) for B. gouldi and T. navalis. Tests were run on data collected from January, 1976 through November, 1984 and also on data from the most recent calendar year (December, 1983 through December, 1984) and the most recent complete bioyear (July, 1983 through June, 1984). Data from 1975 were excluded because of the incomplete data set collected in that year. Extremely few specimens have been recorded from long-term panels removed in April, May and June; therefore, these months have also been excluded from certain analyses. Based on our previous examination of their negligible impact on the data set (Maciolek-Blake et al., 1981) occasional long-term panels which may have been exposed for less than the full six months were included.

In previous years, the factorial ANOVA was conducted on both the original factors of month, station and biological year (i.e. "bioyear" - July to June, corresponding to the breeding season of the Teredinidae) and the summary factors of season, region, and bioyear. In order to simplify fitting the ANOVA model, 2-way and 3-way interactions were based on these summary factors. The computer resources necessary to process this ANOVA increase as the square of the product of the number of categories for each factor. Hence, as the data set increases linearly each year, the computing resources needed to process it increase exponentially.

With the addition of this year's data, the ANOVA program (SPSS, Inc., 1983) using original factors (month, station, bioyear) would require more memory than is presently available on the Woods Hole Oceanographic Institution's VAX/11-780 computer. Accordingly, we have conducted the analysis using only summary factors and are continuing to investigate alternative solutions for this problem. The summary factors are derived by grouping the months into seasons (winter = January, February, March; spring (deleted for biological variables) = 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). Both groupings are the same as those used in previous reports.

In addition to the analyses based on bioyear conducted similarly to those in previous reports, we have conducted a similar analysis to investigate the potential effect of the extended OCNGS shutdown on biological and water quality variables in the study area. This was performed in a manner analogous to that described above, but a dichotomous dummy variable representing plant operating status was used in place of bioyear. This was set to "0" (i.e. operational) for data collected prior to February, 1983 and to "1" (i.e. non-operational) for data collected since that time. Although we recognize that this crude division does not accurately represent the complex variation in plant load and capacity factor prior to the outage, it should be sufficient to indicate any gross changes in the area due to the recent extended outage. All ANOVAS were carried out using the ANOVA procedure of the SPSS-X statistical package (SPSS, Inc., 1983).

Multiple classification analyses (MCA) were used to quantify the systematic variation detected by the analysis of variance procedures. 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 $X_1, X_2, \ldots X_k$ be k sample means based on $N_1, N_2, \ldots N_k$ observations respectively. Let $M_1, M_2, \ldots M_k$ be the corresponding population means. These sample averages might originate as the average values in k levels of a factor unde. .tudy.

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

H_0 will be rejected at significance level α if

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

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

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

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, ... X_k denote the sample averages in groups 1, 2, ... k based on n_1, n_2, ... n_k observations respectively. Let μ_1, μ_2, ..., μ_k, be the corresponding population means. Let s^2 denote the error mean square from an analysis of variance, based on ν d.f. The SNK procedure assumes n_1, = n_2 ... = 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 α.

Let $X_{i(1)} \leq X_{i(2)} \leq X_{i(3)} \leq \cdots \leq X_{i(k)}$ 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- α; ν, r) denote the upper α point of Tukey's studentized range statistic with ν degress of freedom and based on r groups.

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

then all the means μ_i, μ_2, ..., $_k$ are declared to be equal.

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

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

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

then compare

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

and compare

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

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

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

At the conclusion of this process, the means μ_i, μ_j are declared significantly different at level α 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) = $\log_e \frac{p}{p-1}$. This transformation converts the (0,1) scale into a ($-\infty$, $+\infty$) 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:

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

where β = the unknown regression coefficient
and E = error or unexplained variability.

This regression analysis was carried out using the Regression procedure of SPSS-X. Analysis of variance was carried out on residuals of the regression fit.

Results and Discussion

Modifi~~ to Panel Exposure

During the present report period, there were some deviations from the routine protocol. These are reported below. None was considered serious enough to affect the overall data base.

In February, the dock from which the panel rack was suspended at Station 17 collapsed from borer attack. The rack was moved to a dock approximately 50 feet south of the previous location.

Because of severe borer attack at Station 17, the long-term panel which was to have been removed in February, 1984 had to be removed in December, 1983. The results of the inspection of that panel are included in this report.

Due to bad weather, the field trip to remove panels in March had to be rescheduled from the second week to the third week.

During the June 12 panel exchange, the creosoted panel at Station 17 was inadvertantly removed and sent to the laboratory in Duxbury. The panel was returned to GPU Nuclear and reinstalled at Station 17 on July 10.

On September 10, during the panel exchange trip, the rack at Station 8 was found to have been pulled out of the water. It was resubmerged at that time. At Station 3 during the same trip, one creosoted panel was found missing. It was replaced.

The creosoted panel at Station 11 was removed for examination on November 11, and then replaced.

Species Identified

For the second consecutive report period, only two species of molluscan woodborers, the teredinids Teredo navalis and Bankia gouldi, were identified from short-term and 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 now retrieved nearer the middle of each month, the results reflect activity during the end of the previous month and the beginning of the month in which the panels were removed.

The species and number of teredinids found in short-term panels during the present report period are shown in Table A-3.

Settlement was occurring at least as late as late-November and possibly into early December, 1983, at Station 1. Although the teredinids were too small to identify to species, they were probably T. navalis.

The first settlement of the bioyear on short-term panels was on the panels retrieved in July from Stations 1, 8, and 11. Setting persisted at Station 1 through the November retrieval period, and at Station 11 through the September panel retrieval. Very light settlement also occurred in August at Station 2 and in September at Station 12.

The data shown in Table A-3 represent slight change from the short-term panel data of the previous report (Hillman et al., 1984). During that report period, settlement on short-term panels occurred at nine stations: 1, 2, 8, 11, 12, 13, 14, 15 and 17. In the present report period it was limited to five stations: 1, 2, 8, 11 and 12. Over 95 percent of the settlement occurred at Station 1 both years.

No settlement occurred for the third consecutive year at Station 7, a site where considerable settlement usually occurred during the summer months.

TABLE A-3. NUMBERS OF TEREDINIDS IN SHORT-TERM PANELS REMOVED MONTHLY FROM DECEMBER, 1983 THROUGH NOVEMBER, 1984*

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

Site	Dec	Jul	Aug	Sep	Oct	Nov
1	60 T	2 T	15 Tn, 485 T	210 T	260 T	1400 T
2			1 T			
3						
4						
4A						
5						
6						
7						
8		1 T				
9						
10						
10A						
10B						
11		1 Bs, 6 T	3 T	1 T		
12				2 Bg, 1 T		
13						
14						
15						
16B						
17						

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

The amount of destruction to short-term panels (Table A-4) again remained at less than 1 percent except at Station 1, where it was 2 percent during August and September. This is less than the 5 percent recorded during the previous report period (Hillman et al., 1984), and far less than the 15 and 75 percent for the two previous years respectively (Hillman et al., 1983; Maciolek-Blake et al., 1982).

A comparison of the total number of teredinids settling on short-term panels each year from 1975 through November, 1984 is shown in Table A-5. Total set during the present report period was close to what it was during the previous report period, but 99 percent of that set occurred at Station 1.

Destruction. The average percent destruction of short-term panels for each year from July, 1975 through November, 1984 is shown in Table A-6. Destruction was generally very light at the five sites where there was borer settlement on short-term panels. At Station 1, destruction was only 1.4 percent, and that was more than twice the destruction at Station 11, the next nearest station in terms of attack in short-term panels.

Identifications. Individuals are only infrequently identified to species from short-term panels because their size is usually less than 10 mm, and specific taxonomic features are not fully distinguishable. During this report period, Teredo navalis was identified only at Station 1 in August, and Bankia gouldi was identified at Station 12 in September (Table A-3). The remaining identifications were either at the generic or family level.

Over 2000 short-term panels have been examined since the beginning of this program in 1975. Table A-7 presents summaries for family, genus, and species identifications made from these collections. Teredo furcifera, not collected since March, 1977, has been excluded.

The number of Teredo navalis identified during this report period (500) was up considerably from last year's 40, but the overall number of Teredinidae reported through November, 1984 (2,388), was only down slightly from last year. For all practical purposes, the total settlement of teredinids on short-term panels during this report period was about what it was last year.

The pattern of occurrence of teredinids on short-term panels during the present report period was, again, generally similar to what it has been in previous years. Most of the settlement has come at Station 1 (Region 3), an area not affected by the zone of thermal influence. Much of that settlement probably comes from spawning individuals located outside of Barnegat Bay proper.

TABLE A-4. PERCENT DESTRUCTION OF SHORT-TERM PANELS REMOVED MONTHLY FROM DECEMBER, 1983 THROUGH NOVEMBER, 1984*

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

* Teredinids were not present in short-term panels removed from January through June, 1984.

TABLE A-5. TOTAL AMOUNT OF TEREDINID SETTLEMENT IN SHORT-TERM PANELS FROM JULY, 1975 THROUGH NOVEMBER, 1984

Site	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
1	8199	1090	654	1015	535	88	1396	1425	2353	2372
2	17	2		1	8				1	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	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	11
12	34	1	5	1	13	4	1		2	3
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	1483	2457	2388

* No panels examined in October and November.

TABLE A-6. MEAN PERCENT DESTRUCTION OF SHORT-TERM PANELS REMOVED DURING THE JULY THROUGH NOVEMBER PERIOD, 1975 THROUGH 1984*

Site	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
1	13.0	3.6	2.8	1.6	4.4	0.8	16.0	3.4	2.4	1.4
2	1.0	0.4		0.2	0.6				0.2	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	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	0.6
12	2.0	0.2	0.4	0.2	1.6	0.4	0.2		0.4	0.2
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 1984 Times

Year	No.	Season	No.	Region	No.
1975	0	Winter		1	0
1976	2	Spring	0	2	2
1977	1	Summer	1984	3	1976
1978	1	Fall	0	4	6
1979	10			5	0
1980	0				
1981	1369				
1982	61				
1983	40				
1984	500				

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				
1984	0				

All Teredo*: Identified a Total of 2053 Times

Year	No.	Season	No.	Region	No.
1975	7	Winter	0	1	41
1976	6	Spring	0	2	7
1977	4	Summer	2047	3	1995
1978	7	Fall	6	4	9
1979	21			5	1
1980	2				
1981	1391				
1982	74				
1983	41				
1984	500				

TABLE A-7. (continued)

	Year	No.	Season	No.	Region	No.
All Bankia**: Identified a Total of 87 Times						
	1975	17	Winter	0	1	13
	1976	6	Spring	0	2	5
	1977	8	Summer	87	3	3
	1978	4	Fall	0	4	30
	1979	13			5	36
	1980	9				
	1981	16				
	1982	3				
	1983	1				
	1984	10				
Teredinidae***: Identified a Total of 8248 Times						
	1975	47	Winter	1	1	374
	1976	21	Spring	0	2	23
	1977	26	Summer	6025	3	7614
	1978	23	Fall	2222	4	90
	1979	52			5	147
	1980	22				
	1981	1729				
	1982	1393				
	1983	2547				
	1984	2388				

* 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

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, 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, 1983) through A-19 (November, 1984).

Panels submerged in June, 1983 and retrieved in December, 1983 (Table A-8) contained specimens ranging from less than 1 mm up to 460 mm. The 460 mm specimen of Bankia gouldi was collected at Station 10A. Other B. gouldi up to 410 mm were collected at Station 5, and up to 400 mm at Station 12. These are larger than any teredinides collected in the past several years. As in previous years, the size ranges of specimens collected during January and February (Tables A-9 and A-10) declined somewhat from those found in December, but were larger overall for the December through February period than during the previous report period. The smallest individuals, those of less than 1 mm probably set in late October or November and ceased growing as the water cooled.

Teredinids were collected in March (Table A-11) from Stations 1, 11, 14 and 17. They ranged in size from less than 1 mm to 44 mm at Station 1, considerably larger than those collected in March, 1983 (Hillman et al., 1984). Of the 500 specimens collected at Station 1, 130 were large enough to be identified as T. navalis. The largest specimen at any of the other three stations was 12 mm at Station 11, whereas the smallest were less than 1 mm.

Of the panels removed in April, only those from Stations 1 and 17 contained teredinids (Table A-12), all of which were in a range from less than 1 mm to 2 mm. Again, almost all of them were at Station 1, and probably represented the late fall set.

In May (Table A-13), only Station 1 produced panels with teredinids in them, and they were all less than 1 mm in length. They were probably the last of the late fall larvas spawned. If they had been from a very early spring spawning, there would probably have been some juveniles on panels removed in June, but none were collected from either short-term (Table A-3) or long-Term (Table A-14) panels.

As expected, the July long-term panels (Table A-15) contained young teredinids ranging in length from less than 1 mm at the three stations (7, 11 and 12) where they occurred, up to 5 mm at Station 7. These specimens would probably have come from a late May to early June spawning.

TABLE A-8. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED DECEMBER 5-6, 1983.

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	P	400+	99		400 Teredinidae*	Only section 2"x4" received. Tubes broken. None alive.
	C	60	<1	<1	60 Teredinidae*	
5	P	5	35	180-410	5 B. gouldi	
	C	0				
7	P	7	18	<1-250	6 B. gouldi, 1 Teredinidae*	
	C	0				
8	P	10	60	<1-335	9 B. gouldi, 1 Teredinidae*	1 B. gouldi dead
	C	0				
10A	P	4	25	<2-460	3 B. gouldi, 1 Teredo spp.*	
	C	0				
10B	P	1	4	260	1 B. gouldi	
	C	0				
11	P	47	98	40-160	47 B. gouldi	
	C	0				
12	P	3	12	15-400	3 B. gouldi	1 dead
	C	0				
13	P	18	90	95-230	18 B. gouldi	3 dead
	C	0				
14	P	90	90	<1-170	40 B. gouldi, 2 T. navalis, 48 Teredinidae*	
	C	0				
15	P	7	8	<1-250	1 B. gouldi, 3 T. navalis, 3 Teredinidae*	
	C	0				
17	P	23	15	<1-160	15 T. navalis; 8 Teredinidae*	1 dead
	C	0				

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

P = Long-term panel submerged June 6-7, 1983.
C = Short-term panel submerged November 7-8, 1983.
* = Not speciated due to size or condition.

TABLE A-9. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED JANUARY 9-10, 1984

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	P*	400±	99		4 T. navalis, 396± Teredinidae**	Wood crumbling, None alive
	C	0				
2	P	1	2	160	1 T. navalis	
	C	0				
5	P	2	<1	<1-1	2 Teredinidae**	
	C	0				
7	P	2	4	<1-220	1 B. gouldi, 1 Teredinidae**	
	C	0				
8	P	5	15	65-200	5 B. gouldi	
	C	0				
10A	P	1	<1	1	1 Teredinidae**	
	C	0				
11	P	16	50	11-260	13 B. gouldi, 3 T. navalis	
	C	0				
12	P	1	4	230	1 B. gouldi	
	C	0				
13	P	5	20	180-200	5 B. gouldi	
	C	0				
14	P	36	85	90-240	36 B. gouldi	
	C	0				
15	P	3	8	140-230	3 T. navalis	
	C	0				
17	P	24	10	7-110	24 T. navalis	
	C	0				

Stations 3-4A, 6, 9, 10, 10B, and 16B - No Teredinidae present.

P = Long-term panel submerged July 5-6, 1983.
C = Short-term panel submerged December 5-6, 1983.
* = Long-term panel removed November 7, 1983 due to severity of attack.
** = Not speciated due to size or condition.

TABLE A-10. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED FEBRUARY 13-14, 1984

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	P*	600+	99		600+ Teredinidae**	Only 15% of panel received. None live.
	C	0				
2	P	1	<2	113	1 T. navalis	
	C	0				
4	P	3	<1	<1	3 Teredinidae**	
	C	0				
5	P	1	<1	32	1 B. gouldi	
	C	0				
10A	P	1	2	145	1 T. navalis	
	C	0				
10B	P	1	2	135	1 B. gouldi,	
	C	0				
11	P	9	5	2-165	5 B. gouldi, 2 T. navalis 2 Teredinidae**	
	C	0				
12	P	1	1	85	1 T. navalis	
	C	0				
13	P	2	<1	<1-6	2 Teredinidae**	
	C	0				
14	P	3	1	<1-100	2 B. gouldi, 1 Teredinidae**	
	C	0				
15	P	1	<1	<1	1 Teredinidae**	
	C	0				
17	P	20	2	<1-85	12 T. navalis, 1 Teredo spp., 7 Teredinidae**	
	C	0				

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

P = Long-term panel submerged August 1-2, 1983.
C = Short-term panel submerged January 9-10, 1984.
* = Long-term panel removed November 7, 1983 due to severity of attack.
** = Not speciated due to size or condition.

TABLE A-11. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED MARCH 19-20, 1984

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification
1	P	500±	10	<1-44	130 T. navalis, 370 Teredinidae*
	C	0			
11	P	22	<1	<1-12	5 Teredo spp., 17 Teredinidae*
	C	0			
14	P	4	<1	1-5	1 Bankia spp., 3 Teredinidae*
	C	0			
17	P	16	<1	<1-6	2 Teredo spp., 14 Teredinidae*
	C	0			

Stations 2-10B, 12, 13, 15, 16B - No Teredinidae present.

P = Long-term panel submerged September 6-7, 1983.
C = Short-term panel submerged February 13-14, 1984.
* = Not speciated due to size or condition.

TABLE A-12. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED APRIL 16-17, 1984

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification
1	P	680	1	<1-2	680 Teredinidae*
	C	0			
17	P	2	<1	1	2 Teredinidae*
	C	0			

Stations 2-16B, - No Teredinidae present.

P = Long-term panel submerged October 4-5, 1983.
C = Short-term panel submerged March 19-20, 1984.
* = Not speciated due to size.

TABLE A-13. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED MAY 14-15, 1984

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification
1	P	170	<1	<1	170 Teredinidae*
	C	0			

Stations 2-17, - No Teredinidae present.

P = Long-term panel submerged November 7-8, 1983.
C = Short-term panel submerged April 16-17, 1984.
* = Not speciated due to size.

TABLE A-14. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED JUNE 11-12, 1984

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

TABLE A-15. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED JULY 9-10, 1984

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification
1	P	0			
	C	2	<1	1-2	2 Teredinidae*
7	P	1	<1	5	1 Bankia spp.
	C	0			
8	P	9			
	C	1	<1	<1	1 Teredinidae*
11	P	9	<1	1-3	2 Bankia spp., 7 Terediniade*
	C	7	<1	1-3	1 Bankia spp., 6 Teredinidae*
12	P	1	<1	<1	1 Teredinidae*
	C	0			

Stations 2-6, 9-10B, 13-17 - No Teredinidae present.

P = Long-term panel submerged January 9-10, 1984.
C = Short-term panel submerged June 11-12, 1984.
* = Not speciated due to size.

The numbers of shipworms collected as well as their size range increased substantially by August (Table A-16), similar to what has been reported in previous years (e.g., Hillman et al., 1983, 1984). At Station 1, specimens ranged from less than 1 mm to 65 mm. These were primarily T. navalis. One specimen of B. gouldi was found at Station 14, but it was already 130 mm in length. At Station 11, the shipworms ranged from 19 mm to 120 mm. The numbers and sizes of teredinids on the June and July panels compared to those on the August panels indicates that spawning can occur as early as May, and possibly in late April, and growth of the young teredinids is rapid.

Teredinids were collected on long-term panels in September from Stations 1, 4A, 5, 10A, 11, 12 and 14 (Table A-17), but only at Station 1 was there any substantial abundance of shipworms (351). They ranged in size from 4 mm to 110 mm. At Station 11, which was second to Station 1 in abundance with 26 shipworms, sizes ranged from 14 mm up to 205 mm.

The number of stations at which teredinids were collected in long-term panels increased sharply in October (Table A-18), but the overall number of teredinids collected was not substantially greater. Teredinids were collected from 11 of the 20 stations in October, but, again, Stations 1 and 11 were responsible for 94 percent of them. Only two specimens, both T. navalis, were collected from Station 2, but they were 172 and 240 mm in length, which is large for T. navalis. The largest B. gouldi collected in October was 272 mm at Station 12. The size range at Station 11 was 10 to 250 mm and, although there were only 58 teredinids collected at that station (40 of them being B. gouldi) the size was enough to result in 97 percent of the panel being filled. By contrast, there were 297 individuals (mostly juvenile Teredinidae) at Station 1, ranging in size from 1 to 60 mm, and the panel there was also 97 percent filled. Little attack occurred at the other 9 stations.

The incidence of teredinids in panels recovered in November (Table A-19) was not much different from that recorded for October. Little evidence of growth was seen, with the largest individual (265 mm) being the only B. gouldi collected at Station 13. The panel at Station 1, where over 91 percent of all the teredinids collected from long-term panels in November occurred, was 99 percent filled. At Station 11, the 31 teredinids collected comprised about 7 percent of the November long-term collection, filling 75 percent of the panel. The remaining 2 percent of the total number of teredinids retrieved from long-term panels in November were split between 8 stations.

Species Distribution and Dominance. Tables A-20 through A-22 present a summary of the abundance of Teredo navalis and Bankia gouldi, respectively, recorded

TABLE A-16. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED AUGUST 13-14, 1984

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	P	240	10	<1-65	50 T. navalis, 190 Teredinidae*	Ripe gonads and larvae
	C	500	2	<1-18	15 T. navalis, 485 Teredinidae*	
2	P	0				
	C	1	<1	4	1 Teredinidae*	
11	P	44	20	19-120	24 B. gouldi, 20 T. navalis	Ripening gonads
	C	3	<1	<1-1	3 Teredinidae*	
14	P	1	2	130	1 B. gouldi	
	C	0				
15	P	1	<1	<1	1 Teredinidae*	
	C	0				

Stations 3-10B, 12, 13, 16B and 17 - No Teredinidae present.

P = Long-term panel submerged February 13-14, 1984.
C = Short-term panel submerged July 9-10, 1984.
* = Not speciated due to size or condition.

TABLE A-17. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED SEPTEMBER 10-11, 1984.

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	P	351	60	4-110	1 B. gouldi, 230 T. navalis, 120 Teredinidae*	Ripening gonads
	C	210	2	<1-3	210 Teredinidae*	
4A	P	1	5	250	1 B. gouldi	
	C	0				
5	P	1	<1	<1	1 Teredinidae*	
	C	0				
10A	P	1	<1	<1	1 Teredinidae*	
	C	0				
11	P	26	60	14-205	19 B. gouldi, 7 T. navalis	
	C	1	<1	2	1 Teredinidae*	
12	P	3	<1	<1-11	2 B. gouldi, 1 Teredinidae*	
	C	3	<1	1-9	2 B. gouldi, 1 Teredinidae*	
14	P	2	<2	45-60	2 B. gouldi	
	C	0				

Stations 2-4, 6-10, 10B, 13, 15-17 - no Teredinidae present.

P=Long-term panel submerged March 19-20, 1984.
C=Short-term panel submerged August 13-14, 1984.
*=Not speciated due to size or condition.

TABLE A-18. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED OCTOBER 8-9, 1984

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification
1	P	297	97	1-60	2 B. gouldi, 55 T. navalis, 240 Teredinidae*
	C	260	1	<1-1	260 Teredinidae*
2	P	2	7	172-240	2 T. navalis
	C	0			
5	P	1	1	75	1 B. gouldi
	C	0			
7	P	2	<1	10-24	2 B. gouldi
	C	0			
8	P	2	<1	4-6	2 Bankia spp.*
	C	0			
9	P	2	1	62-64	2 B. gouldi
	C	0			
10B	P	5	8	<1-233	2 B. gouldi, 2 T. navalis, 1 Teredinidae*
	C	0			
11	P	58	97	10-250	40 B. gouldi, 18 T. navalis
	C	0			
12	P	5	13	1-272	4 B. gouldi, 1 Teredinidae*
	C	0			
14	P	2	2	60-118	2 B. gouldi
	C	0			
17	P	1	<1	4	1 Teredo spp.*
	C	0			

Stations 3-4A, 6, 10, 10A, 13, 15 and 16B - No Teredinidae present.

P = Long-term panel submerged April 16-17, 1984.
C = Short-term panel submerged September 10-11, 1984.
* = Not speciated due to size or condition.

TABLE A-19. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED NOVEMBER 12-13, 1984

Station	Panel	No. of Specimens	Percent Filled	Size Range in mm	Species Identification	Remarks
1	P	500	99	2-60	25 T. navalis, 475 Teredinidae*	95% of specimens dead.
	C	1400	1	<1-1	1400 Teredinidae*	
2	P	3	7	155-225	3 T. navalis	
	C	0				
8	P	2	<1	1	2 Teredinidae*	
	C	0				
10B	P	1	1	82	1 B. gouldi	
	C	0				
11	P	31	75	80-235	20 B. gouldi, 11 T. navalis	
	C	0				
12	P	5	7	22-220	5 B. gouldi	
	C	0				
13	P	1	5	265	1 B. gouldi	
	C	0				
14	P	1	2	125	1 Teredinidae*	Broken pallets.
	C	0				
15	P	3	2	2-107	2 T. navalis, 1 Teredinidae*	
	C	0				
17	P	2	<1	3-13	1 T. navalis, 1 Teredinidae*	
	C	0				

Stations 3-7, 9-10A, and 16B - No Teredinidae present

P = Long-term panel submerged May 14-15, 1984.
C = Short-term panel submerged October 8-9, 1984.
* = Not speciated due to size or condition.

TABLE A-20. NUMBER OF Teredo navalis IN 6-MONTH PANELS REMOVED JULY, 1975 THROUGH NOVEMBER, 1984

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

TABLE A-20. (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	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)

Year	Station	1	2	3	4	4A	5	6	7*	8	9	10	10A	10B	11	12	13	14	15	16**	17
1983	Jan	100						1			1	2		57				2		19	
	Feb														4						27
	Mar								1												
	Apr	10																			
	May																				
	Jun																				
	Jul																				
	Aug	10													3						
	Sep	650							1					1						4	
	Oct	30																1			6
	Nov	25													8		1		1		10
	Dec																	2	3		15
1984	Jan	4	1												3				3		24
	Feb		1										1		2	1					12
	Mar	130																			
	Apr																				
	May																				
	Jun																				
	Jul																				
	Aug	50													20						
	Sep	230													7						
	Oct	55	2											2	18						
	Nov	25	3												11				2		1

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

TABLE A-21. NUMBER OF Bankia gouldi IN 6-MONTH PANELS REMOVED JULY, 1975 THROUGH NOVEMBER, 1984

	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					-							-	-							
	Jun					-							-	-							
1976	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												-	-							
1977	Jul												-	-							
	Aug				1		1		3			1	-	-	15	1	5	1	1		
	Sep				2	1	6		4	1		1	-	-	82	3	13	5			
	Oct			1		3	3		7			2	-	-	59	7	10	9			
	Nov				1		5		7			1	-	-	39	7	8	5			
	Dec					1	4	1	7	1		2	-	-	25	7	18	9			
	Jan			2	1	1	1		2	2	2	1	-	-	34	5	4	6			
	Feb												-	-	1			1	1		
	Mar												-	-							
	Apr												-	-							
	May																				
	Jun																				
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			

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				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-21. (Continued)

Year	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
	Dec						5		6	9			3	1	47	3	18	40	1		
1984	Jan								1	5					13	1	5	36			
	Feb						1							1	5			2			
	Mar																				
	Apr																				
	May																				
	Jun																				
	Jul																				
	Aug														24			1			
	Sep	1				1									19	2		2			
	Oct	2					1		2		2			2	40	4		2			
	Nov													1	20	5	1				

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

TABLE A-22. PRESENCE AND DOMINANCE OF SPECIES OF TEREDINIDAE IN LONG-TERM PANELS REMOVED FROM DECEMBER, 1983 THROUGH NOVEMBER, 1984

Station	Bankia gouldi	Teredo navalis
1	x	x dominant
2		
3		
4		
4A	x dominant	
5	x dominant	
6		
7	x dominant	
8	x dominant	
9	x dominant	
10		
10A	x dominant	x
10B	x dominant	x
11	x dominant	x
12	x dominant	x
13	x dominant	
14	x dominant	x
15	x	x
16B		
17		x dominant

x = Species present.

from long-term panels since July, 1975. Dominant species at each station are indicated in Table A-22. Since no T. bartschi have been collected from the study area since February, 1982, no summary data for that species are presented here. Information concerning T. bartschi can be reviewed in the previous annual report (Hillman et al., 1984). A discussion of T. navalis and B. gouldi collected on the 6-month panels follows:

Teredo navalis. Teredo navalis was recorded from six-month panels from 8 of the 20 stations from December, 1983 through March, 1984, and at only 6 stations from August through November, 1984. This decrease in the number of stations at which T. navalis was collected during the warmer months continues the same pattern reported for the previous report period (Hillman et al., 1984).

In January, for the first time since December, 1980, an individual T. navalis was collected at Station 2, a site where T. navalis was formerly quite abundant. Another was collected there in February, two in October and three in November.

Whereas T. navalis may be reemerging at Station 2, it was noticeably scarce at Station 17 after March, 1984, with only one individual being collected, and that as late as November.

Although present at 9 of the 20 stations during the present report period, T. navalis was dominant at only four: Stations 1, 2, 15 and 17 (Table A-22). This represents an overall decline in dominance from the previous report period (Hillman et al., 1984) and is a reflection of the decrease in abundance of T. navalis.

The results of the factorial ANOVA on Teredo navalis are given in Table A-23 (based on $\log_e$ (1 + abundance)) and Table A-24 (based on presence/absence). Consistent with results reported previously (Hillman et al., 1984), all three main effects were very highly significant for both analyses. Further discussion of the ANOVA results is based on the ANOVA carried out on $\log_e$ (1 + abundance) values.

Based on examination of the relative magnitude of the mean square values (Table A-24) and the results of the multiple classification analysis, region was by far the most important variable influencing the spatio-temporal distribution of T. navalis. Region accounted for approximately 32% of the total variation observed. Season and bioyear, though statistically significant, were each responsible for less than 1% of the total variation.

Replacing the bioyear factor with a dummy variable for OCNGS operating status indicated that there has been a statistically significant decrease in T. navalis

TABLE A-23. ANALYSIS OF VARIANCE OF LOG_e (1 + ABUNDANCE) OF *Teredo navalis* BASED ON LONG-TERM (6-MONTH) PANELS REMOVED JULY, 1976 THROUGH NOVEMBER, 1984, 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	621.181	13	47.783	56.74007	0.000
Region	574.791	4	143.698	170.6339	0.000
Season	15.309	2	7.654	9.089094	0.000
Bioyear	32.718	7	4.674	5.550070	0.000
2-Way Interactions	94.523	50	1.890	2.244824	0.000
Region/Season	60.211	8	7.526	8.937168	0.000
Region/Bioyear	26.596	28	0.950	1.127917	0.295
Season/Bioyear	5.911	14	0.422	0.5013837	0.933
3-Way Interactions	19.863	56	0.355	0.4211835	1.000
Region/Season/Bioyear	19.863	56	0.355	0.4211835	1.000
Explained	735.567	119	6.181	7.339902	0.000
Residual	1063.624	1263	0.842		
Total	1799.191	1382	1.302		

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	659.936	7	94.277	112.2153	0.000
Region	634.060	4	158.515	188.6770	0.000
Season	20.722	2	10.361	12.33237	0.000
Outage	4.504	1	4.504	5.360673	0.021
2-Way Interactions	74.242	14	5.303	6.312087	0.000
Region/Season	71.597	8	8.950	10.65260	0.000
Region/Outage	1.777	4	0.444	0.5288630	0.715
Season/Outage	0.908	2	0.454	0.5402854	0.583
3-Way Interactions	9.585	8	1.198	1.426153	0.181
Region/Season/Outage	9.585	8	1.198	1.426153	0.181
Explained	743.764	29	25.647	30.52709	0.000
Residual	1343.384	1599	0.840		
Total	2087.147	1628	1.282		

TABLE A-24. ANALYSIS OF VARIANCE OF PRESENCE/ABSENCE OF Teredo navalis BASED ON LONG-TERM (6-MONTH) PANELS REMOVED JULY, 1976 THROUGH NOVEMBER, 1984, 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	46.107	13	3.547	28.40967	0.000
Region	33.190	4	8.298	66.46497	0.000
Season	2.608	2	1.304	10.44425	0.000
Bioyear	10.671	7	1.524	12.21063	0.000
2-Way Interactions	13.241	50	0.265	2.121245	0.000
Region/Season	4.044	8	0.506	4.049274	0.000
Region/Bioyear	6.550	28	0.234	1.873809	0.004
Season/Bioyear	2.124	14	0.152	1.215212	0.257
3-Way Interactions	5.693	56	0.102	0.8143783	0.834
Region/Season/Bioyear	5.693	56	0.102	0.8143783	0.834
Explained	65.041	119	0.547	4.378094	0.000
Residual	157.674	1263	0.125		
Total	222.716	1382	0.161		

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	41.210	7	5.887	44.89054	0.000
Region	36.048	4	9.012	68.71924	0.000
Season	4.170	2	2.085	15.89727	0.000
Outage	0.969	1	0.969	7.388168	0.007
2-Way Interactions	6.198	14	0.443	3.375975	0.000
Region/Season	5.787	8	0.723	5.516136	0.000
Region/Outage	0.158	4	0.040	0.3017664	0.877
Season/Outage	0.247	2	0.123	0.9410616	0.390
3-Way Interactions	1.245	8	0.156	1.186421	0.303
Region/Season/Outage	1.245	8	0.156	1.186421	0.303
Explained	48.653	29	1.678	12.79272	0.000
Residual	209.698	1599	0.131		
Total	258.351	1628	0.159		

densities since OCNGS has been off-line. This was true both for abundances and presence/absence (Tables A-23 and A-24, respectively). Most of the decline occurred at Station 1, however, so its relationship to the outage is questionable.

In order to further investigate patterns of Teredo navalis abundance, one-way ANOVAs follwed by Student-Newman-Keuls multiple range tests were carried out on various combinations of data. The specific ways in which stations, months, and years were compared were identical with those used in previous reports; those in turn were based on the results of interaction plots conducted as part of the report on data collected for the period December, 1980 - November, 1981 (Maciolek-Blake et al., 1982). The comparisons included the following:

1) Stations
   a) all data
   b) summer months only
   c) fall and winter months only
   d) December, 1983 - November, 1984 only

2) Bioyears
   a) all data
   b) Region 3 only
   c) Region 1 only

3) Months
   a) all data
   b) complete bioyears only (7/76-6/84)
   c) Region 3 only
   d) December, 1983 - November, 1984 only

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

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

A very nearly identical pattern resulted from the analysis based on fall and winter data:

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

and was only slightly different when data from the summer only were included:

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

These observations are essentially identical with those reported in previous years (Maciolek-Blake et al., 1982; Hillman et al., 1983, 1984) and continue to indicate significantly elevated abundances of T. navalis near Barnegat Inlet (Stations 1 and 17) and at Stations 2 and 11.

The positioning of the Region 1 (OCNGS vicinity) stations (5, 6, 7, 8) in the middle to lower areas of the density range and statistically indistinguishable from the majority of Barnegat Bay stations continues to support the conclusion that OCNGS has had no significant effect on T. navalis densities.

Analysis of spatial variation in T. navalis densitites during the present reporting period (December, 1983 - November, 1984) produced a pattern not unlike that described above:

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

Only Station 1 at Barnegat Inlet was clearly different than the remainder of stations in the study area.

The results of the Student-Newman-Keuls analysis on T. navalis densities by bioyear indicated few significant differences:

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

This indicates that there has been no overall trend in T. navalis densities in the Bay during the course of this program. Only one bioyear (1979/1980) had statistically different densities; all other bioyears were statistically equivalent to each other.

Analysis of T. navalis densities in Region 3 (Stations 1 and 17) only indicated no significant differences. When only the data from Region 1, near OCNGS were analyzed, bioyear 1982/1983 had significantly higher densities than the other years, which were not significantly different from each other. No directed trend is indicated by this result, particularly in view of the very low T. navalis densities in Region 1 during the most recent bioyear (1983/1984).

As reported previously (Hillman et al., 1984), Teredo navalis densities in the study area are strongly seasonal, with lowest densities found in the spring and summer. Seasonal maxima occur in fall and early winter. Addition of the current year's results to the data set did not alter this pattern when all data were analyzed:

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Essentially similar results were obtained when the data were analyzed separately for complete bioyears and for Region 3, respectively. When the analysis was conducted on data from the current reporting period only (November, 1983 - December, 1984) no significant differences were found.

Bankia gouldi. Bankia gouldi occurred in long-term panels from 10 of the 20 stations from December, 1983 through February, 1984, an increase of one station over the same period last year. As during the previous year no additional B. gouldi were collected until August, 1984. Unlike the previous year, B. gouldi were collected at only 10 of the 20 stations from August through November.

In last year's report (Hillman et al., 1984) it was stated that because of a considerable increase in abundance of B. gouldi over what had been reported for the past several seasons, the declining trend may have been reversed. While this year's total abundance of B. gouldi is much greater than it had been until last year, it is still lower than for the corresponding period last year. Therefore, it remains to be seen whether the declining trend in B. gouldi abundance is really over.

Despite an overall decline in abundance, B. gouldi remained the dominant teredinid at 11 of the 13 stations at which it occurred during the present report period (Table A-22).

Results of the three-way factorial ANOVAs for presence/absence and $\log_e$ (abundance +1) of Bankia gouldi are shown in Tables A-25 and A-26, respectively. As in previous years, all main effects were very highly significant for both data types. Subsequent discussion will address the analysis performed on $\log_e$ (1 + abundance) data only.

Based on an examination of relative mean square values and the results of the multiple classification analysis, region was the most important factor of the three in determining B. gouldi abundance. On average, Regions 1, 2, and 3 had fewer individuals than Regions 4 and 5. This factor alone explained approximately 10% of the variation in the data. Season and bioyear each accounted for less than 6% of the variation, and the combination of all three main effects was able to account for only 21% of the variation in B. gouldi abundance.

When the analysis was repeated using a dichotomous dummy variable to represent OCNGS operating status, all three main effects (i.e. region, season, outage) were again significant. Region was again the most important factor, and OCNGS operating status accounted for less of the variation in abundance than did the factors of region and season. Bankia gouldi densities in the bay have been, on average, significantly lower during the extended outage which began in February of 1983.

TABLE A-25. ANALYSIS OF VARIANCE OF LOG_e (1 + ABUNDANCE) OF Bankia gouldi BASED ON LONG-TERM (6-MONTH) PANELS REMOVED JULY, 1976, THROUGH NOVEMBER, 1984, 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	244.566	13	18.813	28.63743	0.000
Region	120.146	4	30.037	45.72265	0.000
Season	57.656	2	28.828	43.88292	0.000
Bioyear	57.590	7	8.227	12.52372	0.000
2-Way Interactions	68.251	50	1.365	2.077869	0.000
Region/Season	23.207	8	2.901	4.415870	0.000
Region/Bioyear	33.878	28	1.210	1.841807	0.005
Season/Bioyear	8.650	14	0.618	0.9405536	0.514
3-Way Interactions	20.377	56	0.364	0.5538951	0.997
Region/Season/Bioyear	20.377	56	0.364	0.5538951	0.997
Explained	333.193	119	2.800	4.262170	0.000
Residual	829.702	1263	0.657		
Total	1162.895	1382	0.841		

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	284.304	7	40.615	37.76091	0.000
Region	170.711	4	42.678	39.67886	0.000
Season	96.751	2	48.375	44.97620	0.000
Outage	15.377	1	15.377	14.29604	0.000
2-Way Interactions	36.463	14	2.604	2.421465	0.002
Region/Season	31.986	8	3.998	3.717323	0.000
Region/Outage	3.771	4	0.943	0.8764441	0.477
Season/Outage	0.300	2	0.150	0.1396631	0.870
3-Way Interactions	2.315	8	0.289	0.2690270	0.976
Region/Season/Outage	2.315	8	0.289	0.2690270	0.976
Explained	323.081	29	11.141	10.35790	0.000
Residual	1719.850	1599	1.076		
Total	2042.931	1628	1.255		

TABLE A-26. ANALYSIS OF VARIANCE OF PRESENCE/ABSENCE OF *Bankia gouldi* BASED ON LONG-TERM (6-MONTH) PANELS REMOVED JULY, 1976, THROUGH NOVEMBER, 1984 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	58.515	13	4.501	26.57988	0.000
Region	28.383	4	7.096	41.90107	0.000
Season	17.409	2	8.704	51.39963	0.000
Bioyear	10.469	7	1.496	8.831678	0.000
2-Way Interactions	15.657	50	0.313	1.849129	0.000
Region/Season	2.558	8	0.320	1.888484	0.058
Region/Bioyear	10.315	28	0.368	2.175447	0.000
Season/Bioyear	2.515	14	0.180	1.060361	0.390
3-Way Interactions	7.491	56	0.134	0.7898898	0.868
Region/Season/Bioyear	7.491	56	0.134	0.7898898	0.868
Explained	81.663	119	0.686	4.052342	0.000
Residual	213.883	1263	0.169		
Total	295.546	1382	0.214		

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	57.077	7	8.154	43.77840	0.000
Region	30.202	4	7.551	40.53922	0.000
Season	23.946	2	11.973	64.28365	0.000
Outage	2.647	1	2.647	14.21295	0.000
2-Way Interactions	4.176	14	0.298	1.601342	0.072
Region/Season	2.763	8	0.345	1.854062	0.063
Region/Outage	1.283	4	0.321	1.721676	0.143
Season/Outage	0.118	2	0.059	0.3167232	0.729
3-Way Interactions	1.249	8	0.156	0.8380412	0.569
Region/Season/Outage	1.249	8	0.156	0.8380412	0.569
Explained	62.501	29	2.155	11.57145	0.000
Residual	297.817	1599	0.186		
Total	360.318	1628	0.221		

One-way ANOVAs followed by formal multiple comparison procedures were conducted in order to understand the significance of the factorial ANOVA results. The Student-Newman-Keuls multiple range test was used to determine significantly different subsets in the data. The specific way in which stations, months and years were compared were the same as used in previous reports (Maciolek-Blake et al., 1983; Hillman et al., 1984). These in turn were developed from the results of interaction plots conducted as part of the analysis of the 1980-1981 data (Maciolek-Blake et al., 1982). The following comparisons were made:

1) Stations
   a) all data
   b) fall months only
   c) winter and summer months only
   d) December, 1983 - November, 1984 only

2) Bioyears
   a) All data

3) Months
   a) all data
   b) complete bioyears only (7/76 - 6/84)
   c) December, 1983 - November, 1984 only

Comparisons among stations using all available data indicated the following grouping (stations connected by an underline were not significantly different at $p < .05$):

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

This pattern is exactly the same as that presented in the previous report (Hillman et al., 1984) and is generally similar to that reported in previous years (Maciolek-Blake et al., 1982; Hillman et al., 1983). This pattern is sufficiently persistent that it allows some generalized conclusions regarding the spatial distribution of B. gouldi in the Bay. The first is that stations in the vicinity of the OCNGS discharge (Stations 5, 6, 7 and 8) do not appear to be radically different from the remainder of the Bay and in fact had intermediate B. gouldi densities.

Analysis using the most recent data (December, 1983 - November, 1984) indicated a pattern generally similar to that for the larger data set and again indicated significantly greater densities of B. gouldi at stations immediately north of OCNGS:

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

It is also immediately apparent that Stations 10A, 11, 12, 13, and 14 have significantly elevated B. gouldi densities. These stations form a spatially contiguous group on the western side of the Bay immediately north of the OCNGS site.

Finally, it appears that, except for Station 11 which has elevated densities of both species, there is some indication that densities of Bankia gouldi and Teredo navalis may be inversely correlated. For example, Stations 1, 2, and 17 had the highest densities of T. navalis yet were among the lowest for B. gouldi. Conversely, Stations 12 and 13, which had significantly higher densities of B. gouldi were among the lowest ranked stations for T. navalis. Testing this relationship with Spearman's Coefficient of Rank Correlation (Sokal and Rohlf, 1969), however, did not indicate any significant negative correlation.

Repeating the analysis using only data from summer and from fall/winter, respectively, did not alter the general pattern discussed above.

Comparison of Bankia gouldi abundance across bioyears, using data from all complete bioyears (July, 1976 - June, 1984) produced the following pattern:

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

This pattern of overlapping significant differences is difficult to interpret but it does appear to reverse somewhat the pattern of decreasing B. gouldi abundance discussed in last year's report (Hillman et al., 1984).

Analysis of B. gouldi abundances by month were identical for both all data and full bioyears only:

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This seasonal pattern is by now well established in the data and has been discussed in previous reports (Hillman et al., 1983, 1984). Analysis of the most recent year's data (December, 1983 - November, 1984) produced a similar pattern with fewer significant groups due to the smaller amount of data available for analysis:

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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-27, and in Table A-28. The stations are ranked in descending order of amount of attack as it has been calculated through half of the 1984 breeding season.

Destruction was down about eight percentage points at Station 1 over what it was in 1983, but Station 1 remained the station which consistently shows the highest rate of destruction. Nearly as much destruction to long-term panels was shown at Station 11, where the rate remained at about last year's levels.

Destruction was down sharply at Stations 14 and 13, particularly. In 1983 percent destruction at Station 14 was over 50 percent, whereas through November, 1984 it was less than 2 percent.

Table A-29 shows the number of times a station has received a first place ranking in terms of destruction to long-term panels. By assigning 10 points to a station each time it was ranked first, 9 points for a second place ranking, 8 points for a third place ranking, down to 1 point for a tenth place ranking, and totaling the points it is possible to determine a relative ranking of stations. That ranking is shown in Table A-30.

Station 1 has consistently shown the most amount of destruction to long-term panels throughout the study, with Station 11 being ranked a close second. Stations 7 and 14 are tied for third place, 39 points behind Station 1.

For this year's report, we have refined the unweighted least squares regression model used to investigate the relative contribution of various teredinid taxa to determining the degree of destruction of the wood panels.

The model employed in previous reports (Hillman et al., 1984) was the logistic response function (commonly known as logit analysis) which is based on the assumption that the phenomenon under study (in this case the increase in percent destruction as a function of increasing teredinid density) exhibits threshold-type behavior (Chatterjee and Prize, 1977). The purpose of the logit transformation in this case is to linearize the characteristic sigmoid dose-response curve and thereby allow application of multiple linear regression methodology.

Reexamination of the raw data collected since the initiation of this study indicated that there was no apparent justification for the logistic model and that a simple logarithmic transformation of percent destruction and abundances may prove to better model the relationship. This is also intuitively appealing in that it, in effect, assumes

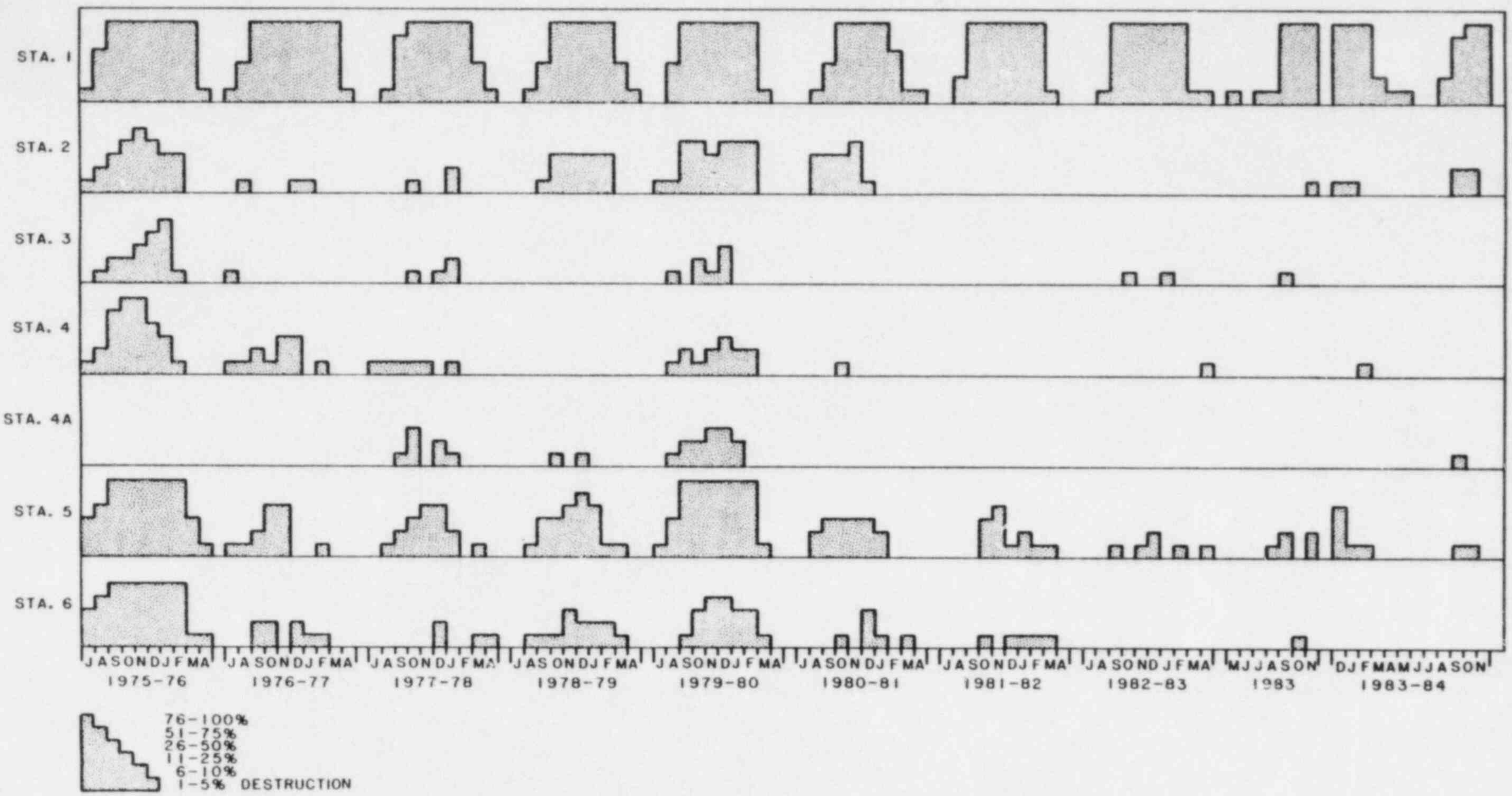

FIGURE A-5. PERCENT DESTRUCTION BY TEREDINIDS TO LONG-TERM (6-MONTH) EXPOSURE PANELS FROM JULY, 1975 THROUGH NOVEMBER, 1984.

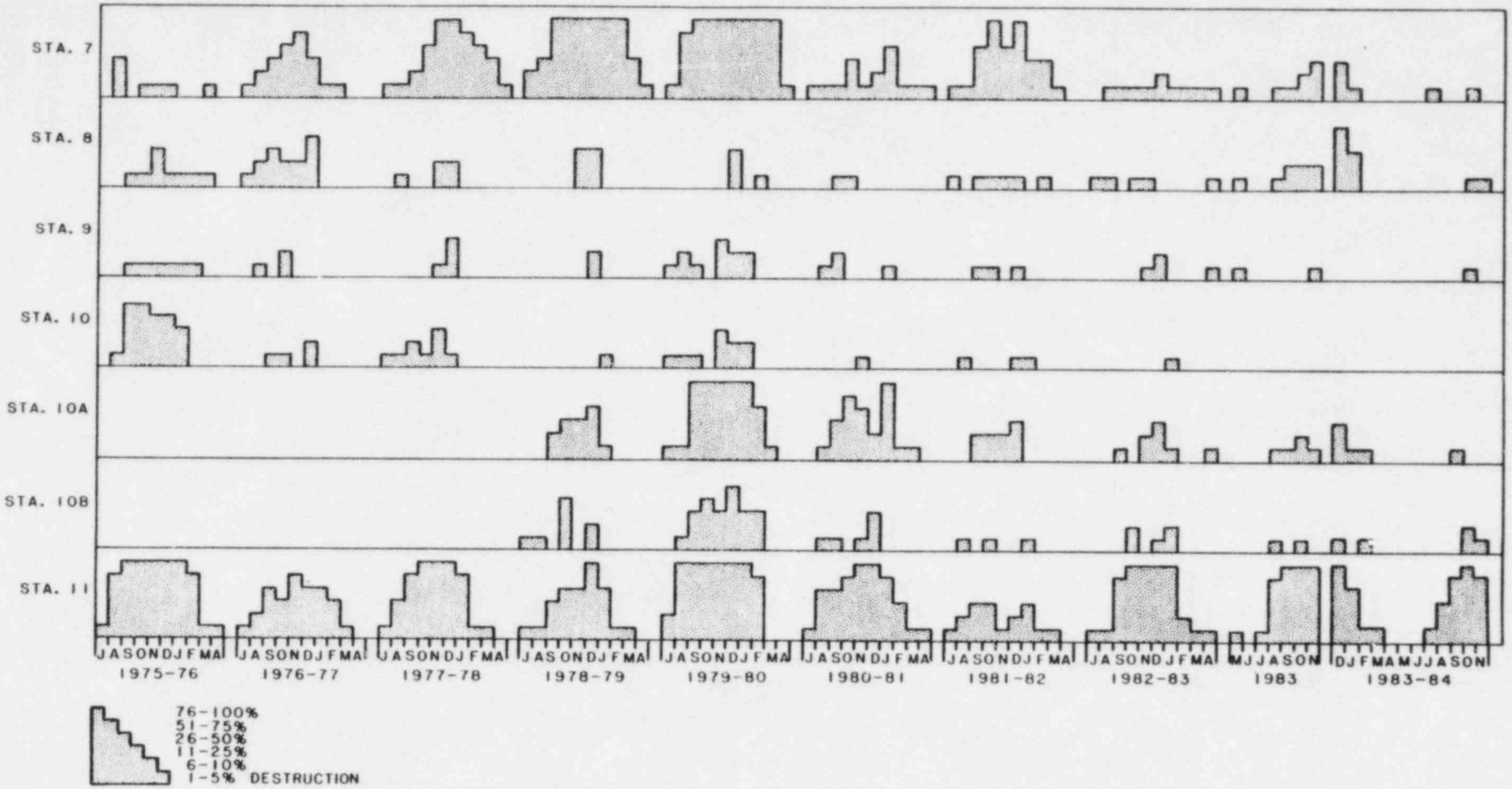

FIGURE A-5. (Continued)

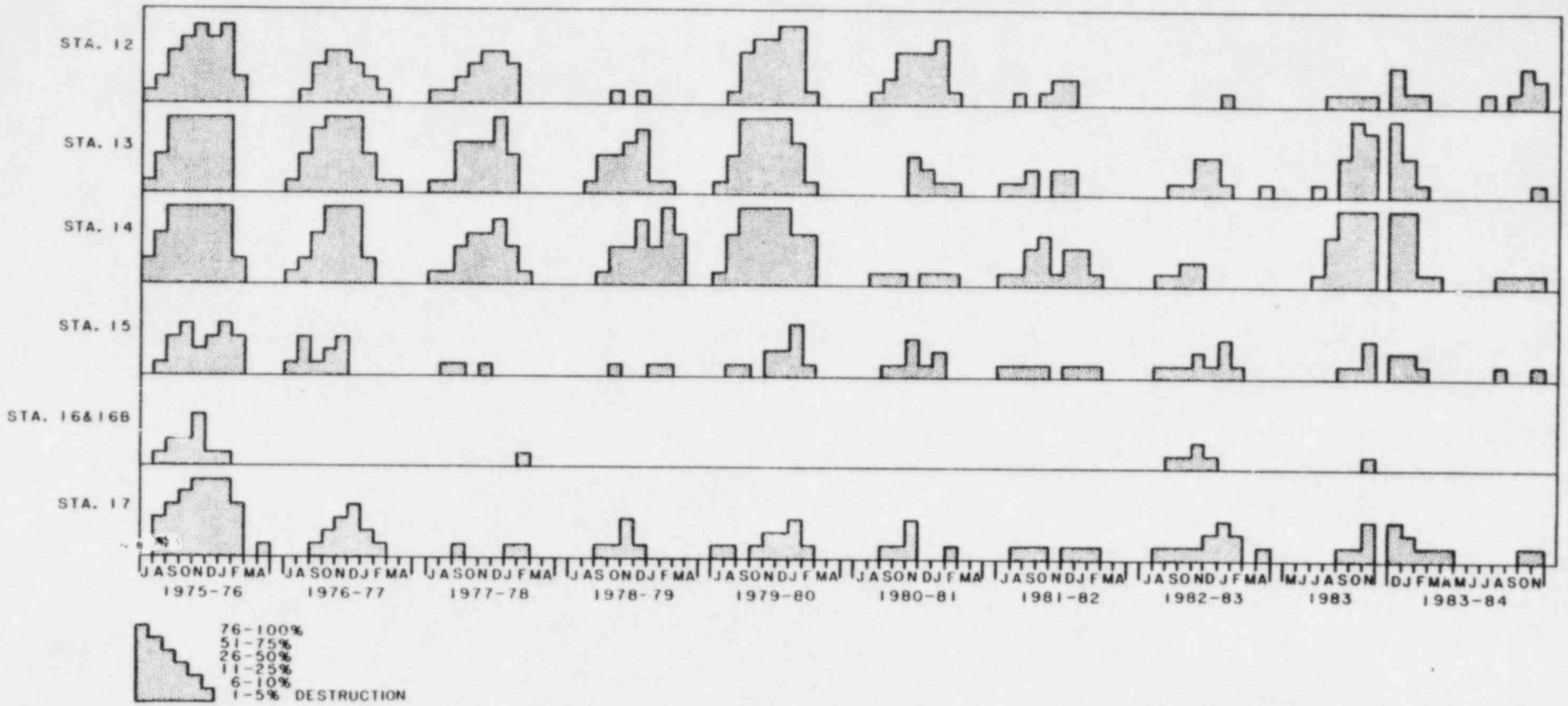

FIGURE A-5. (Continued)

TABLE A-27. AVERAGE PERCENT DESTRUCTION TO LONG-TERM PANELS OVER BREEDING SEASONS

	Breeding Season*									
Station	1975	1976	1977	1978	1979	1980	1981	1982	1983	1985
1	72.7**	61.1	58.8	52.7	60.7	40.2	60.6	49.5	61.0	53.2
2	23.7	0.4	1.1	8.8	19.4	8.4	0.0	0.0	0.7	1.4
3	15.4	0.1	0.9	0.0	2.7	0.0	0.0	0.5	0.3	0.0
4	33.0	5.1	1.3	2.6	4.8	0.2	0.0	0.1	0.1	0.0
4A	-	-	3.1	0.6	8.2	0.0	0.0	0.0	0.0	1.0
5	67.9	7.2	9.9	21.9	61.1	8.5	6.5	0.8	5.2	0.4
6	65.1	3.1	0.9	4.7	14.9	2.3	0.5	0.0	0.2	0.0
7	2.1**	18.1	36.5	53.0	67.5	6.9	29.9	2.0	5.6	0.4
8	3.5**	7.4	2.1	3.3	2.5**	1.1	0.7	0.8	10.1	0.4
9	2.3**	1.1	1.4	0.8	4.2	1.3	0.3	1.2	0.1	0.2
10	23.7	1.6	3.3	0.2	3.9	0.2	0.5	0.4	0.0	0.0
10A	-	-	-	8.0	49.6	22.4	3.2	3.0	4.5	0.2
10B	-	-	-	2.4	14.4	2.1	0.4	2.0	1.2	1.8
11	64.5	24.5	43.1	24.7	66.6	40.5	7.7	42.8	50.5	50.6
12	39.6	15.7	12.4	0.8	35.6	18.3	2.0	0.2	2.4	4.4
13	57.2**	38.2	24.9	13.7	42.2	2.8	3.1**	4.4	29.8	1.0
14	56.3	32.4	19.2	24.3	48.5	2.2	10.2	2.0	50.4	1.6
15	15.4	5.1	0.5	0.7	5.6	2.9	1.2	2.9	4.9	0.6
16/16B	6.6	0	0.1	0.0	0.0	0.0	0.0**	1.8	0.3	0.0
17	44.4	8.5	0.8	1.8	3.5	2.0	0.8	5.0	4.7	0.4

* 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-April, 1984
1984: July, 1984-November, 1984

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

TABLE A-28. RANK OF STATIONS IN DESCENDING ORDER OF TEREDINID ATTACK*

1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
1	1	1	7	7	11	1	1	1	1
5	13	11	1	11	1	7	11	11	11
6	14	7	11	5	10A	14	17	14	12
11	11	13	14	1	12	11	13	13	10B
14	7	14	5	10A	5	5	10A	8	14
13	12	12	13	14	2	10A	15	7	2
17	17	5	2	13	7	13	7	5	4A
12	8	10	10A	12	15	12	10B	15	13
4	5	4A	6	2	13	15	14	17	15
10	4	8	8	6	6	17	16B	10A	5
2	15	9	4	10B	14	8	9	12	7
3	6	4	10B	4A	10B	6	5	10B	8
		2	17	15	17	10	8	2	17
15	10	3	9	4	9	10B	3	3	9
16	9	6	12	9	8	9	10	16B	10A
8	2	17	15	10	4	2	12	6	3
9	3	15	4A	17	10	3	4	4	4
7	16	16	10	3	3	4	2	4	6
			3	8	4A	4A	4A	4A	10
			16	16	16	16	6	10	16B

* = From mean percentages, Table A-27.
** = Half season.

TABLE A-29. 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	7	2		1						
2						2	1		1	
3										
4									1	1
4A							1		1	
5		1	1		3		2		1	1
6			1						1	2
7	2	1	1		1	1	2			
8					1			1		2
9										
10								1		1
10A			1		2	1		1		1
10B				1				1		
11	1	5	1	3						
12			1	1		2		3		
13		1		3		2	2	1	1	
14			3	1	3	1			1	
15						1		2	2	
16/16B										1
17			1				2		1	1

TABLE A-30. RELATIVE RANKING OF STATIONS IN TERMS OF PERCENT TEREDINID ATTACK FROM 1975 THROUGH 1984.

Rank	Station	Points
1	1	95
2	11	84
3	7	56
3	14	56
4	13	53
5	5	46
6	12	34
7	10A	29
8	17	19
9	2	16
10	15	15
11	6	12
12	8	11
13	10B	10
14	4A	6
15	10	4
16	4	3
17	16/16B	1
18	3	0
18	9	0

destruction is roughly linear with increasing density until the available substratum becomes limiting. Also, it allows somewhat for the observation that extremely high densities of teredinids usually imply that the individuals are newly settled and thus the destruction per individual is smaller than that for adult individuals.

In addition to performing log transformations on both the dependent and independent variables, we have further refined the regression model by forcing the regression to pass through the origin. Destruction, in the sense it is used throughout this study, is attributable solely to damage done by marine borers and it is intuitively obvious that a panel which has no borers should also have zero percent destruction.

The model was fit in a stepwise fashion using the REGRESSION procedure of the SPSS-X Statistical Package (SPSS, Inc., 1983). Of the five independent variables used (log (1 + abundance) of B. gouldi, T. navalis, T. bartschi, Teredo spp. and unidentified Teredinidae, respectively) only four were found to account for a significant amount of the observed variation in log (1 + percent destruction). The calculated regression coefficients for these were:

Variable	Unstandardized Coefficient	Standardized Coefficient
Bankia gouldi	1.094	0.596
Teredo navalis	0.666	0.427
Teredo bartschi	0.391	0.188
Teredinidae	0.154	0.124

The magnitude of the standardized coefficients may be considered indicative of the relative importance of the various taxa in determing the amount of destruction of test panels (Zan, 1974). The unstandardized coefficients indicate the relative amount of damage done per individual. For this analysis, the damage per individual and the overall importance of each taxon were clearly related.

As in previous analyses (Hillman et al., 1984) Bankia gouldi was the most important taxon in the analysis followed closely by T. navalis in terms of overall importance though the difference in destruction per individual was large. This appears related to the generally higher densities of T. navalis in the panels. The remaining two taxa were of much less importance. The multiple coefficient of determination (r^2) for the fit was 0.829, indicating that approximately 83% of the observed variation in percent destruction could be explained in terms of the abundances of the four taxa.

As in prior years, the residual variation in percent destruction (i.e. the random error remaining after fitting the model described above) was examined via three-way factorial ANOVA to determine if any significant amount of variation could be attributed to the effects of region, season, or bioyear. All three main effects were highly significant, but only 10% of the residual variation was explained by the ANOVA, based on the results of the multiple classification analysis. While it is clear from these results that the number of borers in the panels is adequate to account for the degree of destruction, even without additional information on the date of recovery or location of the panel, the abundance of borers in panels is affected significantly by region, station, and bioyear.

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, 1983 and retrieved in May, 1984 is shown in Table A-31. Table A-32 shows incidence in the panels submerged in June, 1983 and retrieved in June, 1984.

Most teredinids in 12-month panels were collected at Station 1, where the panels were 99 percent filled with dead juveniles. The 12-month panels at Station 14 were 98 to 99 percent filled, primarily with Bankia gouldi. The incidence of borer attack in the 12-month panels at the other stations was relatively light.

Limnoria

Table A-33 shows the incidence of the crustacean woodborer Limnoria in 6-month and 1-month panels removed monthly from December, 1983 through November, 1984.

During the present report period, Limnoria was present at Stations 1, 2, 3, 4, 4A and 5, a distribution pattern the same as it was during the previous report period.

TABLE A-31. INCIDENCE OF TEREDINIDAE IN 12-MONTH PANELS SUBMERGED MAY 2-3, 1983 AND REMOVED MAY 14-15, 1984*

Station	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	400	99		12. T. navalis, 388 Teredinidae	All dead.
5	1	4	280	1 Teredinidae	Dead.
7	5	22	80-340	5 B. gouldi	
8	5	8	10-190	4 B. gouldi, 1 Teredinidae	Teredinidae dead.
9	1	<1	30	1 Teredinidae	Dead.
10B	2	7	110-300	2 B. gouldi	
11	3	25	280-390	3 B. gouldi	1 dead.
12	1	5	360	1 B. gouldi	
14	51	98	12-190	33 B. gouldi, 1. T. navalis, 17 Teredinidae	T. navalis with ripening gonads, 17 Teredinidae dead.
15	8	30	140-320	3 B. gouldi, 3 T. navalis, 2 Teredinidae	1. T. navalis with larvae, 1 T. navalis and 2 Teredinidae dead.
16B	1	4	265	1 B. gouldi	
17	4	7	70-240	2 B. gouldi, 2 T. navalis	

No Teredinidae in panels from Stations 2-4A, 6, 10, 10A, 13.

* Panel from Station 1 removed June 11, 1984.
Panel from Station 4A removed February 13, 1984.

TABLE A-32. INCIDENCE OF TEREDINIDAE IN 12-MONTH PANELS SUBMERGED JUNE 6-7, 1983 AND REMOVED JUNE 11-12, 1984*

Station	No. of Specimens	Percent Filled	Size Range in mm.	Species Identification	Remarks
1	400	99		6 T. navalis, 394 Teredinidae	All dead.
5	1	5	285	1 B. gouldi	Dead.
7	4	23	180-350	4 B. gouldi	Ripening gonads.
8	3	18	240-305	3 B. gouldi	
10A	1	5	280	1 B. gouldi	Dead.
11	4	17	115-420	2 B. gouldi, 1 T. navalis 1 Teredinidae	T. navalis with ripening gonads, Teredinidae dead.
12	1	6	265	1 B. gouldi	
13	1	4	240	1 B. gouldi	Ripening gonads.
14	60	99	30-230	28 B. gouldi, 32 Teredinidae	10 live, 50 dead.
15	3	20	245-300	2 B. gouldi, 1 Teredinidae	Teredinidae dead.
16B	1	5	290	1 B. gouldi	
17	16	10	13-160	9 T. navalis, 7 Teredinidae	All dead.

No Teredinidae in panels from Stations 2-4A, 6, 9, 10, 10B.

* Panel from Station 1 removed January 9, 1984.
Panel from Station 14 removed May 15, 1984.
Panel from Station 17 removed July 10, 1984.

TABLE A-33. INCIDENCE OF LIMNORIA IN 6-MONTH (P) AND 1-MONTH (C) EXPOSURE PANELS REMOVED DECEMBER, 1983 THROUGH NOVEMBER, 1984

Station	Panel	Dec 1983 Tunnels/ Specimens	Jan 1984 Tunnels/* Specimens	Feb 1984 Tunnels/* Specimens	Mar 1984 Tunnel/ Specimens	Apr 1984 Tunnels/ Specimens	May 1984 Tunnels/ Specimens	Jun 1984 Tunnels/** Specimens	Jul 1984 Tunnels/*** Specimens	Aug 1984 Tunnels/*** Specimens	Sep 1984 Tunnels/*** Specimens	Oct 1984 Tunnels/*** Specimens	Nov 1984 Tunnels/ Specimens
1	P	0/0	0/0	0/0	5/0	5/3	0/0	0/0	14/21	80/65	40/36	12/2	16/0
	C	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	1/0	0/0	0/0
2	P	1500/800	280/165	50/10	5/2	2/1	2/0	93/153	310/480	1800/2000	2300/2500	4500/3517	2000/2000
	C	0/0	0/0	0/0	0/0	0/0	7/2	34/37	36/49	20/29	18/12	0/0	0/0
3	P	27/15	4/0	2/2	1/0	0/0	0/0	4/6	16/11	0/0	1/2	45/7	0/0
	C	0/0	0/0	0/0	0/0	0/0	0/0	2/3	0/0	0/0	0/0	0/0	0/0
4	P	3/2	2/1	0/0	0/0	0/0	0/0	0/0	3/2	0/0	2/1	0/0	0/0
	C	0/0	0/0	0/0	0/0	0/0	0/0	1/0	0/0	0/0	0/0	0/0	0/0
4A	P	6000/4500	3600/1500	380/300	30/10	0/0	2/2	230/220	690/1000	1300/1300	1000/810	700/612	220/200
	C	0/0	0/0	0/0	0/0	0/0	0/0	14/4	56/80	3/0	0/0	0/0	0/0
5	P	0/0	0/0	7/2	0/0	0/0	0/0	0/0	0/0	0/0	0/0	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

Attack continued high at Stations 2 and 4A (Figure A-6) although it averaged considerably less at Station 4A than during the previous report period (Hillman et al., 1984). Attack continued to decline at Station 4, and was also down at Station 3.

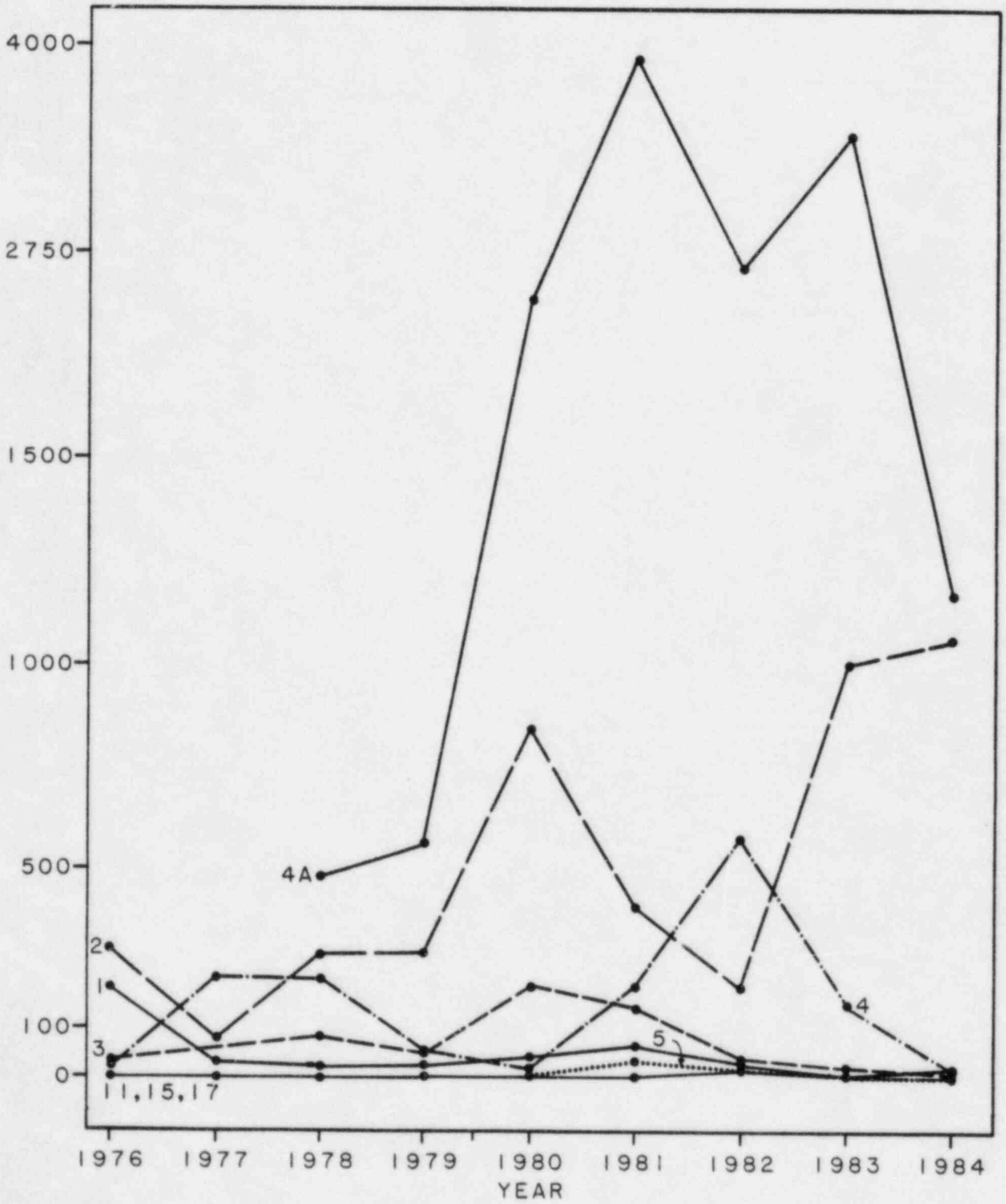

FIGURE A-6. AVERAGE NUMBER OF Limnoria TUNNELS IN LONG-TERM (6-MONTH) PANELS FROM 1976 THROUGH 1984.

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APPENDIX B

APPENDIX B

BORER DEVELOPMENTAL STATUS

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APPENDIX B
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, 1983 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, 1984.

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, and although they are no longer used for pathology purposes, they supply information on gonad conditions year-round.

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 generally suitable. In some cases, especially during the warmer months, it appears as if early active development began again shortly after the shipworm had just spawned, so that the follicles showed both early active and spent characteristics simultaneously. In general, however, 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, 1983, a total of 4835 teredinid borers was examined histologically for gonad condition. This included 1986 Teredo navalis, 534 T. bartschi, 24 T. furcifera, 2229 Bankia gouldi, and 62 immature teredinids too small to be identified to species. The data from those observations were included in the annual report to GPU Nuclear Corporation for the period December 1, 1982 through November 30, 1983. From December 1, 1983 through November 30, 1984, an additional 262 T. navalis, 386 B. gouldi, and 1 small unidentifiable teredinid were examined. The results of the examinations for T. navalis and B. gouldi are tabulated in Tables B-1 and B-2 respectively. The unidentifiable teredinid occurred in November at Station 14. Although it was very small, the gonads were in the spent condition.

As in past years (Hillman et al., 1984) no unusual variations in expected reproductive patterns were observed. For all intents and purposes OCNGS was not operating during the present report period, and the populations of shipworms were subjected to normal seasonal ambient environmental parameters.

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

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, 1983 THROUGH NOVEMBER, 1984.

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

Gonad Stage	1983 Dec	Jan	Feb	Mar	Apr	May	1984 June	Jul	Aug	Sep	Oct	Nov	Station
EA				18					1	1	1	1	
LA									1	1	1	4	
R									2	3			
PS									2			1	1
S										11	6	9	
NG									2			1	
EA										1			
LA		1	1									2	
R													2
PS							1					1	
S											5		
NG												1	
EA													
LA			1										
R													10A
PS													
S													
NG													
EA													
LA													
R													10B
PS													
S											2		
NG													

TABLE B-1. (continued)

Gonad Stage	1983 Dec	Jan	Feb	Mar	Apr	May	1984 June	Jul	Aug	Sep	Oct	Nov	Station
EA		1	1								2	3	
LA		2	1				1		2				
R									2				11
PS									3				
S										3	6	3	
NG													
EA													
LA			1										
R													12
PS													
S													
NG													
EA													
LA													
R						1							14
PS	2												
S													
NG													
EA												1	
LA	1	2				1							
R						1							
PS	1												15
S												1	
NG	1	1											
EA	4	12	17	11	1	1							
LA	10	1	1	3	1	2	1						
R					1	3	4		1				17
PS	3				5	6	18	2					
S	6	2			2			6		8			
NG					1						2	1	

TABLE B-2. NUMBERS OF SPECIMENS AND STAGE OF GONAD DEVELOPMENT OF *Bankia gouldi* IN EXPOSURE PANELS AT STATIONS IN BARNEGAT BAY, NEW JERSEY, FROM DECEMBER, 1983 THROUGH NOVEMBER, 1984

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

Gonad Stage	1983 Dec	Jan	Feb	Mar	Apr	May	1984 June	Jul	Aug	Sep	Oct	Nov	Station
EA											1		
LA													
R													1
PS											1		
S										1			
NG													
EA													
LA													
R													4A
PS													
S													
NG										1			
EA													
LA													
R													5
PS													
S	1										1		
NG	4		1										
EA		1	12	2		1					2		
LA						3	2						
R							1		1				7
PS							3						
S	2		5		2			2			1		
NG	3	3	3		1	4	2	1			1		

TABLE B-2. (Continued)

Gonad Stage	1983 Dec	Jan	Feb	Mar	Apr	May	1984 June	Jul	Aug	Sep	Oct	Nov	Station
EA													
LA						2							
R							3						8
PS													
S	6	4				1							
NG	2	1				1							
EA													
LA													
R													9
PS													
S											2		
NG													
EA													
LA													
R													10A
PS													
S	1												
NG	2												
EA													
LA						1							
R													10B
PS													
S											1	1	
NG	1		1			1					1		

TABLE B-2. (Continued)

Gonad Stage	1983 Dec	Jan	Feb	Mar	Apr	May	1984 June	Jul	Aug	Sep	Oct	Nov	Station
EA		8	1	12	11	10					8		
LA						12	1		3				
R								1	4				11
PS						1	1	1	5				
S	14	10		1				1		9	1	10	
NG	6	5	3	2	2	1			1	1	5	5	
EA	1	1		1		2							
LA						2							
R									1				12
PS							1						
S	2	2	1		1						4	5	
NG	2	2	1		1	1	3		2	3	1		
EA	6	1										1	
LA													
R													13
PS							1						
S	8	1											
NG	1	3											
EA	8	11				10							
LA						13							
R													14
PS													
S	7	1				1				2	1		
NG			2			1			1		1		

TABLE B-2. (Continued)

Gonad	1983						1984						
Stage	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Station
EA													
LA						1							
R													15
PS							2						
S	1												
NG						2							
EA						1							
LA							1						
R													16
PS													
S													
NG													
EA	1			2		2							
LA													
R													17
PS													
S													
NG	2					1							

Teredo navalis. During the present report period, Teredo navalis occurred at 9 of the 20 stations at which panels are exposed (Table B-1), a decrease of three stations from the previous year's collection.

Ripe gonads were found during April, May and June at Station 17, in May at Stations 14 and 15, in August at Station 11, and in August and September at Station 1. Early and late active gonads apparently persisted throughout the winter, and were found in shipworms from several stations during January and February, 1984. Early active stages which occurred in February and March 1984 could be expected at that time since the mollusks are preparing for their normal late spring spawning (Maciolek-Blake et al., 1981). Early and late active stages were also found late into the fall at Stations 1, 2, 11 and 15. These were the result of development in shipworms that were spawned and set during mid- to late-summer.

Most spent T. navalis occurred during September and October, as expected.

The annual and seasonal pattern of gonad development in T. navalis in Barnegat Bay from August, 1977 through November, 1984 is shown in Figure B-1. Development can begin as early as February in those shipworms which have survived the winter. Late active stages generally appear by March and ripe and spawning individuals can occur by May and June.

Shipworms which set in June and July are often ripe within four weeks of setting, initiating another spawning peak later in the summer. By late fall, most of the shipworms have spawned, but late setting individuals have begun early developmental activity. This usually ceases when the water cools, accounting for shipworms with what appear to be early and late active stages in late fall and winter.

Bankia gouldi. B. gouldi was examined for gonadal development from 15 of the 20 exposure panel stations during the present report period (Table B-2). There was no change in the number of stations from which B. gouldi was examined as compared to the previous report period, but there were some slight differences in the sites from which B. gouldi was collected. During this period, individuals from Stations 1 and 4A were examined, and during the previous period individuals from Stations 3 and 6 were examined.

Gonadal development followed a seasonal pattern similar to that reported throughout the study (e.g., Hillman et al., 1984). Early active stages were found from December (Stations 12, 13, 14 and 17) through May (Stations 11, 12 and 14). Those found

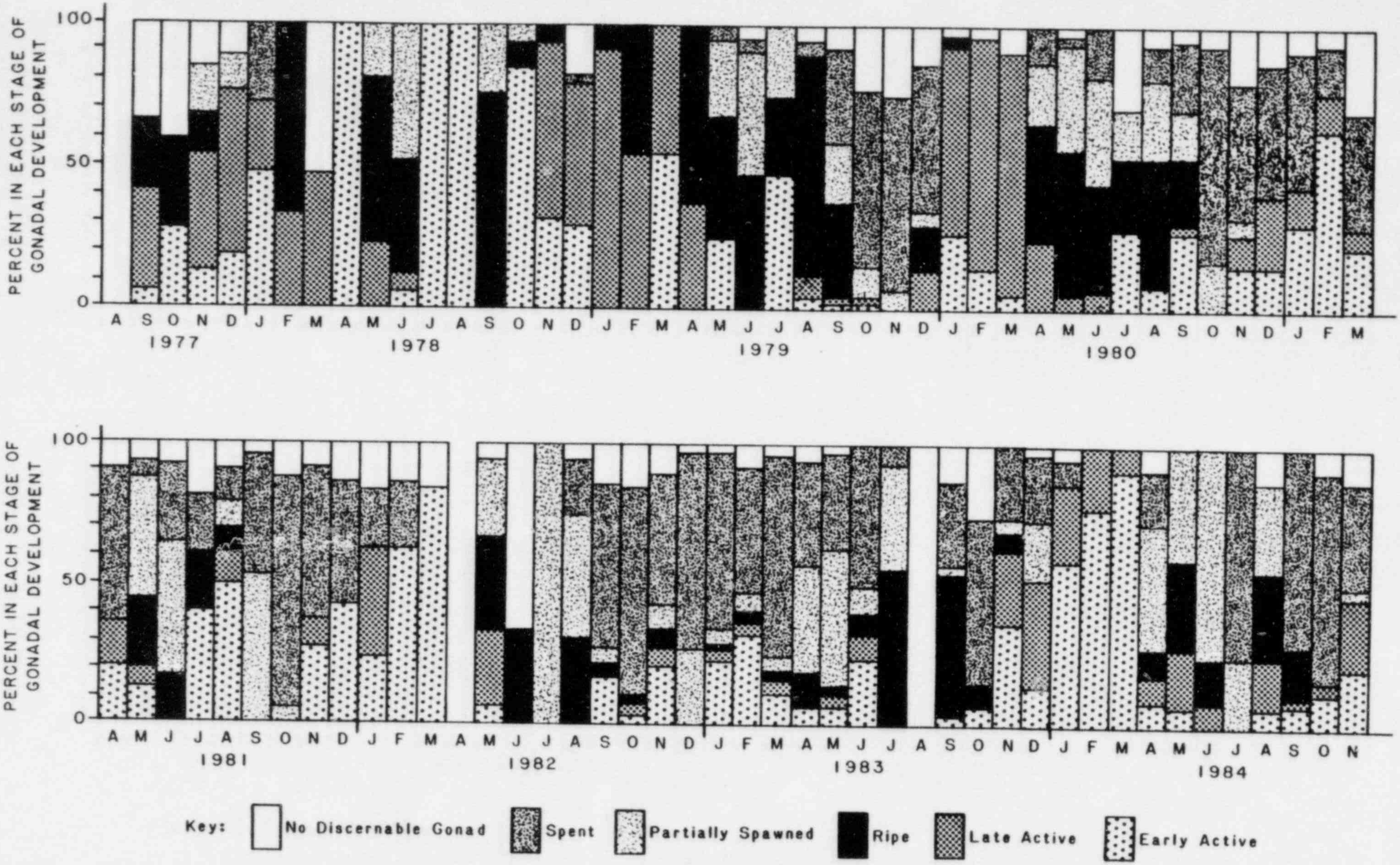

FIGURE B-1. PERCENT OF ALL SPECIMENS OF Teredo navalis IN EACH STAGE OF GONAD DEVELOPMENT FROM AUGUST, 1977 THROUGH NOVEMBER, 1984.

in December and January were probably in that stage from the previous fall. By June, spawning began to occur, although one partially spawned individual was found at Station 11 in May. It is difficult to say whether this was a shipworm which had remained in that condition from the previous fall or one which had actually begun spawning that soon.

Spawning continued through October. By September and October, most shipworms were in the partially spawned to spent stages. There was some early development activity carrying on into the fall.

In previous reports (e.g., Hillman et al., 1984) gonad developmental patterns of B. gouldi from Region 1, the thermally affected area (see Appendix A), were compared with patterns of development in shipworms from Regions 2, 4 and 5 combined. That comparison was carried out for the present report period, even though the plant was not operating throughout most of it. Figure B-2 shows the pattern of development from August, 1977 through November, 1984 in those shipworms collected from Region 1. Figure B-3 shows a similar pattern for shipworms collected from Regions 2, 4 and 5 combined. Again, no unusual differences in seasonal developmental patterns were observed.

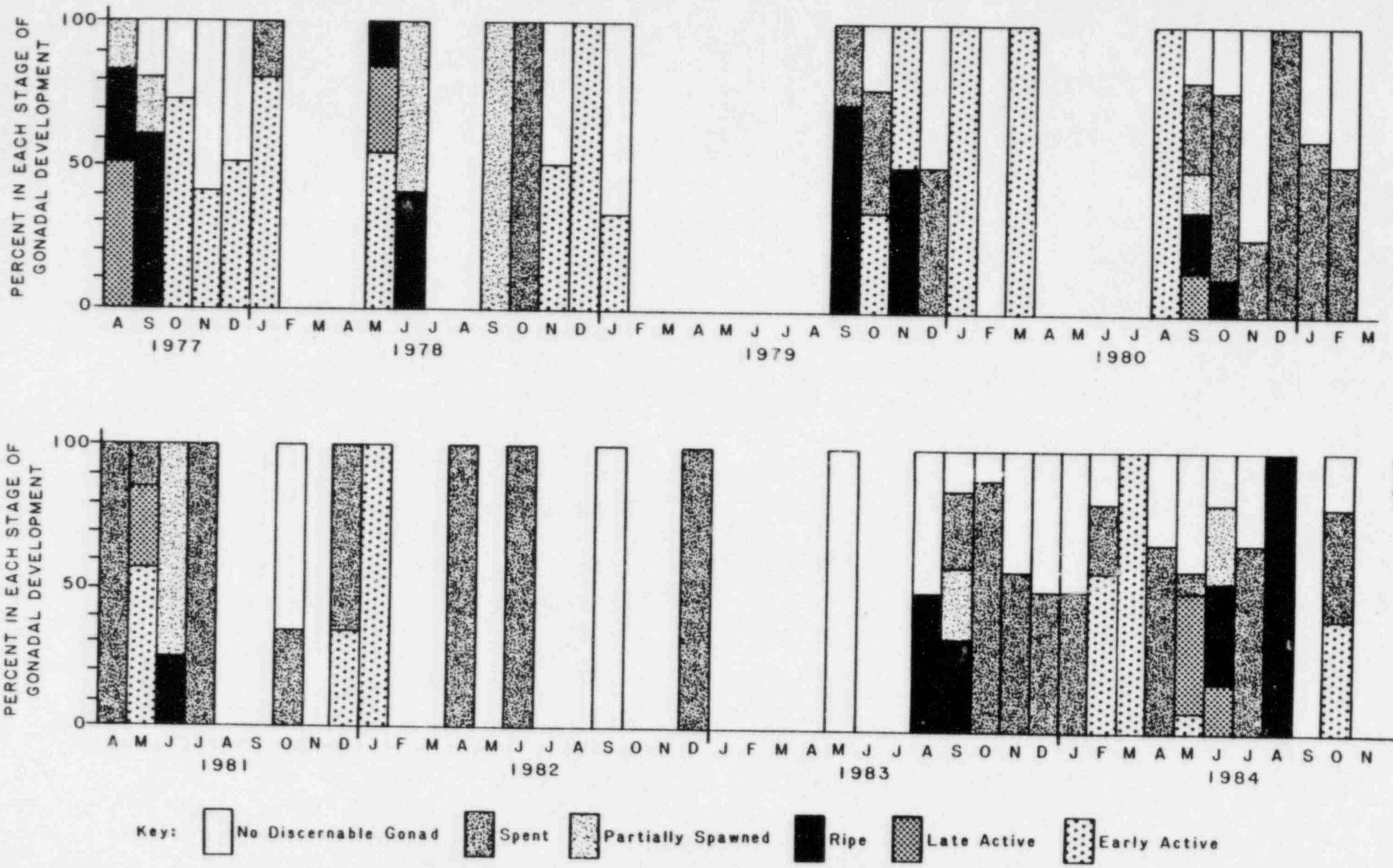

FIGURE B-2. PERCENT OF SPECIMENS OF *Bankia gouldi* FROM REGION I IN EACH STATE OF GONAD DEVELOPMENT FROM AUGUST, 1977 THROUGH NOVEMBER, 1984.

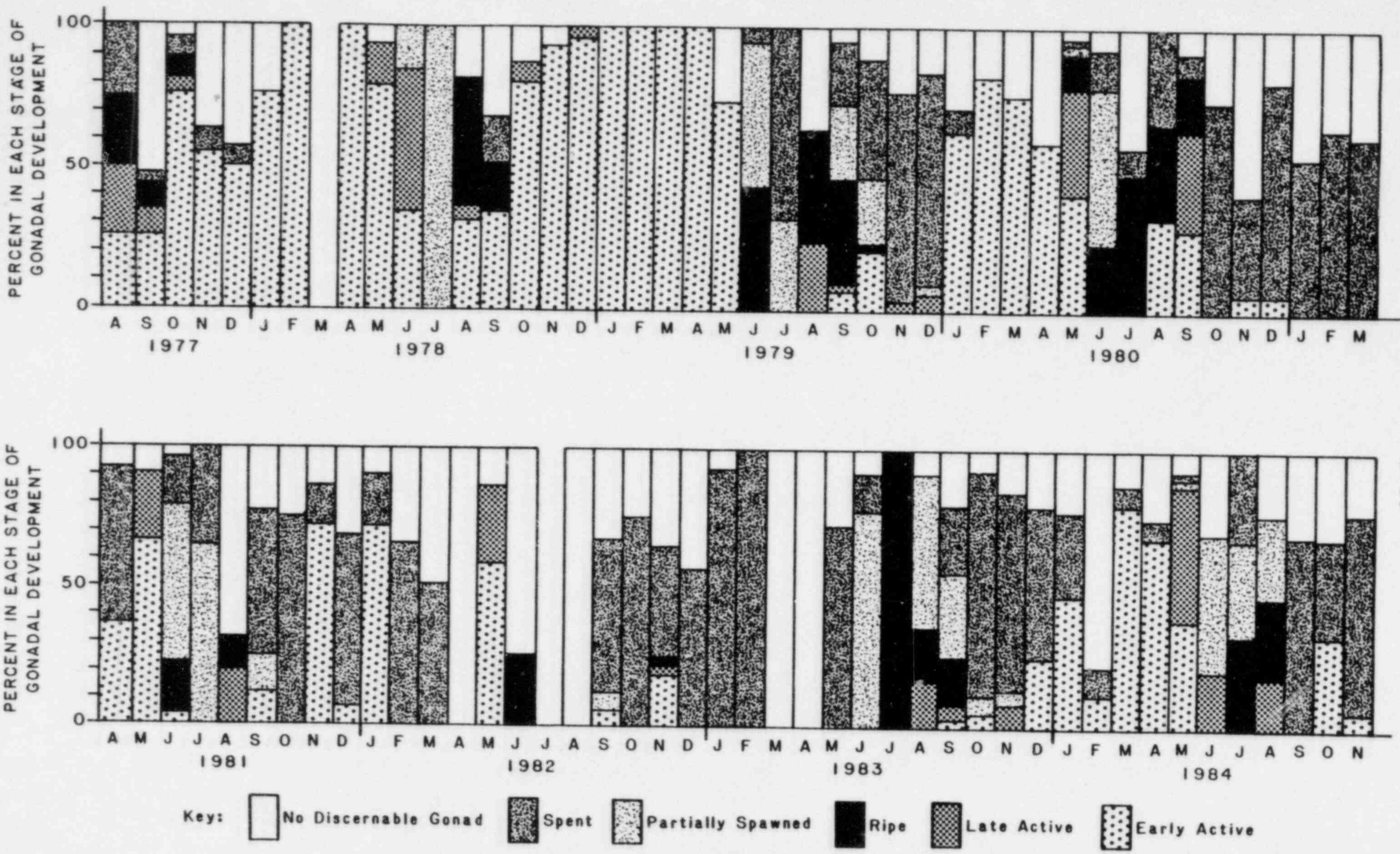

FIGURE B-3. PERCENT OF SPECIMENS OF Bankia gouldi FROM REGIONS 2, 4, AND 5 IN EACH STAGE OF GONAD DEVELOPMENT FROM AUGUST, 1977 THROUGH NOVEMBER, 1984.

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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, 1983 through November, 1984, 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 expo.ure 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 $\pm$ 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, 1984 were calculated and plotted for each station. A biological year is defined as July, Year A through June, Year B, and corresponds to the breeding season of the teredinids. The period of July, 1984 through November, 1984 was not included

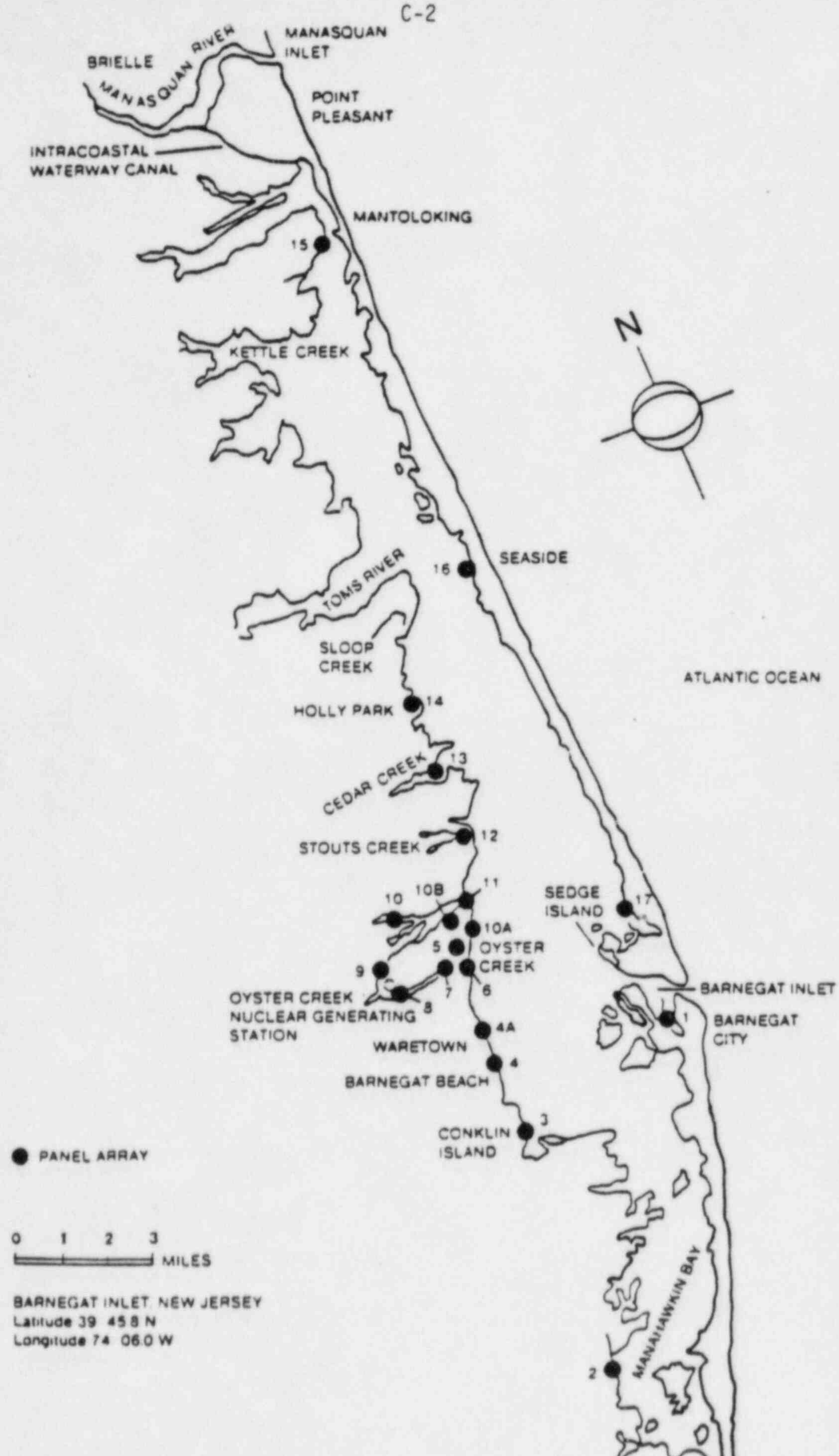

FIGURE C-1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHIC LOCATIONS OF EXPOSURE PANELS because it represents only 5 months of a 12 month period, and average values over this period are not comparable to the other averages calculated.

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.

E). Because of the extensive outage which began in February of 1983, we conducted an additional analysis this year to investigate the potential effect of the termination of power plant operation on water quality parameters. A dichotomous dummy variable was added to the data set corresponding to power plant status. This variable was assigned the value "0" (i.e., operational) for data collected prior to February 1983 and "1" (i.e., non-operational) for data collected since that time. An additional factorial ANOVA was carried out using this variable in place of bioyear.

Analyses of variance (ANOVAs) were carried out on each of the four water quality parameters (temperature, salinity, pH, dissolved oxygen) measured since July, 1975. In previous years, we conducted ANOVAs on both unsummarized (i.e., station, month) and summarized (i.e., region, season) factors and then combined the two ANOVAs to produce a residual mean square based on the combined fit which was more appropriate than a mean square based on summary factors alone. As the data set has grown over the years, the computing resources necessary to analyze the unsummarized factors have increased geometrically to the point where available capacity on the VAX-11/780 at Woods Hole Oceanographic Institute has been exceeded. Accordingly, the ANOVAs in this and subsequent reports will be performed on summarized factors only. All ANOVAs were carried out using the ANOVA procedure of SPSS-X (SPSS, Inc., 1983).

Multiple classification analyses (MCA) were then used to quantify the systematic variations detected by the analysis of variance procedures (SPSS, Inc., 1983).

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 $X_1, X_2, \ldots X_k$ be k sample means based on $N_1, N_2, \ldots N_k$ observations respectively. Let $M_1, M_2, \ldots, M_k$ 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 ν pairwise comparisons among $M_1, M_2, \ldots, M_k$. For example, to test H_0: M_i $i \neq j = 1, \ldots, k$ we must make $r = \frac{k(k-1)}{2}$ pairwise comparisons.

H_0 will be rejected at significance level α if

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

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

This procedure leads to the confidence 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, 1983, through November, 1984 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, 1983 (Table C-1) were more normal for the month than those recorded during December, 1982. The maximum temperature for the month was 9.1°C at Station 8. Stations 1 and 17 recorded temperatures of 9.0 and 8.9 during that same period. The minimum temperature for the month was 6.6°C at Stations 3 and 14. The mean temperature for December, 1983 was 7.6°C (Table C-13), which was considerably colder than the 14.4°C listed as the mean December water temperature for the bay in 1982 (Hillman, et. al., 1984).

By January, the water temperatures around the bay had dropped considerably. The maximum temperature for the period, 5.3°C, was recorded at Station 13 (Table C-2), and the minimum, 0.2°C, was at Station 2. The mean temperature of 2.5°C (Table C-13) was somewhat lower than the 4.4°C mean of last year.

Usually, the February water temperatures are the lowest of the year, especially during the first week of February. As the sun gets higher in the sky water temperatures rise noticeably through the month. During the present report period, water parameters were measured closer to the middle of the month than the beginning, and the higher temperatures in February (Table C-3) are a reflection of that later measurement. The mean of 5.8°C is quite a bit warmer than the 1.9°C recorded in February last year (Hillman, et. al., 1984).

Water temperatures rose only slightly into March (Table C-4), and the mean of 6.6°C (Table C-13) is less than a degree higher than the February mean, and very close to the mean temperature for the bay during March, 1983.

By the middle of April, water temperatures had risen to a maximum of 13.3°C at Stations 12, 14 and 17 (Table C-5), while the minimum was 8.0 at Station 1. The mean of 11.8°C (Table C-13) was close to what it was last year.

The mean May water temperature of 16.0°C (Table C-13) was somewhat lower than last year's mean of 17.6°C. The highest water temperature in May, 1984 was only 17.2°C at Station 4A (Table C-6), in contrast to 19.0°C recorded at Station 9 in May, 1983

TABLE C-1. WATER QUALITY AT EXPOSURE PANEL STATIONS DECEMBER, 1983

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	12/5/83	0905	9.0	29.1	9.0	9.2	8.1
2	12/5/83	0940	3.0	22.6	7.0	10.0	8.1
3	12/5/83	1012	3.0	24.2	6.6	10.2	8.1
4	12/5/83	1033	4.5	25.0	7.2	9.9	8.1
4A	12/5/83	1052	3.0	24.0	7.1	10.1	8.2
5	12/5/83	1109	3.0	20.8	7.8	10.0	8.0
6	12/5/83	1121	3.5	21.9	7.8	10.3	7.9
7	12/5/83	1136	2.5	15.1	8.0	11.0	7.3
8	12/5/83	1200	4.0	22.0	8.1	9.9	7.7
9	12/5/83	1222	5.5	21.1	9.1	7.8	7.0
10	12/5/83	1420	5.5	20.8	8.0	8.6	7.8
10A	12/5/83	1330	3.0	21.8	8.2	9.6	7.7
10B	12/5/83	1342	4.5	23.1	7.3	9.8	7.9
11	12/5/83	1400	3.0	21.2	7.3	9.6	8.1
12	12/5/83	1442	3.0	20.9	7.3	9.6	7.9
13	12/5/83	1505	3.0	20.8	6.8	9.3	7.9
14	12/5/83	1522	5.5	21.8	6.6	9.4	7.9
15	12/6/83	0850	4.5	17.9	7.3	10.6	7.7
16B	12/6/83	0920	5.5	14.0	7.1	11.1	7.6
17	12/6/83	0956	2.0	28.6	8.9	10.6	8.0

TABLE C-2. WATER QUALITY AT EXPOSURE PANEL STATIONS
JANUARY, 1984

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	1/9/84	0910	7.0	23.1	0.3	11.4	8.2
2	1/9/84	0945	3.5	21.2	0.2	12.0	8.1
3	1/9/84	1025	1.0	20.5	0.5	11.4	8.1
4	1/9/84	1055	3.0	24.9	1.2	11.6	8.2
4A	1/9/84	1115	1.5	23.1	2.0	11.4	8.1
5	1/9/84	1130	1.0	14.0	1.2	12.0	7.6
6	1/9/84	1150	1.3	14.1	0.7	11.6	7.3
7	1/9/84	1204	3.0	24.2	3.0	11.2	8.2
8	1/9/84	1225	2.0	22.4	3.0	10.8	8.2
9	1/9/84	1355	6.0	23.8	4.0	9.4*	7.8
10	1/9/84	1526	3.5	19.9	3.3	10.7	7.8
10A	1/9/84	1438	0.8	19.0	3.3	10.9	7.5
10B	1/9/84	1458	3.0	20.2	3.3	10.4	7.6
11	1/9/84	1510	1.0	17.6	2.3	11.6	7.9
12	1/9/84	1601	1.8	11.3	2.8	11.6	7.3
13	1/10/84	1128	2.0	9.8	5.3	13.0	7.4
14	1/10/84	1110	2.5	10.0	3.5	12.2	7.5
15	1/10/84	0858	3.0	15.0	2.4	12.8	7.5
16B	1/10/84	0935	3.5	17.2	4.2	9.4	7.4
17	1/10/84	1012	0.8	16.8	4.1	5.0	7.1

*Changed DO meters after Station 9. Air bubble under membrane.

TABLE C-3. WATER QUALITY AT EXPOSURE PANEL STATIONS FEBRUARY, 1984

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	2/13/84	0920	2.5	28.2	4.8	11.6	8.2
2	2/13/84	1000	2.0	19.8	5.3	11.6	8.2
3	2/13/84	1030	1.0	21.8	5.0	13.2	8.3
4	2/13/84	1050	3.0	21.8	5.0	12.2	8.1
4A	2/13/84	1100	1.5	17.5	5.0	12.6	8.3
5	2/13/84	1142	1.0	7.0	6.4	13.2	7.2
6	2/13/84	1200	1.5	11.8	3.6	13.8	8.1
7	2/13/84	1215	2.0	17.0	6.0	12.6	8.1
8	2/13/84	1234	1.5	3.3	7.2	13.3	6.7
9	2/13/84	1350	5.0	16.5	5.3	12.0	7.7
10	2/13/84	1523	3.0	17.1	5.3	12.6	7.9
10A	2/13/84	1420	0.8	14.6	5.3	12.8	8.0
10B	2/13/84	1440	2.0	16.9	5.3	13.2	8.2
11	2/13/84	1456	0.8	17.1	5.4	12.6	8.3
12	2/13/84	1550	1.5	15.5	5.0	12.4	7.9
13	2/14/84	1242	2.0	2.8	8.6	13.0	6.7
14	2/14/84	1225	3.0	14.2	6.8	13.1	8.3
15	2/14/84	0900	2.0	18.2	6.3	12.4	7.9
16B	2/14/84	0938	3.5	14.3	5.4	13.6	8.2
17	2/14/84	1040	1.0	24.8	8.8	12.1	8.3

TABLE C-4. WATER QUALITY AT EXPOSURE PANEL STATIONS
MARCH, 1984

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	3/19/84	0910	7.0	25.2	5.2	10.4	7.8
2	3/19/84	0945	5.5	19.2	6.0	9.5	7.7
3	3/19/84	1012	2.0	18.2	6.0	9.6	7.7
4	3/19/84	1033	4.0	18.5	6.0	9.4	7.6
4A	3/19/84	1050	2.5	18.0	6.2	9.8	7.6
5	3/19/84	1110	2.0	4.8	7.0	10.8	6.8
6	3/19/84	1123	3.0	11.5	6.2	11.2	7.1
7	3/19/84	1140	4.0	16.5	6.2	10.6	7.5
8	3/19/84	1200	3.0	16.2	6.8	10.5	7.5
9	3/19/84	1320	5.5	15.8	6.1	10.4	6.8
10	3/19/84	1438	4.9	15.0	7.0	10.4	7.1
10A	3/19/84	1345	2.0	13.5	8.5	10.2	7.3
10B	3/19/84	1400	3.8	17.1	7.1	9.8	7.7
11	3/19/84	1415	2.0	6.6	8.8	11.6	7.0
12	3/19/84	1500	3.0	16.2	6.5	11.2	7.7
13	3/19/84	1526	3.0	15.5	6.2	11.1	7.7
14	3/19/84	1545	3.5	16.5	6.2	11.0	7.8
15	3/20/84	0840	3.0	16.6	6.5	11.3	7.8
16B	3/20/84	0917	4.0	14.0	6.2	10.8	7.5
17	3/20/84	1055	1.5	21.5	7.5	9.8	7.8

TABLE C-5. WATER QUALITY AT EXPOSURE PANEL STATIONS
APRIL, 1984

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	4/16/84	0940	7.5	23.9	8.0	9.6	7.8
2	4/16/84	1034	6.5	17.2	10.2	9.8	7.6
3	4/16/84	1105	3.0	15.2	10.8	9.6	7.5
4	4/16/84	1130	4.8	15.2	11.0	8.8	7.2
4A	4/16/84	1155	3.0	14.1	11.4	9.0	7.5
5	4/16/84	1214	2.5	2.0	11.4	10.7	6.4
6	4/16/84	1244	3.5	2.1	11.4	10.8	6.4
7	4/16/84	1258	2.5	0.5	11.6	10.8	4.5
8	4/16/84	1324	3.5	1.1	11.9	10.6	5.1
9	4/16/84	1613	5.0	11.2	11.5	7.6	6.6
10	4/16/84	1506	5.0	7.5	13.0	8.7	6.4
10A	4/16/84	1525	2.5	12.1	12.8	9.8	7.4
10B	4/16/84	1536	4.0	11.0	12.1	9.6	7.2
11	4/16/84	1552	2.5	7.1	12.6	10.2	7.1
12	4/17/84	1217	3.5	14.5	13.3	9.4	7.5
13	4/17/84	1152	4.0	14.2	12.6	9.1	7.5
14	4/17/84	1125	3.0	12.0	13.3	9.6	7.5
15	4/17/84	0848	4.0	14.8	11.2	10.0	7.5
16B	4/17/84	0925	5.0	9.6	12.0	9.8	7.4
17	4/17/84	1010	2.0	20.0	13.3	8.4	7.8

TABLE C-6. WATER QUALITY AT EXPOSURE PANEL STATIONS MAY, 1984

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	5/14/84	0939	5.5	28.8	11.8	8.0	7.6
2	5/14/84	1025	5.5	20.0	17.0	7.6	8.1
3	5/14/84	1110	2.0	18.0	17.1	7.8	8.1
4	5/14/84	1138	3.0	20.0	17.0	7.4	8.0
4A	5/14/84	1200	2.0	19.9	17.2	6.6	7.5
5	5/14/84	1230	1.5	7.2	16.2	9.4	7.4
6	5/14/84	1252	2.0	9.3	16.9	9.4	7.8
7	5/14/84	1313	3.5	15.1	17.1	8.9	7.9
8	5/14/84	1337	2.0	15.1	16.7	9.0	7.9
9	5/14/84	1444	5.5	16.7	16.2	7.6	7.0
10	5/15/84	1343	4.0	16.1	15.3	7.2	7.4
10A	5/14/84	1518	1.5	16.9	17.0	9.8	8.0
10B	5/14/84	1530	3.0	17.1	17.1	9.6	8.1
11	5/14/84	1548	1.5	12.8	16.2	9.4	7.8
12	5/15/84	1308	2.5	14.9	16.0	9.3	8.2
13	5/15/84	1240	3.0	13.9	16.0	8.5	7.7
14	5/15/84	1208	2.0	12.2	15.8	8.8	7.7
15	5/15/84	0900	3.0	13.9	14.0	8.7	7.5
16B	5/15/84	0930	4.0	9.5	15.0	8.1	7.3
17	5/15/84	1012	1.0	24.0	13.8	7.9	7.9

TABLE C-7. WATER QUALITY AT EXPOSURE PANEL STATIONS
JUNE, 1984

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH[1]
1	6/11/84	0910	5.0	28.8	19.6	6.2	6.2*
2	6/11/84	0950	5.5	21.6	27.9	5.3	6.0*
3	6/11/84	1020	1.5	20.9	27.5	5.8	6.1*
4	6/11/84	1045	3.5	20.7	28.0	4.0	6.1*
4A	6/11/84	1100	2.0	20.7	28.0	5.4	6.4*
5	6/11/84	1120	1.2	13.0	27.3	6.8	6.3*
6	6/11/84	1133	2.0	13.8	28.0	6.6	6.3*
7	6/11/84	1148	3.0	16.7	26.5	5.6	6.0*
8	6/11/84	1210	2.0	16.8	27.0	5.6	6.1*
9	6/11/84	1340	5.0	16.3	25.2	4.1	6.6
10	6/11/84	1511	4.0	13.7	27.2	4.7	6.7
10A	6/11/84	1408	1.2	17.0	29.8	6.8	7.6
10B	6/11/84	1424	3.0	16.6	29.9	7.0	7.6
11	6/11/84	1440	2.0	11.9	30.3	7.0	7.3
12	6/11/84	1533	3.0	16.6	29.5	6.6	7.5
13	6/11/84	1600	2.5	12.7	28.9	5.4	6.9
14	6/12/84	1240	3.5	11.8	27.3	6.4	7.2
15	6/12/84	0925	3.0	14.8	26.9	6.4	7.3
16B	6/12/84	1000	4.0	11.0	27.0	6.3	7.2
17	6/12/84	1122	1.0	22.8	26.5	5.4	7.0

[1] Problems were experienced with the operation of pH meters on both days. Values identified with an asterisk are unusually low and probably represent erroneous readings.

TABLE C-8. WATER QUALITY AT EXPOSURE PANEL STATIONS
JULY, 1984

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	7/9/84	0906	5.0	27.0	19.0	6.9	7.8
2	7/9/84	0942	5.0	26.8	22.5	6.2	7.6
3	7/9/84	1015	1.5	19.0	22.9	6.1	7.5
4	7/9/84	1037	3.5	20.0	23.5	6.0	7.2
4A	7/9/84	1059	2.0	20.3	24.5	5.6	7.3
5	7/9/84	1117	1.0	8.4	22.0	7.2	6.9
6	7/9/84	1133	2.0	7.6	21.5	7.4	6.7
7	7/9/84	1149	3.5	14.0	24.2	6.0	7.0
8	7/9/84	1210	2.0	13.8	24.8	5.6	7.0
9	7/9/84	1232	5.5	16.0	24.2	5.4	7.1
10	7/9/84	1434	4.0	14.0	24.5	5.2	7.1
10A	7/9/84	1339	1.0	16.5	25.5	8.2	8.0
10B	7/9/84	1358	3.0	16.8	25.2	7.6	7.8
11	7/9/84	1410	1.0	13.8	24.2	8.3	7.8
12	7/9/84	1548	3.0	15.0	25.3	9.6	8.3
13	7/9/84	1458	2.5	11.8	24.2	7.2	7.1
14	7/9/84	1521	3.0	13.6	24.5	8.4	7.9
15	7/10/84	0858	4.0	10.7	23.3	7.3	7.0
16B	7/10/84	0930	4.0	11.2	23.5	7.0	7.2
17	7/10/84	1013	1.0	23.0	23.1	3.4	7.3

TABLE C-9. WATER QUALITY AT EXPOSURE PANEL STATIONS
AUGUST, 1984

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	8/13/84	0918	6.0	26.5	24.7	5.2	8.0
2	8/13/84	1015	5.0	23.2	26.1	5.3	7.2
3	8/13/84	1043	2.0	20.2	26.3	4.6	7.4
4	8/13/84	1104	3.0	17.5	26.1	3.4	7.1
4A	8/13/84	1126	2.5	17.2	26.5	4.4	7.3
5	8/13/84	1146	2.0	17.2	26.2	5.8	7.6
6	8/13/84	1158	2.0	17.2	26.4	6.2	7.7
7	8/13/84	1215	4.0	14.4	26.2	5.2	7.2
8	8/13/84	1233	3.0	6.6	25.2	7.4	7.0
9	8/13/84	1345	6.0	14.2	25.6	6.9	7.0
10	8/13/84	1515	5.0	13.7	26.2	4.2	6.9
10A	8/13/84	1417	2.0	17.9	26.2	6.4	7.6
10B	8/13/84	1433	3.5	18.0	26.6	6.4	7.6
11	8/13/84	1448	2.0	17.7	26.6	7.2	7.7
12	8/13/84	1535	3.5	17.2	26.3	6.6	7.5
13	8/13/84	1604	3.0	2.2	25.0	7.4	6.6
14	8/13/84	1630	4.0	13.7	26.1	7.7	7.8
15	8/14/84	0900	3.5	20.0	25.7	6.6	7.6
16B	8/14/84	0931	4.0	12.8	25.8	6.1	7.3
17	8/14/84	1010	2.0	25.0	25.9	4.8	7.8

TABLE C-10. WATER QUALITY AT EXPOSURE PANEL STATIONS
SEPTEMBER, 1984

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	9/10/84	0906	5.0	30.2	22.0	6.1	8.3
2	9/10/84	0950	5.0	24.5	21.4	5.8	7.9
3	9/10/84	1012	2.0	21.8	21.8	6.5	7.9
4	9/10/84	1032	3.5	21.1	21.5	6.1	8.0
4A	9/10/84	1050	2.5	21.3	21.6	6.7	8.0
5	9/10/84	1110	1.5	18.8	22.2	7.5	8.0
6	9/10/84	1122	2.0	18.9	22.2	7.2	7.9
7	9/10/84	1145	3.5	18.6	22.2	7.3	7.9
8	9/10/84	1217	2.5	16.9	22.0	7.4	7.8
9	9/10/84	1330	5.5	17.9	22.4	7.6	7.8
10	9/10/84	1445	4.0	12.8	22.9	7.5	7.6
10A	9/10/84	1350	2.0	19.6	22.8	8.0	8.1
10B	9/10/84	1405	3.5	20.0	22.5	8.1	8.1
11	9/10/84	1420	2.0	19.6	22.5	8.5	8.1
12	9/10/84	1510	3.0	19.0	23.0	7.4	7.9
13	9/10/84	1540	3.0	9.5	23.0	8.3	7.7
14	9/10/84	1610	4.5	17.2	22.9	7.4	8.0
15	9/11/84	0910	3.0	16.8	20.5	6.9	7.6
16B	9/11/84	0940	4.0	15.0	22.0	6.5	7.7
17	9/11/84	1018	1.5	24.8	22.8	4.0	7.5

TABLE C-11. WATER QUALITY AT EXPOSURE PANEL STATIONS OCTOBER, 1984

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	10/8/84	0900	6.0	28.8	15.1	7.7	7.8
2	10/8/84	0934	3.5	25.5	14.0	8.2	7.9
3	10/8/84	1004	1.5	23.3	14.2	8.1	7.8
4	10/8/84	1023	2.0	23.4	15.1	7.4	7.7
4A	10/8/84	1039	2.0	22.2	15.0	7.8	7.8
5	10/8/84	1054	1.2	20.1	14.6	8.4	7.8
6	10/8/84	1106	2.0	20.1	14.4	8.2	7.7
7	10/8/84	1124	3.0	18.8	14.9	8.2	7.7
8	10/8/84	1155	2.2	19.4	15.1	8.2	7.6
9	10/8/84	1314	5.0	20.4	15.1	7.9	7.5
10	10/8/84	1429	4.0	18.5	16.0	8.0	7.5
10A	10/8/84	1334	1.2	20.7	15.5	8.2	7.8
10B	10/8/84	1350	3.0	21.2	15.3	8.6	7.9
11	10/8/84	1406	1.2	21.3	14.8	8.6	7.9
12	10/8/84	1450	3.0	20.2	15.8	9.0	7.9
13	10/8/84	1526	2.0	16.5	17.0	8.6	7.8
14	10/8/84	1547	3.0	16.9	15.5	9.0	8.0
15	10/9/84	0906	3.0	20.5	15.0	8.2	7.9
16B	10/9/84	0933	4.0	14.7	15.0	8.5	7.8
17	10/9/84	1009	1.0	24.9	15.8	6.8	8.0

TABLE C-12. WATER QUALITY AT EXPOSURE PANEL STATIONS
NOVEMBER, 1984

Station	Date	Time	Depth in Feet	Salinity o/oo	Temperature (°C)	O_2 (mg/l)	pH
1	11/12/84	0903	6.5	25.6	12.2	7.6	7.9
2	11/12/84	0935	5.0	23.2	11.5	7.6	7.8
3	11/12/84	1005	2.5	23.6	11.2	8.0	7.8
4	11/12/84	1030	4.0	24.5	11.8	7.8	7.8
4A	11/12/84	1045	3.0	24.7	12.2	7.5	7.9
5	11/12/84	1100	2.0	22.4	11.8	7.9	7.8
6	11/12/84	1115	2.5	21.0	10.3	8.3	7.7
7	11/12/84	1134	4.5	20.7	11.5	8.4	7.7
8	11/12/84	1150	3.0	21.5	11.6	7.8	7.8
9	11/12/84	1312	6.0	22.5	11.5	8.5	7.9
10	11/12/84	1440	5.5	21.2	11.5	8.2	7.8
10A	11/12/84	1330	2.5	22.4	11.5	8.2	7.9
10B	11/12/84	1345	4.0	22.5	11.2	8.3	7.9
11	11/12/84	1422	2.5	22.3	10.0	9.0	8.0
12	11/12/84	1508	3.5	19.8	11.1	8.4	7.7
13	11/12/84	1528	2.5	15.1	10.8	9.0	7.6
14	11/12/84	1552	5.0	20.7	10.4	8.6	7.9
15	11/13/84	0857	4.0	21.3	9.8	8.4	7.8
16B	11/13/84	0928	4.5	18.5	8.6	8.4	7.6
17	11/13/84	1008	2.0	25.4	6.8	9.4	7.7

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, THROUGH NOVEMBER.

Parameter	Date	Maximum	Minimum	Mean	± Standard Deviation
	Dec. 1983	9.1	6.6	7.6	0.7
	Jan. 1984	5.3	0.2	2.5	1.4
	Feb.	8.8	3.6	5.8	1.2
	Mar.	8.8	5.2	6.6	0.8
	Apr.	13.3	8.0	11.8	0.9
	May	17.2	11.8	16.0	1.4
Temperature (°C)	Jun.	30.3	19.6	27.4	2.2
	Jul.	25.5	19.0	23.6	1.6
	Aug.	26.6	24.7	26.0	0.4
	Sep.	23.0	20.5	22.2	0.6
	Oct.	17.0	14.0	15.2	0.7
	Nov.	12.2	6.8	10.9	1.3
	Dec. 1983	29.1	14.0	22.0	3.6
	Jan. 1984	24.9	9.8	18.4	4.6
	Feb.	28.2	2.8	16.0	6.2
	Mar.	25.2	4.8	15.8	4.4
	Apr.	23.9	0.5	11.3	6.2
Salinity (o/oo)	May	28.8	7.2	16.1	4.9
	Jun.	28.8	11.0	16.9	4.4
	Jul.	27.0	7.6	16.0	4.2
	Aug.	26.5	2.2	16.6	5.5
	Sep.	30.2	9.5	19.2	4.3
	Oct.	28.8	14.7	20.9	3.2
	Nov.	25.6	15.1	21.9	2.4
	Dec. 1983	8.2	7.0	7.9	0.3
	Jan. 1984	8.2	7.1	7.7	0.4
	Feb.	8.3	6.7	7.9	0.6
	Mar.	7.8	6.8	7.5	0.4
	Apr.	7.8	4.5	7.0	0.7
pH	May	8.2	7.0	7.7	0.3
	Jun.	7.6	6.0	6.7	0.5
	Jul.	8.3	6.7	7.4	0.5
	Aug.	8.0	6.6	7.4	0.4
	Sep.	8.3	7.5	7.9	0.2
	Oct.	8.0	7.5	7.8	0.3
	Nov.	8.0	7.6	7.8	0.1

TABLE C-13. (Continued)

Parameter	Date	Maximum	Minimum	Mean	± Standard Deviation
	Dec. 1983	11.1	7.8	9.8	0.8
	Jan. 1984	12.8	5.0	11.0	1.6
	Feb.	13.8	11.6	12.7	0.7
	Mar.	11.6	9.4	10.5	0.6
Dissolved Oxygen (mg/l)	Apr.	10.8	7.6	9.6	0.8
	May	9.8	6.6	8.5	0.9
	Jun.	7.0	4.0	5.9	0.9
	Jul.	8.4	3.4	6.7	1.3
	Aug.	7.7	3.4	5.9	1.2
	Sep.	8.5	4.0	7.0	1.0
	Oct.	9.0	6.8	8.2	0.5
	Nov.	9.4	7.5	8.3	0.4

(Hillman, et. al., 1984). The minimum again in May was at Station 1, which had a water temperature of 11.8°C by the middle of the month.

The warmest water of the year was recorded in June, 1984. The mean temperature of 27.4°C (Table C-13) was quite a bit warmer than the mean of 22.6 for June, 1983. Station 11 had the warmest water, with a maximum of 30.3°C (Table C-7). The minimum temperature was again at Station 1, with a temperature of 19.6°C.

Temperatures dropped slightly in July, and the mean was at 23.6° (Table C-13), with the maximum of 25.3°C being recorded at Station 12 (Table C-8).

The mean water temperature, and water temperatures at most of the stations, rose again in August. By mid-month, the mean water temperature was 26.0°C (Table C-13), with the warmest water 26.0°C, recorded at Stations 10B and 11 (Table C-9).

Water temperatures throughout the area were quite uniform in September, when the mean water temperature was 22.2°C (Table C-13). This was several degrees cooler than the mean water temperature of 28.2°C for the bay in September, 1983 (Hillman, et. al., 1984), the highest mean water temperature of the report period.

Water temperature dropped sharply through October (Table C-1) and November (Table C-12) with means of 15.2°C and 10.9°C respectively (Table C-13). The October mean temperature was quite a bit lower than the mean of 20.9°C for October, 1983 (Hillman, et. al., 1984), but by November the water was at about the same temperature as in November, 1983.

Ice cover was quite extensive in January, 1984. Stations 3, 4, 4A, 5, 6, 7, 9, 10A, 10B, 12, 16 and 17 reported coverage, and Stations 11 and 14 had ice in the area. No ice was reported during any other month.

The average temperature at each station for the bioyear July, 1983 through June, 1984 is shown in Figure C-2. Average temperatures were fairly uniform throughout the bay except at Station 1, where the water was somewhat cooler. Temperatures tended to be slightly warmer on the west side of the bay. This is reflected in Figure C-3, which shows the average water temperatures for the various regions (see Appendix A). Regions 1 and 4 are the westernmost regions, and have the higher average temperatures.

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, water temperatures at Station 8 have been elevated above those at Stations 2 and 15 86 percent of the time, above those at Stations 17 79 percent of the time, and above those at Stations 9 and 12 72 percent of the time. Since the plant was not in operation for almost two years, some of the elevation was due to normally higher ambient temperatures at Station 8 than at some of the other stations.

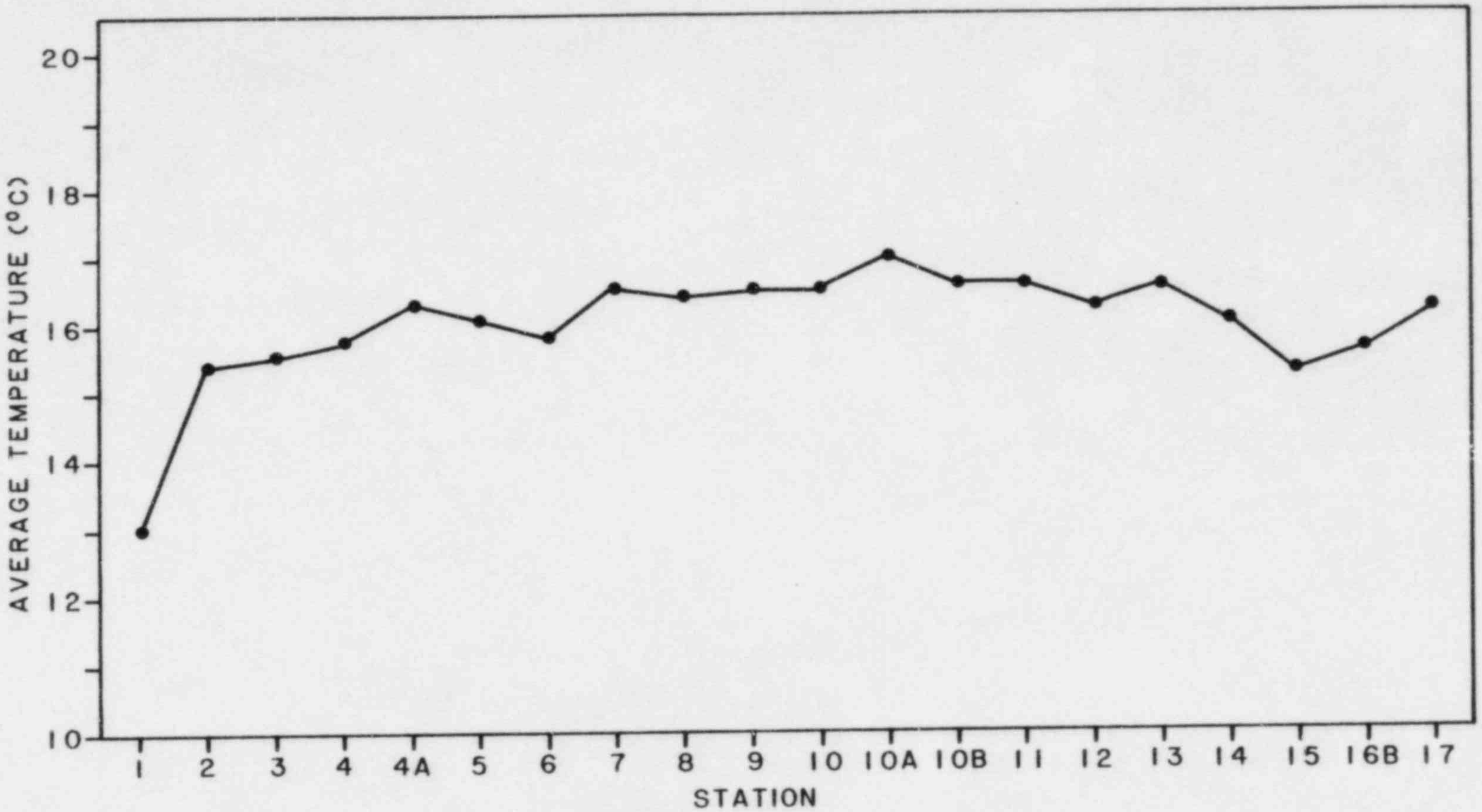

FIGURE C-2. AVERAGE WATER TEMPERATURE AT EACH EXPOSURE PANEL STATION CALCULATED FOR THE BIOLOGICAL YEAR JULY, 1983 THROUGH JUNE, 1984. NUMBER OF OBSERVATIONS IS 12.

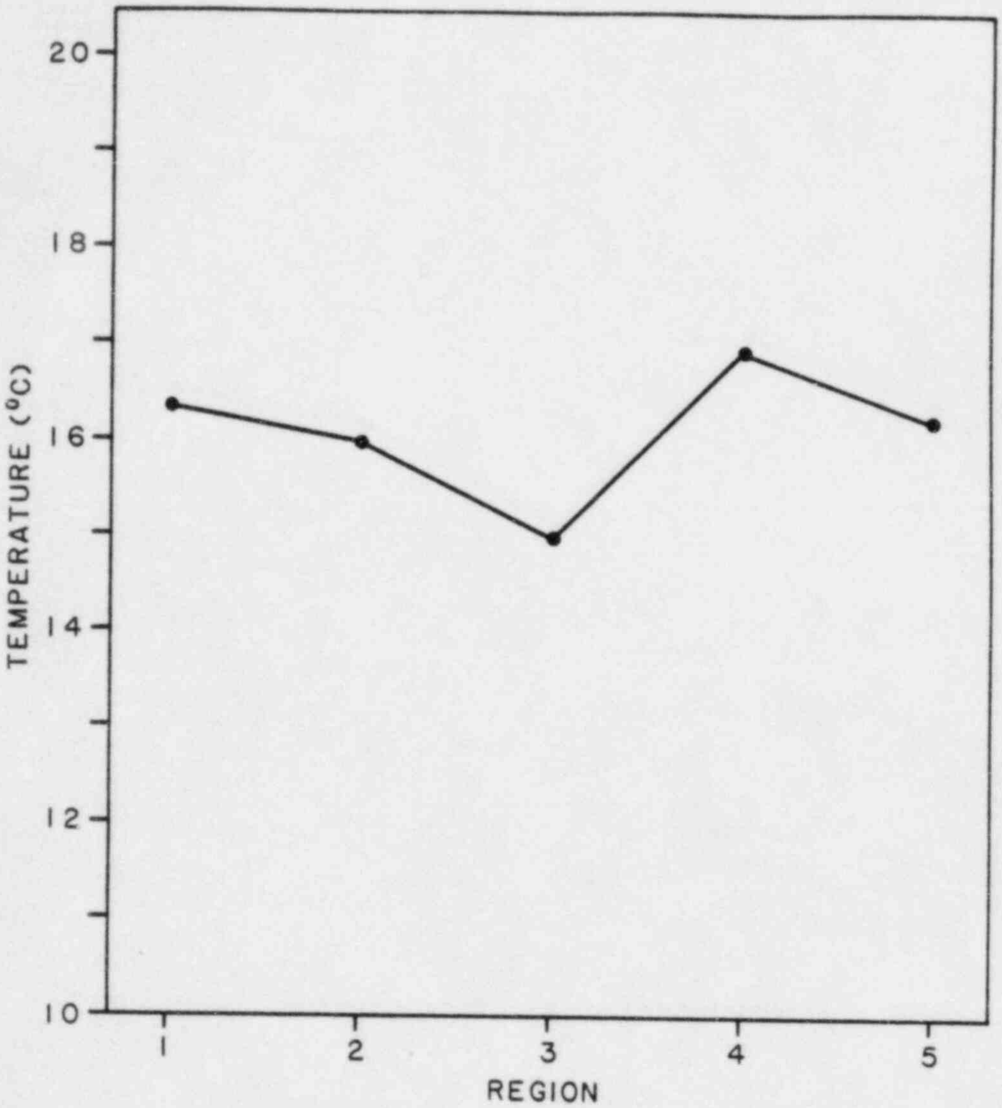

FIGURE C-3. AVERAGE WATER TEMPERATURE FOR STATIONS GROUPED INTO REGIONS FOR BIOLOGICAL YEAR JULY, 1983 THROUGH JUNE, 1984

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

Station 8 Compared To:	Station 2	Station 9	Station 12	Station 15	Station 17
Number of Observations					
Lower Than	14	19	27	9	21
Equal To	1	12	3	6	2
0.1 to 0.9°C Higher	16	10	12	13	8
1.0 to 1.9°C Higher	12	12	13	14	16
2.0 to 2.9°C Higher	10	16	12	13	14
3.0 to 3.9°C Higher	18	18	21	14	11
4.0 to 4.9°C Higher	21	17	7	20	18
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	110	111	109	110	110
Number of Times Elevated	95	80	79	95	87
Percent of Times Elevated	86	72	72	86	79
Number of Times 3.0-5.9°C	49	40	37	49	39
Percent of Times 3.0-5.9°C	45	36	34	45	35

The results of the factorial ANOVAs on temperature data are shown in Table C-15. All three main effects (region, season, bioyear) were highly significant, with season being the most important based on an examination of the mean square values. This result is expected and is consistent with our observations in previous reports (Hillman, et. al., 1984). Multiple classification analysis indicated that season was the most important controlling variable for temperature, accounting for nearly 80% of the observed variation. In addition, the two most recent complete bioyears (i.e. bioyears 8 and 9) have averaged over 1°C warmer than the mean annual temperature since the initiation of the study.

When the ANOVA was repeated using a dummy variable for power plant operating status (labelled "outage", Table C-15), all three main effects of region, season, and outage were very highly significant. Further examination of this result using multiple classification analysis indicated that, contrary to what might be expected, mean temperatures in the Bay have been warmer since OCNGS has been off-line. Although statistically significant, this effect was responsible for less than 1% of the total variation in temperature and was far less important than season. These results underscore the lack of overall impact on Bay temperatures due to OCNGS operation.

One-way ANOVAs were also used to examine underlying patterns of variation in temperature by station, month, and bioyear. These were run on all data collected since July, 1975. No significant difference was found among stations ($p=.2959$) but month was highly significant ($p<.001$) with all months being significantly different. The analysis indicated the following pattern:

Month	Mean °C
February	1.07
January	2.49
March	4.98
December	7.96
April	10.26
November	12.97
May	15.76
October	17.61
June	21.81
September	24.15
July	25.62
August	27.59

These results are similar to those reported in previous years (Hillman, et al., 1984).

TABLE C-15. ANALYSIS OF VARIANCE OF TEMPERATURES RECORDED AT EXPOSURE PANEL STATIONS IN BARNEGAT BAY FROM JULY, 1975 THROUGH NOVEMBER, 1984.

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	114328.729	14	8166.338	468.3110	0.000
Region	1412.676	4	353.169	20.25301	0.000
Season	111293.410	3	37097.803	2127.429	0.000
Bioyear	1593.494	7	227.642	13.05447	0.000
2-Way Interactions	2758.017	61	45.213	2.592830	0.000
Region/Season	177.559	12	14.797	0.8485312	0.600
Region/Bioyear	335.826	28	11.994	0.6878019	0.889
Season/Bioyear	2236.565	21	106.503	6.107581	0.000
3-Way Interactions	563.228	79	7.129	0.4088501	1.000
Region/Season/Bioyear	563.228	79	7.129	0.4088501	1.000
Explained	117649.974	154	763.961	43.81049	0.000
Residual	27447.181	1574	17.438		
Total	145097.155	1728	83.968		

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	130295.107	8	16286.888	927.7193	0.000
Region	1487.210	4	371.802	21.17828	0.000
Season	128780.905	3	42926.968	2445.168	0.000
Outage	681.416	1	681.416	38.81419	0.000
2-Way Interactions	548.547	19	28.871	1.644517	0.039
Region/Season	190.575	12	15.881	0.9046136	0.542
Region/Outage	230.646	4	57.661	3.284460	0.011
Season/Outage	121.499	3	40.500	2.306906	0.075
3-Way Interactions	38.781	12	3.232	0.1840821	0.999
Region/Season/Outage	38.781	12	3.232	0.1840821	0.999
Explained	130882.434	39	3355.960	191.1592	0.000
Residual	34391.884	1959	17.556		
Total	165274.319	1998	82.720		

Analysis of temperature data by bioyear indicated marginally significant differences among years ($p=.0417$). The magnitude of the difference was so small, however, that the Student-Newman-Keuls test was not able to define homogeneous subsets of bioyears.

Salinity

The twenty stations at which teredinids are collected reflect the broad salinity range found throughout Barnegat Bay. Salinities at the stations are shown in Tables C-1 through C-12. Mean salinities for the bay throughout the report period are shown in Table C-13.

As with temperature, there is a seasonal cycle to the salinity pattern, with salinities being highest in the late fall and early winter and lowest in the early spring. The mean salinity of 22.0 °/oo in December, 1983 (Table C-13) was the highest mean salinity recorded during the present report period. Salinities fell generally throughout the area through January, February and March, 1984 and reached a mean low of 11.3 °/oo in April.

Mean salinities from May through August were in the 16 to 17 °/oo range. By September the mean salinity rose to 19.2 °/oo, and stood at 21.9 °/oo in November, 1984.

The minimum salinities at which Teredo navalis will grow and reproduce have been reported as 5 to 10 °/oo (Turner, 1973; Richards, et. al., 1978) and 10 to 14 °/oo for Bankia gouldi (Allen, 1924; Turner, 1973). For T. bartschi, the range is 7 to 10 °/oo (Hoagland, et. al., 1980), but in this area temperature is far more critical for T. bartschi. Salinities rarely reached the critical range throughout the report period, although there were records of salinities dropping below 10 °/oo. In January, for example, the salinity at Station 13 was recorded at 9.8 °/oo (Table C-2).

The frequency of sub-10 °/oo levels increased through the winter. Station 13 had a salinity of 2.8 °/oo in February, and Stations 8 and 5 were recorded as having salinities of 3.3 °/oo and 7.0 °/oo respectively during that month (Table C-3).

Salinities in March (Table C-4) tended to be more uniform throughout the bay, and only Stations 5 and 11 had salinities below 10°/oo (4.8 °/oo and 6.6 °/oo, respectively).

In April, a wide range of salinities were recorded at the various stations. The standard deviation was 6.2 °/oo around a mean of only 11.3 °/oo (Table C-13). Seven of the 20 stations had salinities below 10 °/oo in April. They included Stations 5 (2.0 °/oo), 6 (2.1 °/oo), 7 (0.5 °/oo), 8 (1.1 °/oo), 10 (7.5 °/oo), 11 (7.1 °/oo), and 16B (9.6 °/oo) Table C-5).

By May, salinities increased considerably, and the only stations at which the salinity was below 10 °/oo were Stations 5 (7.2 °/oo), 6 (9.3 °/oo) and 16B (9.5 °/oo) (Table C-6).

Stations 5 and 6 again had salinities below 10 °/oo in July, when salinities were 8.4 °/oo and 7.6 °/oo respectively (Table C-8). In August, Station 13 recorded an unusually low 2.2 °/oo (Table C-9). The salinity at Station 8 during that month was only 6.6 °/oo.

As salinities in the area rose through the fall, the only other sub-10 °/oo reading was at Station 13 in September, where the salinity was recorded at 9.5 °/oo (Table C-10).

Average salinities at each exposure panel station, calculated for the bioyear from July, 1983 through June, 1984 are shown in Figure C-4, and the average salinity for each region for the bioyear is plotted in Figure C-5. The patterns are similar to what has been shown in previous years (e.g., Hillman, et al., 1984), with salinities tending to be higher on the eastern side of the bay, especially at Stations 1 and 17.

The results of the factorial ANOVAs for salinity are shown in Table C-16. As in previous years (Hillman, et. al., 1984) all three main effects and two-way interaction terms were significant. Based on the relative magnitudes of the mean square, region was the most important determinant of salinity, accounting for approximately 18% of the total variation according to the results of the multiple classification analysis.

When bioyear was replaced with a dummy variable for OCNGS operating status, all three main effects were again significant (Table C-16). Multiple classification analysis indicated that salinities were significantly lower in the bay during the outage period. Using one-way ANOVA, the Region 1 stations and non-Region 1 stations were examined separately and the same pattern of significance was found in both cases. This indicates that any decrease in salinities in Region 1 which may be attributable to the OCNGS outage is also part of a more widespread general salinity decrease in the bay in recent years.

Examination of the variation in salinity among stations using all data collected since 1975 via ANOVA and SNK produced the following pattern of significance (stations joined by a single line are not significantly different at $p<.05$):

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

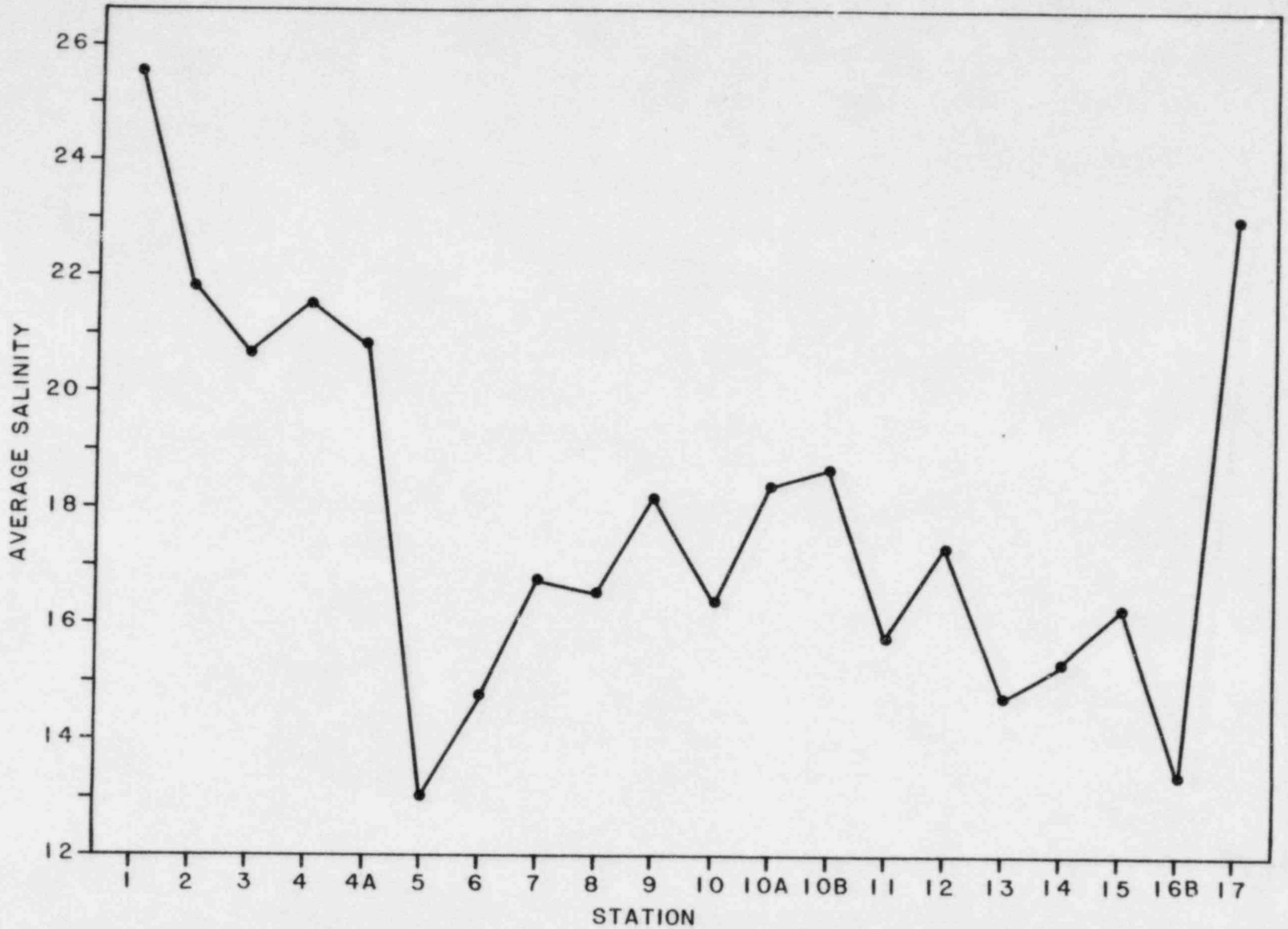

FIGURE C-4. AVERAGE SALINITY AT EACH EXPOSURE PANEL STATION CALCULATED FOR THE BIOLOGICAL YEAR JULY, 1983 THROUGH JUNE, 1984. NUMBER OF OBSERVATIONS IS 12.

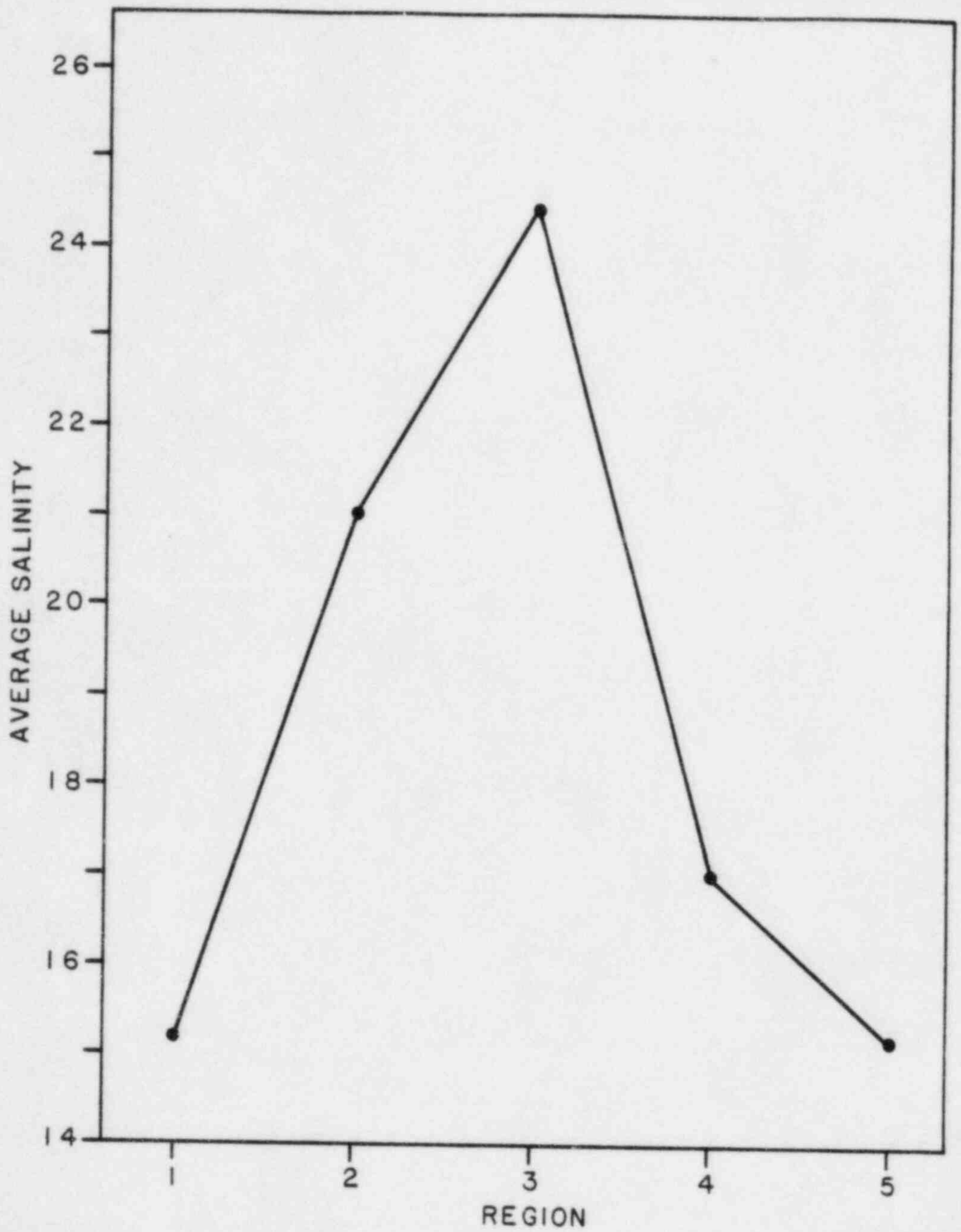

FIGURE C-5. AVERAGE SALINITY FOR STATIONS GROUPED INTO REGIONS FOR BIOLOGICAL YEAR JULY, 1983 THROUGH JUNE, 1984

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, 1984.

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	27031.773	14	1930.841	138.5196	0.000
Region	11240.343	4	2810.086	201.5971	0.000
Season	7433.049	3	2477.683	177.7503	0.000
Bioyear	8135.530	7	1162.219	83.37818	0.000
2-Way Interactions	10028.766	61	164.406	11.79457	0.000
Region/Season	369.560	12	30.797	2.209370	0.009
Region/Bioyear	828.082	28	29.574	2.121680	0.001
Season/Bioyear	8781.860	21	418.184	30.00073	0.000
3-Way Interactions	1347.940	79	17.063	1.224075	0.092
Region/Season/Bioyear	1347.940	79	17.063	1.224075	0.092
Explained	38408.480	154	249.406	17.89250	0.000
Residual	21940.177	1574	13.939		
Total	60348.657	1728	34.924		

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	21579.699	8	2697.462	121.4969	0.000
Region	12733.343	4	3183.336	143.3812	0.000
Season	7180.430	3	2393.477	107.8050	0.000
Outage	1377.452	1	1377.452	62.04209	0.000
2-Way Interactions	4309.765	19	226.830	10.21668	0.000
Region/Season	452.941	12	37.745	1.700082	0.061
Region/Outage	838.546	4	209.637	9.442279	0.000
Season/Outage	2991.761	3	997.254	44.91749	0.000
3-Way Interactions	162.751	12	13.563	0.6108764	0.835
Region/Season/Outage	162.				
Explained	26052.215	39	668.006	30.08776	0.000
Residual	43493.524	1959	22.202		
Total	69545.739	1998	34.808		

These results are similar to those reported previously (Hillman, et. al., 1984) and clearly show stations to the north of OCNGS to have significantly lower salinities. Station 1, at Barnegat Inlet, has significantly higher salinities than all other stations.

Repeating this analysis for the most recent year's data (December, 1983 - November, 1984) produced a slightly different pattern:

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

the primary differences appear to be a shift of Stations 5, 6, 8 and 11 to relatively lower salinities. This would appear to be consistent with OCNGS being off-line but, as indicated by the overlapping homogeneous groups, the magnitude of the change is not statistically significant.

One-way ANOVA and SNK of salinities by month produced the following pattern of significance:

FEB APR JAN MAR MAY JUN DEC JUL NOV AUG OCT SEP

this pattern is generally similar to that reported last year (Hillman, et. al., 1984), as was the pattern of salinity variation by bioyear:

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

pH

pH values values are generally uniform seasonally and throughout the area. (Tables C-1 through C-13). The lowest mean pH recorded during the report period was 6.7 in June, 1984, and the highest was 7.9 in December, 1983 and February and September, 1984 (Table C-13). Unusually low pH values occurred in April, 1984 at Stations 7 (4.5) and 8 (5.1) (Table C-5). Other low pH's (6.0 to 6.2) were reported at several stations in June (Table C-7), but were attributed to problems with the pH meter.

The results of the factorial ANOVAs on pH are given in Table C-17. All three main effects were highly significant both for the analysis using bioyear and for the analysis using a dummy variable to represent OCNGS operating status. Bioyear was the most important single factor based on mean square values; however, neither ANOVA explained much of the variation in pH (<20% for region-season-bioyear and <3% for region-season-outage). Variation in pH, though statistically significant, continued to be of insufficient magnitude to affect teredinid populations (Maciolek-Blake, et. al., 1982; Hillman, et. al., 1983).

Further analysis of pH patterns via one-way ANOVA and SNK indicated no clear pattern of variation among stations:

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

Similarly, there was no clear pattern of significant variation by month:

JAN FEB SEP DEC APR OCT JUN NOV JUL MAR AUG MAY

although some differences were apparent when the data were examined by bioyear, these did not comprise any directed temporal pattern of change in the bay:

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

Dissolved Oxygen

Dissolved oxygen levels tend to be lower in the summer when the water is warmer and can hold less oxygen, and highest when water temperatures are lowest in the winter. Dissolved oxygen levels at the 20 exposure panel stations for the report period are shown in Tables C-1 through C-12, and the maximum, minimum and mean levels are given in Table C-13.

At no time during the present report period was dissolved oxygen seen to be an especially critical problem. There were some unusually low readings at various times throughout the period, however. For example, in January at Station 17, when levels of

TABLE C-17. ANALYSIS OF VARIANCE OF pH RECORDED AT EXPOSURE PANEL STATIONS IN BARNEGAT BAY FROM JULY, 1975 THROUGH NOVEMBER, 1984.

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	94.113	14	6.722	37.26306	0.000
Region	5.373	4	1.343	7.445654	0.000
Season	10.116	3	3.372	18.69088	0.000
Bioyear	77.122	7	11.017	61.07148	0.000
2-Way Interactions	92.526	61	1.517	8.407915	0.000
Region/Season	4.789	12	0.399	2.212146	0.009
Region/Bioyear	8.563	28	0.306	1.695255	0.013
Season/Bioyear	79.226	21	3.773	20.91253	0.000
3-Way Interactions	17.868	79	0.226	1.253704	0.069
Region/Season/Bioyear	17.868	79	0.226	1.253704	0.069
Explained	204.507	154	1.328	7.361093	0.000
Residual	283.955	1574	0.180		
Total	488.461	1728	0.283		

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	16.913	8	2.114	7.916521	0.000
Region	5.983	4	1.496	5.601374	0.000
Season	4.052	3	1.351	5.057946	0.002
Outage	6.593	1	6.593	24.68734	0.000
2-Way Interactions	27.713	19	1.459	5.461820	0.000
Region/Season	4.745	12	0.395	1.480662	0.124
Region/Outage	2.188	4	0.547	2.048667	0.085
Season/Outage	20.647	3	6.882	25.77251	0.000
3-Way Interactions	3.554	12	0.296	1.109009	0.348
Region/Season/Outage	3.554	12	0.296	1.109009	0.348
Explained	48.179	39	1.235	4.626022	0.000
Residual	523.144	1959	0.267		
Total	571.323	1998	0.286		

dissolved oxygen were generally high throughout the area, the recorded level was 5.0 mg/l (Table C-2). In July, again at Station 17, the dissolved oxygen level was recorded at 3.4 mg/l (Table C-8), and in August it was that same level at Station 4 (Table C-9).

The results of the factorial ANOVAs for dissolved oxygen are shown in Table C-18. For the analysis using bioyear, all three main effects were very highly significant, with seasonal variation being by far the most important factor affecting dissolved oxygen concentrations. Based on the results of the multiple classification analysis, season accounted for nearly 55% of the total variation in dissolved oxygen in the bay. This is clearly attributable to the variation in oxygen solubility with temperature with lowest oxygen values occurring during the warmer months and seasonal maxima during late winter.

When the analysis was repeated replacing bioyear with a dummy dichotomous variable reflecting OCNGS operating status, the results were similar, with all three main effects being very highly significant. Dissolved oxygen values have decreased slightly since OCNGS has been off-line; this is apparently as a result of the recently elevated bay temperatures discussed above.

One-way ANOVA by station indicated no significant differences (p=.327). When this analysis was repeated by month, a clear pattern of relationships was apparent:

JUL AUG SEP JUN OCT MAY NOV APR DEC JAN MAR FEB

this pattern is consistent with both previous reports (Hillman, et. al., 1984) and the relationship between dissolved oxygen and water temperature discussed above.

When the data were analyzed by bioyear, the pattern of significant differences was also consistent with earlier observations on temperature:

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

the two most recent bioyears, which were characterized by elevated temperatures, had correspondingly decreased dissolved oxygen concentrations.

TABLE C-18. ANALYSIS OF VARIANCE OF DISSOLVED OXYGEN RECORDED AT EXPOSURE PANEL STATIONS IN BARNEGAT BAY FROM JULY, 1975 THROUGH NOVEMBER, 1984.

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	7242.052	14	517.289	245.8654	0.000
Region	79.288	4	19.822	9.421258	0.000
Season	6433.236	3	2144.412	1019.230	0.000
Bioyear	909.180	7	129.883	61.73276	0.000
2-Way Interactions	809.092	61	13.264	6.304231	0.000
Region/Season	53.329	12	4.444	2.112263	0.014
Region/Bioyear	76.840	28	2.744	1.304340	0.133
Season/Bioyear	675.445	21	32.164	15.28742	0.000
3-Way Interactions	147.270	79	1.864	0.8860377	0.751
Region/Season/Bioyear	147.270	79	1.864	0.8860377	0.751
Explained	8198.415	154	53.236	25.30306	0.000
Residual	3311.623	1574	2.104		
Total	11510.037	1728	6.661		

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	8130.187	8	1016.273	365.3722	0.000
Region	97.988	4	24.497	8.807236	0.000
Season	7795.049	3	2598.350	934.1628	0.000
Outage	388.668	1	388.668	139.7344	0.000
2-Way Interactions	87.181	19	4.588	1.649650	0.038
Region/Season	56.105	12	4.675	1.680923	0.065
Region/Outage	20.008	4	5.002	1.798339	0.126
Season/Outage	9.585	3	3.195	1.148685	0.328
3-Way Interactions	25.157	12	2.096	0.7537204	0.699
Region/Season/Outage	25.157	12	2.096	0.7537204	0.699
Explained	8242.525	39	211.347	75.98374	0.000
Residual	5448.908	1959	2.781		
Total	13691.433	1998	6.853		

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