ANNUAL REPORT

For the Period December 1, 1981 to November 30, 1982

on

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

to

GPU Nuclear Corporation

May 15, 1983

by

R.E. Hillman, C.I. Belmore and R.A. McGrath

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## MANAGEMENT SUMMARY

The study conducted by Battelle's New England Marine Research Laboratory of the populations of woodboring mollusks in Barnegat Bay, New Jersey, began in June, 1975, at the request of the Jersey Central Power & Light Company, which operates the Oyster Creek Nuclear Generating Station. This report covers the period from December 1, 1981 through November 30, 1982, and includes a discussion of the patterns of distribution, abundance and reproductive activity observed since the beginning of the program.

At least three species of molluscan woodborers were identified from either short-term or long-term panels. These were the teredinids Bankia gouldi, Teredo navalis and T. bartschi. Throughout the report period, a number of specimens too small to be identified to species were collected and categorized as Teredinidae, but they were probably one or more of the above-mentioned species. A fourth species, T. furcifera, which was of concern during the first years of the program, has not been identified from any panel since February, 1977. The crustacean woodborer, Limnoria cf. tuberculata was recorded at seven stations, none of which were in the area affected by the discharge of the Oyster Creek Nuclear Generating Station.

Teredo bartschi, which has heretofore occurred only at stations in the discharge area of the power plant, was not recorded on panels anywhere in the Barnegat Bay area after March 1982, when one specimen was collected at Station 5, the mouth of Oyster Creek. The reasons for the disappearance from panels in the study area are not clear at this time. It is possible that colder than usual water temperatures over the winter months, when OCNGS was not operating, killed the breeding adults of this normally subtropical species. The plant has been down during the winter on other occasions, however, and some specimens of T. bartschi survived. It is also possible that the pathological effects of a haplosporidian parasite described earlier may have been effective in reducing the abundance of T. bartschi. The synergistic effect of both the cold water and the parasite may also have been a factor in the disappearance of T. bartschi from the study area.

Along with the disappearance of T. bartschi from the study area, another major shift in abundance has occurred with the population of Bankia gouldi. There has been a continual and significant decline in the abundance of B. gouldi throughout the study region over the past few years. This species continues to be dominant at stations north of Oyster Creek where Teredo navalis does not occur in large numbers, but the numbers of B.

gouldi have decreased to the point where T. navalis is now the most abundant species in Barnegat Bay. The reasons for the decline in B. gouldi abundance are also not clear at this time.

Teredo navalis is still dominant primarily on the eastern side of the bay, especially at Station 1. With the decline of B. gouldi, T. navalis has now become the dominant species at Station 11.

Gonad development patterns of Teredo navalis and Bankia gouldi remained consistent with what has been reported for previous years, and again, there appears to be no effect of the discharge from OCNGS in altering normal gonadal cycles in any way. The possibility of an extended breeding season for T. bartschi in the discharge area due to the thermal discharge has been discussed in prior reports. This year, with the disappearance of T. bartschi from our panels, it is not possible to comment on any effects that the OCNGS might have had on developmental cycles in that species.

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by

R.E. Hillman, C.I. Belmore and R.A. McGrath

## INTRODUCTION

The study conducted by Battelle's 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 (JCP&L) which owns the Oyster Creek Nuclear Generating Station (OCNGS).

The OCNGS has used salt water from Barnegat Bay as cooling water for its reactor 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 (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 on wind and tide but primarily on wind. Consequently, organisms in Oyster Creek and contiguous waters are exposed, at times, to temperatures above ambient bay levels.

A heavy outbreak of woodboring molluscs in the Oyster Creek area in the early 1970's raised concern about the possible effect of the operation of the OCNGS on populations of shipworms 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 any of the several species of woodborers found in the bay.

### Patterns of Species Abundance

Abundance of teredinids occurring in long-term (6-month) panels are summarized in Table 1. The total abundance of 5737 individuals over the present report

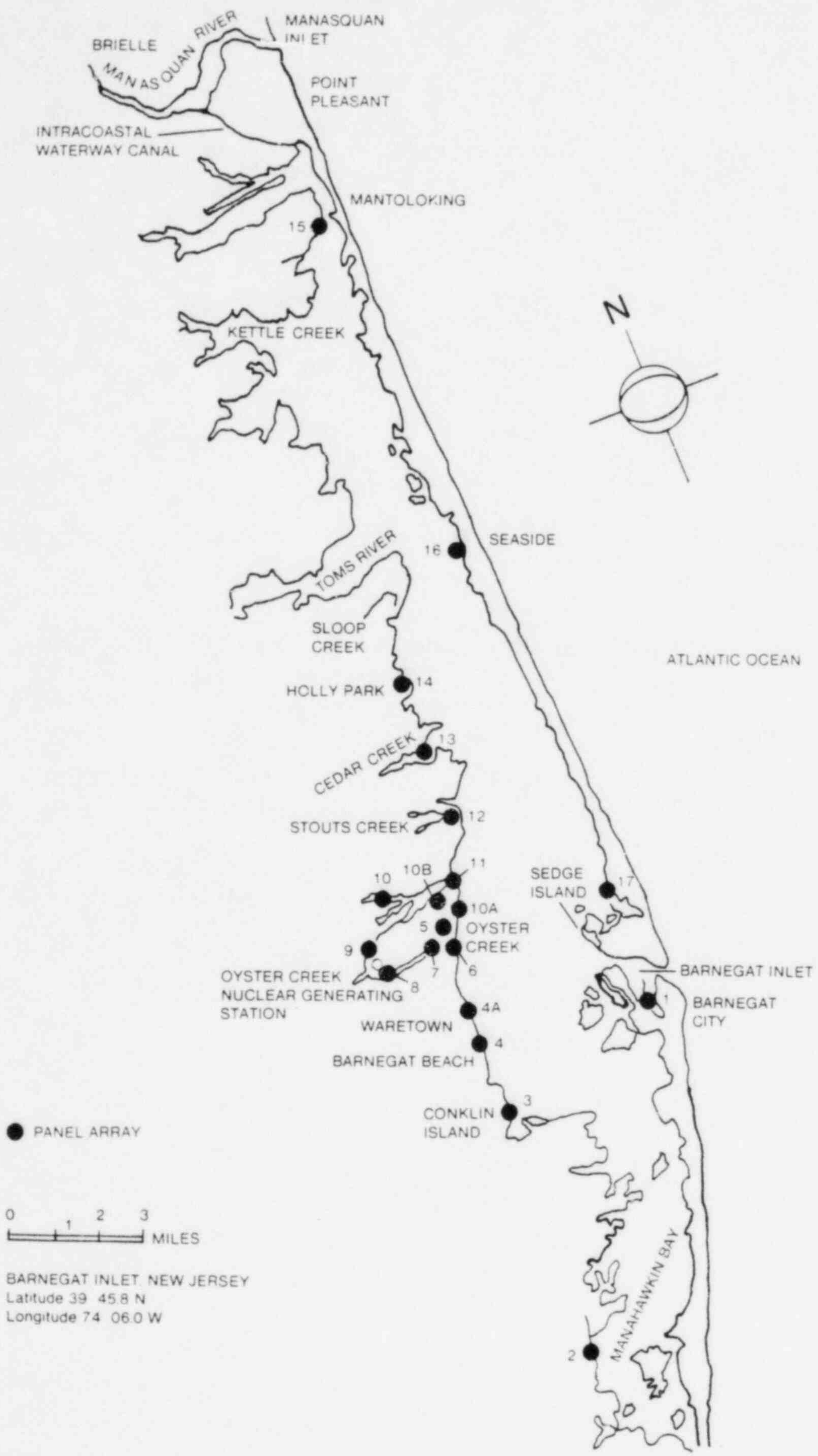


FIGURE 1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHIC LOCATIONS OF EXPOSURE PANELS

TABLE 1. NUMBERS OF TEREDINIDS IN LONG-TERM (6-MONTH) PANELS SUBMERGED JUNE, 1981 THROUGH MAY, 1982 AND REMOVED SEQUENTIALLY FROM DECEMBER, 1981 THROUGH NOVEMBER, 1982

| Site | Submerged<br>Removed | Jun<br>Dec | Jul<br>Jan | Aug<br>Feb | Sep<br>Mar | Oct<br>Apr | Nov<br>May | Dec<br>Jun | Jan<br>Jul | Feb<br>Aug | Mar<br>Sep | Apr<br>Oct | May<br>Nov | Total# | %Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 615 | 275 | 280* | 80 | | | | | 280 | 500 | 1000 | ** | 3030 | 53.00 |
| 2 | | | | | | | | | | | | | | 0 | 0.00 |
| 3 | | | | | | | | | | | | 1 | | 1 | 0.02 |
| 4 | | | | | | | | | | | | | | 0 | 0.00 |
| 4A | | | | | | | | | | | | | | 0 | 0.00 |
| 5 | | 233 | 84 | 35 | 9 | | | | | | 1 | | 1 | 363 | 6.33 |
| 6 | | 1 | 1 | 2 | 1 | | | | | | | | | 5 | 0.09 |
| 7 | | 803 | 600 | 550 | 38 | | | | | 1 | 4 | 2 | 2 | 2000 | 34.86 |
| 8 | | 1 | | 1 | | | | | 1 | 1 | | 1 | 1 | 6 | 0.10 |
| 9 | | | | 1 | | | | | | | | | 1 | 2 | 0.03 |
| 10 | | 3 | 1 | | | | | | | | | | | 4 | 0.07 |
| 10A | | 9 | | | | | | | | | 2 | | 4 | 15 | 0.26 |
| 10B | | | 1 | | | | | | | | | 3 | | 4 | 0.07 |
| 11 | | 3 | 6 | 11 | 1 | | | | 1 | 8 | 56 | 48 | 82 | 216 | 3.77 |
| 12 | | 3 | | | | | | | | | | | | 3 | 0.05 |
| 13 | | 3 | 2 | | | | | | | | 3 | 1 | 5 | 14 | 0.24 |
| 14 | | 10 | 8 | 1 | | | | | | 1 | 4 | 3 | 2 | 29 | 0.51 |
| 15 | | 2 | 1 | 2 | | | | | | | 4 | 3 | 5 | 17 | 0.30 |
| 16/16B*** | | | | | | | | | | | 1 | 1 | 2 | 4 | 0.07 |
| 17 | | 4 | 3 | 2 | | | | | | | 4 | 6 | 5 | 24 | 0.42 |

* Panel sumberged 5 months.

** No panel examined.

*** Original site 16 discontinued, site 16A established Dec, 1981-discontinued June, 1982. Site 16B established June, 1982. Long-term panels from 16B removed July through November exposed 1 to 5 months.

period represents a decline of 13% from the total abundance of 6595 individuals shown last year (Maciolek-Blake et al., 1982). Irrespective of species, 88% of all shipworms recovered from long-term panels occurred at Station 1 (3030 individuals, 53%) and Station 7 (2000 individuals, 35%). These two stations accounted for about 86% of all shipworms last year, although the abundance was more evenly distributed between the two stations (Station 1, 45%; Station 7, 41%). It should be noted that the panel that was to be retrieved at Station 1 in November, 1982, was missing and presumed to be lost due to heavy attack. Therefore, no shipworms were recorded from Station 1 in November. Last year, the November panel yielded almost 500 specimens. Thus the totals for Station 1 over the present report period could have been substantially higher, reducing or eliminating the reported decline in overall abundance.

Possible additional specimens from the November panel at Station 1 not withstanding, there was a major change in the abundance pattern at Station 7 (Table 1), which heretofore has been dominated by Teredo bartschi (e.g., Maciolek-Blake et al., 1982). During the panel removal period from December, 1981 through April 1982, a total of 1941 teredinids were recovered from Station 7, as opposed to a total of 467 from that station over the same 5 months last year. There were, however, 2269 teredinids collected from Station 7 from July through November, 1981, a period when abundance from the newly set larvae normally increases. During the July to November, 1982 period, only 4 teredinids were recovered from long-term panels at Station 7. This represents a change which is markedly different from the normal year-to-year variations in abundance patterns.

Teredinids were recovered from short-term (1-month) panels only during August, September and November (Table 2). The August and September sets were probably by larvae released in late June to July, and the November set was probably by larvae released in late September, indicating the probability of two spawning peaks for at least T. navalis, thus strengthening the contention, arrived at through examination of histological sections of shipworm gonads (Appendix B), that there are two spawning peaks throughout the Bay.

Reflected in Table 2 is the fact that no teredinid settlement was observed at Station 7 since March, 1982, whereas last year, approximately 17 percent of the total set on short-term panels occurred at Station 7 (Maciolek-Blake et al., 1982).

Along with the disappearance of T. bartschi from the study area, another major shift in the patterns of species abundance has occurred with the population of

TABLE 2. NUMBERS OF TEREDINDS IN SHORT-TERM PANELS REMOVED MONTHLY FROM DECEMBER 1981 THROUGH NOVEMBER, 1982*

| Site | Aug | Sep | Nov | Total |
|---|---|---|---|---|
| 1 | $475^{T}$ | $700^{Tn,T}$ | $160^{T}$ | 1335 |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 4A | | | | |
| 5 | | $1^{T}$ | $1^{T}$ | 2 |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 10A | $1^{T}$ | | | 1 |
| 10B | | | | |
| 11 | $29^{T}$ | | $4^{T}$ | 33 |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | $2^{Bg}$ | | | 2 |
| 16B | | $1^{Bg}$ | | 1 |
| 17 | $1^{T}$ | $18^{Tn,Ts,T}$ | | 19 |

* Short-term panels removed December, 1981 through July, 1982 and October, 1982 were free from Teredinidae.
Bg - Bankia gouldi
Tn - Teredo navalis
Ts - Teredo spp.
T - Teredinidae

Bankia gouldi. This species once accounted for over half of the shipworms collected throughout Barnegat Bay (see Appendix A, Tables A-20 through A-22). Although this species continues to be most abundant at stations north of Oyster Creek along the western shore of Barnegat Bay (Appendix A, Table A-23), there has been a continual and significant decline in abundance of B. gouldi throughout the study region over the past few years (Table A-22). Analysis of data grouped by bioyear, using all data collected from January, 1976 through November, 1982 indicated a series of overlapping significantly different groups:

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

Although the number of overlapping groups in this analysis precludes determining a clear pattern of change, a trend toward decreasing densities of B. gouldi over eight years of data is apparent.

Changes in the pattern of T. bartschi abundance might be related to the lower water temperatures in the winter when the power plant was down (Appendix C, Tables C-2 through C-4). These temperatures could have been low enough to kill the breeding population of this subtropical species. The plant was down in the winters of 1976 and 1980 (see e.g., Maciolek-Blake, et al., 1982), however, and at least some of the breeding population survived.

Another factor contributing to the disappearence of T. bartschi may have been the pathological effects of a haplosporidian parasite (Hillman, 1978, 1979; Hillman et al., 1982), which last year infected T. bartschi at rates of 92 percent at Station 5 and 100 percent at Station 7 (Maciolek-Blake et al., 1982).

The reasons for the significant decline in the abundance of Bankia gouldi are not known at this time, but could also be related to another protozoan parasite (e.g., Maciolek-Blake et al., 1982). In this case, the relationship may be more complex, with the presence of the parasite being a symptom rather than a cause of the problem.

## Species Distribution

In general, the distribution of species of teredinids has shifted somewhat from what has been previously reported (Appendix A, Tables A-20 through A-22). Teredo navalis is still dominant primarily on the eastern side of the bay, especially at Station 1. While it is still the dominant species at Station 17, the number of specimens recovered from panels at that station has been relatively low since 1976 (Appendix A, Table A-21). The decline in abundance of Bankia gouldi has led to a shift in dominance at Station 11, an important station in light of the relatively large numbers of shipworms occurring there throughout the study. Whereas B. gouldi has been the dominant species at Station 11 since the study began, it has now given way to T. navalis.

As mentioned before, T. bartschi, previously dominant at Stations 5, 6, and 7 was not reported from any site after March. T. navalis, with only a few specimens, became the dominant species at both Stations 5 and 7 in 1982.

Analysis of variance calculations were carried out on presence/absence results and on $\log_e$ (1 + abundance) for Teredo navalis (Appendix A, Table A-24 and A-25) and Bankia gouldi (Appendix A, Tables A-26 and A-27).

For T. navalis, the results of both ANOVAs indicate month, station and bioyear main effects are all highly significant, with station effects appearing the strongest. This confirms the impressions given by the raw data. The significance of month main effects is to be expected in animals with seasonal reproductive habits, and the histological studies discussed in Appendix B show that, in general, the shipworms in Barnegat Bay have typical molluscan reproductive patterns. The bioyear effects probably reflect natural cycles to some degree, including the natural mitigating effects of parasitism. Station effects can be explained in most cases by the somewhat more euryhaline requirements of T. navalis, allowing it to exist in the higher saline waters of Stations 1 and 17 on the eastern side of the bay. It's dominance at Station 11 appears to be the result of the decline of Bankia gouldi at that station rather than an increase in T. navalis.

Much of what has been discussed above for T. navalis pertains to Bankia gouldi with respect to the significance of month, bioyear and station effects. The reproductive patterns shown by B. gouldi throughout the study varied little from year to year and were strongly seasonal. Atypical of this shipworm species has been the decline in abundance over the past several years. This decline can explain much of the significance of the bioyear effects. Station effects can be attributed to the somewhat lower salinity requirements of B. gouldi, allowing it to predominate at the more western stations.

The abundance and distribution pattern of both T. navalis and B. gouldi do not appear to be affected by the operation of the Oyster Creek Nuclear Generating Station. No unusual reproductive patterns have been described, and the changes in abundance and distribution may be attributed to natural causes.

The probable role of the power plant in sustaining T. bartschi populations in the discharge-affected area has been discussed previously (e.g., Maciolek-Blake et al., 1982). What effect the plant's being down in the winter may have had on the disappearance of T. bartschi from our panels after March is not clear at this time.

During the present report period, the occurrence of the crustacean woodborer Limnoria was recorded at Stations 1, 2, 3, 4, 4A, 11 and 17, an increase in its distribution over that reported last year. Attack was down sharply at Station 1 over what was recorded last year, but has increased considerably at Station 4A.

## Conclusions

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

1) There has been a sudden disappearance of Teredo bartschi from panels in the discharge canal, and in the Barnegat Bay area in general. No specimens have been collected by us since March, 1982. The reasons for the disappearance are not clear at this time, but could be related to cold water when the plant was down in the winter, a parasite, or the synergistic effect of both.

2) There has been a continued and significant decline in the abundance of Bankia gouldi over the past several years, to where it is no longer the most abundant shipworm species in Barnegat Bay. The reasons for this decline are also not clear at this time.

3) Reproductive patterns in both Teredo navalis and Bankia gouldi have been consistent throughout the study. Gonad maturation can begin as early as January in T. navalis, with spawning beginning early in the spring. Maturation in B. gouldi begins somewhat later and spawning can begin in May. There were too few T. bartschi examined for gonad condition during the 1981/1982 report period to comment on the effect of OCNGS on that species reproductive pattern this year, but it is generally felt that the existence of the species in the area was dependent on the warm-water effluent from the power plant.

4) The woodboring crustacean Limnoria cf. tuberculata is limited in its distribution in Barnegat Bay and is not generally found in areas affected by the OCNGS discharge.

## References Cited

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# 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 any of the several species of woodborers found in the bay.

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

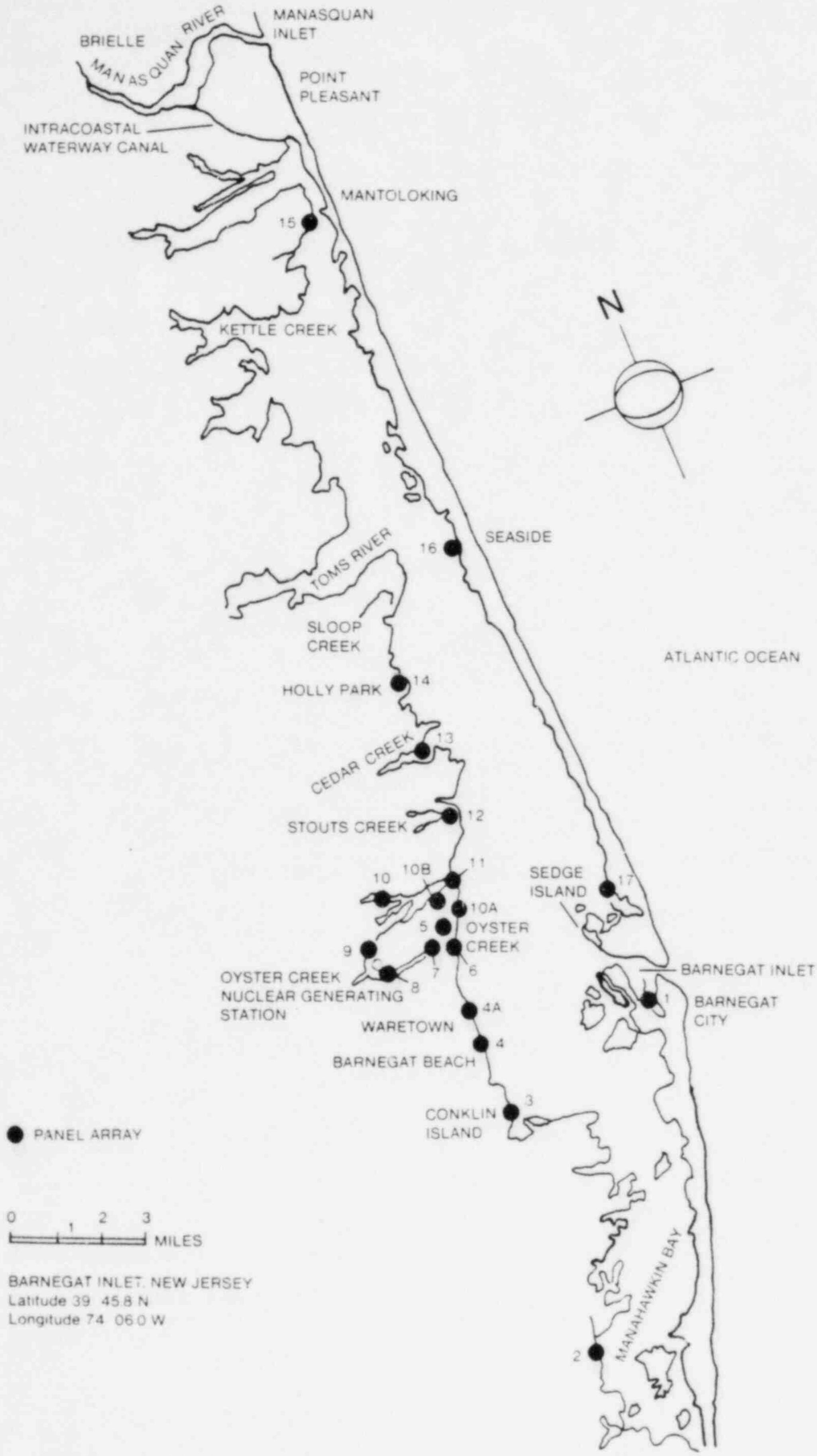



FIGURE 1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHIC LOCATIONS OF EXPOSURE PANELS

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<br>Bulkhead | WC 1<br>WFCL 1948-1967 | Lat. 39° 45.8'N<br>Long. 74° 06.5'W |
| 2. | Ashton Marina<br>1450 Bay Ave.<br>Manahawkin | Bulkhead | WC 13, 14 | Lat. 39° 40'N<br>Long. 74° 13'W |
| 3. | Iggie's Marina<br>East Bay Ave.<br>Barnegat (Conklin Island) | Bulkhead | WC 16, 17, 18, 19 | Lat. 39° 45'N<br>Lonog. 74° 12.5'W |
| 4. | Liberty Harbor Marina<br>Washington Ave.<br>Waretown | Bulkhead | WC 21<br>R. Turner<br>Rutgers U. | Lat. 39° 47'N<br>Long. 74° 11'W |
| 4-A*. | Holiday Harbor Marina<br>Lighthouse Drive<br>Waretown | Bulkhead<br>R. Turner<br>Rutgers U. | WC 21<br>Long. 74° 11'N | Lat. 39° 48'N |
| 5. | Mouth of Oyster Creek,<br>Lot 4, Compass Road<br>Offshore End | Dock | WC 29, 30<br>Rutgers U. | Lat. 39° 48.5'N<br>Long. 74° 10.3'W |
| 6. | Oyster Creek #1<br>Lagoon, Inshore End<br>37 Capstan Drive | Dock | | Lat. 39° 48.5'N<br>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<br>Dock Ave.<br>Oyster Creek<br>Sands Pt. Harbor<br>Waretown | End of Dock | WC 27,28<br>R. Turner<br>Rutgers U. | Lat. 39° 48.5'N<br>Long. 74° 11.1'W |
| 8. | Oyster Creek-R.R.<br>Bridge<br>Discharge Canal | Cross Member<br>Bridge | WC 26<br>Rutgers U. | Lat. 39° 48.7'N<br>Long. 74° 12'W |
| 9. | Forked River<br>South Branch<br>Intake Canal | Cross Member<br>R.R. Bridge | WC 31 | Lat. 39° 49.2'N |
| 10. | Teds Marina<br>Bay Ave.<br>Forked River | Pier | WC 33, 34 | Lat. 39° 50.1'N<br>Long. 74° 11.6'W |
| 10A*. | Private Dock<br>1217 Aquarius Ct.<br>Forked River | Under Dock | | Lat. 39° 49'N<br>Long. 74° 10'W |
| 10B*. | Private Dock<br>1307 Beach Blvd.<br>Forked River | Under Dock | | Lat. 39° 49.4'N<br>Long. 74° 10.1'W |
| 11. | Forked River<br>(near mouth)<br>1413 River View Drive | Bulkhead | Wc 35<br>Rutgers U. | Lat. 39° 49.7'N<br>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<br>1273 Capstan Drive | Bulkhead | WC 38, 40, 41<br>R. Turner<br>Wurtz<br>Rutgers U. | Lat. 39° 50.5'N<br>Long. 74° 08.8'W |
| 13. | Rocknak's Yacht Basin<br>Seaview Ave.<br>Lanoka Harbor<br>Cedar Creek | End of Pier | WC 46 | Lat. 39° 52'N<br>Long. 74° 09'W |
| 14. | Dicks Landing<br>Island Drive<br>Bayville (Holly Park) | Pier | WC 49<br>R. Turner<br>Nelson | Lat. 39° 54'W<br>Long. 74° 08.1'W |
| 15. | Winter Yacht Basin Inc.<br>Rt. 528<br>Mantoloking Bridge | Pier | WC 57 | Lat. 40° 02.5'N<br>Long. 74° 04.9'W |
| 16. | Berkely Yacht Basin<br>J. Street<br>Seaside | Pier | WC 60, 61 | Lat. 39° 55.9'N<br>Long. 74° 04.9'W |
| 16A*. | Municipal Dock<br>Seaside Heights | Pier | WC 60, 61 | Lat. 39° 56.6'N<br>Long. 74° 04.9'W |
| 16B*. | Bayside Boats<br>State Highway #35 and<br>Bay Boulevard<br>Seaside Heights, NJ | Pier | WC 60, 61 | Lat. 39° 56.6'N<br>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<br>Long. 74° 05.9'W |

All exposure panel racks suspended in a minimum water depth at mean low water of at least three feet. Racks hung with nylon line from existing structures so the bottom panels are close to, but not touching the bottom. Racks at Forked River railroad bridge and Oyster Creek railroad bridge suspended with wire rope.

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

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

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 they are processed for borer abundance and distribution information. The procedures for preparation and replacement are similar to what was done by Battelle until March, 1982.

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

**Laboratory**

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

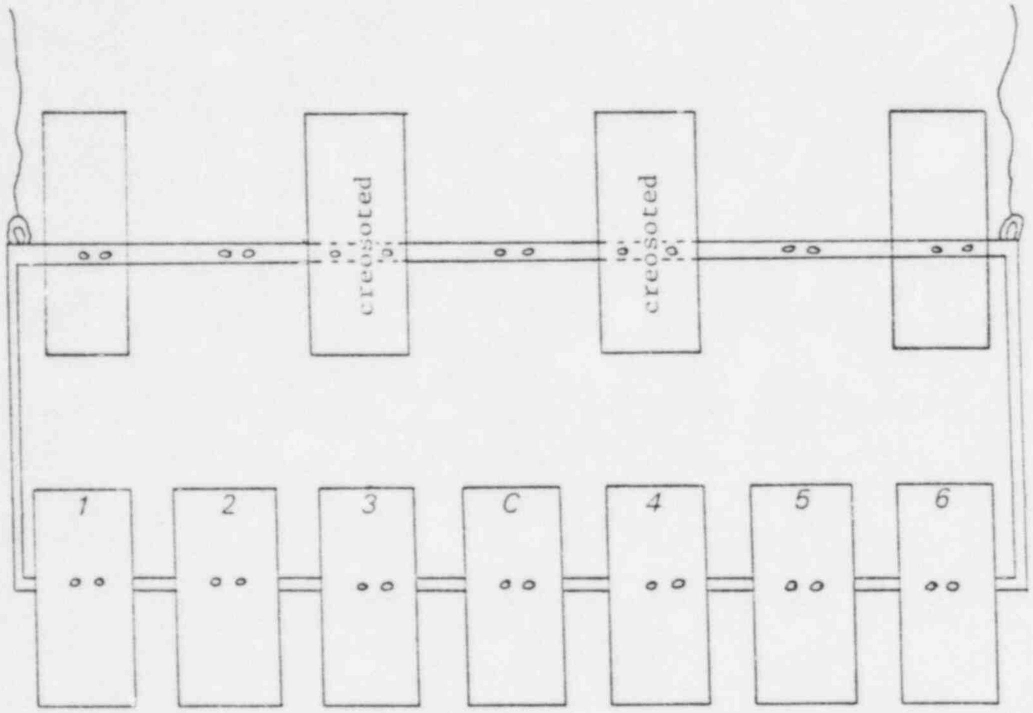



FIGURE A-2. EXPOSURE PANEL ARRAY

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.

TEREDINIDAE

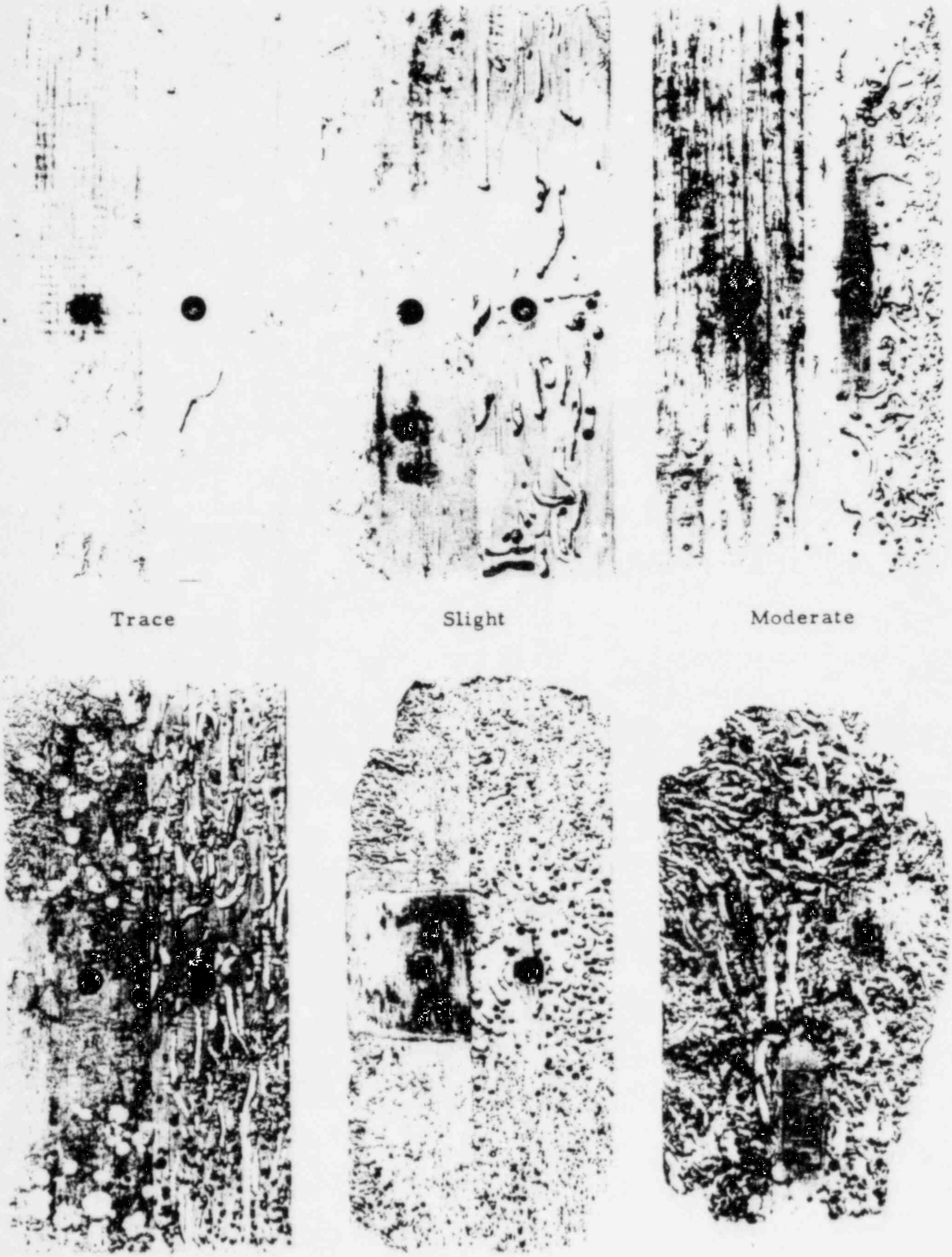
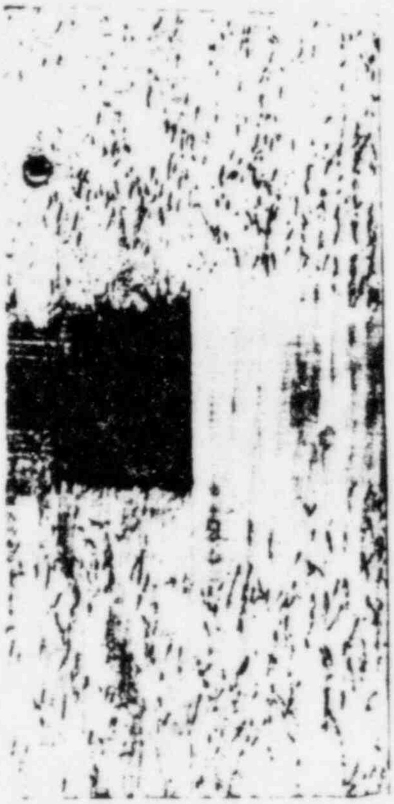
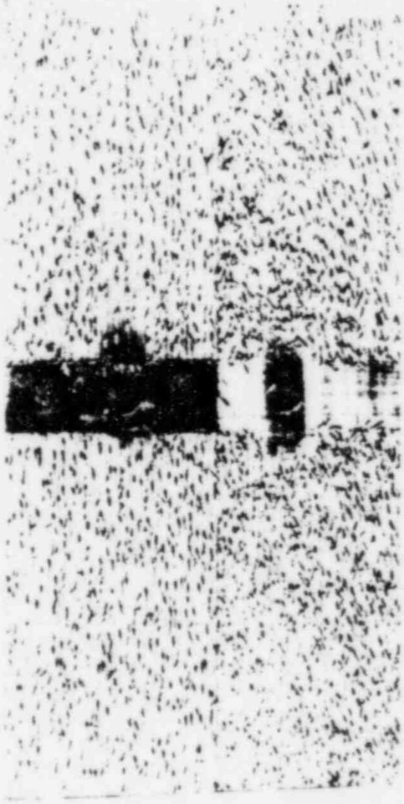



FIGURE A-3. RATING OF TEREDINID ATTACK

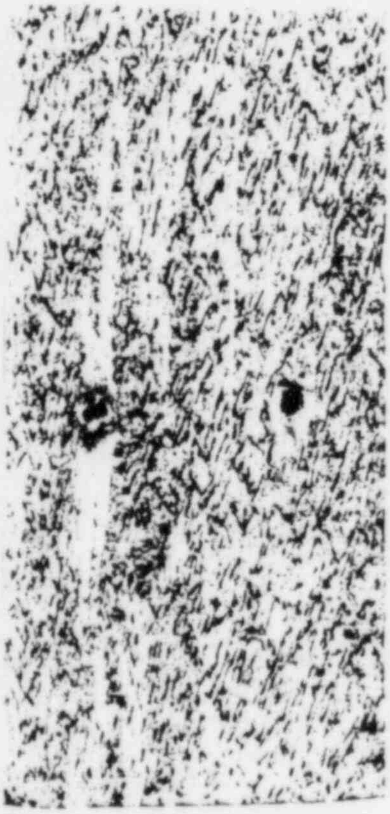
Trace



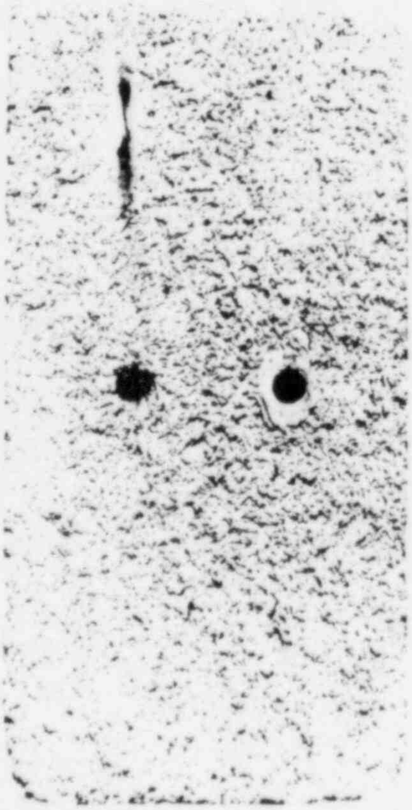
Slight



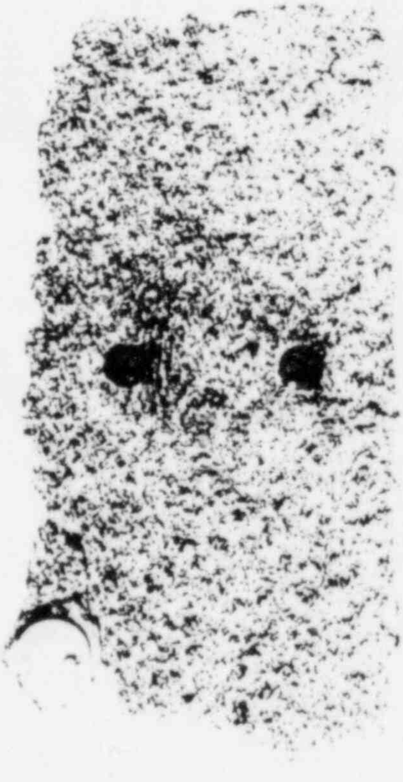
Moderate



Moderately Heavy



Heavy



Very Heavy

FIGURE A-4. RATING OF LIMNORID ATTACK

## Statistical Analysis

Statistical analysis was made of data from 6-month panels only. Parameters which have been analyzed include presence/absence and abundance of Teredo navalis, presence/absence and abundance of Bankia gouldi, and percent destruction. Because of the distinctive and limited distribution of T. bartschi, statistical analyses were not considered necessary to determine significant differences between stations for this species.

Analyses of variance were carried out on presence/absence data and on loge (abundance + 1) for T. navalis and B. gouldi. These tests were run on data collected from January, 1976 through November, 1982; all data from 1975 were excluded because data were collected only from October for 6-month panels, resulting in an incomplete data set for that year. Essentially no specimens were collected from long-term panels removed in the spring months of April, May and June, therefore, these months were also excluded from the analyses. Occasional long-term pan ; which may have been exposed for less than 6 months (i.e., 4-5 months) have been included, based on results of analyses performed for last year's report. Those analyses, in which 68 less-than-6-month panels were deleted from the data set, showed that the results and conclusions were essentially the same whether or not the 68 cases were included (Maciolek-Blake et al., 1981).

The ANOVA calculations include main effects for the original factors of month, station and biological year. A "bioyear" is defined as July, Year A through June, Year B, and corresponds to the breeding season of the Teredinidae. Thus we have data for 6 complete bioyears, from July, 1976 through June, 1982. In order to simplify the fitting of the model, 2-way and 3-way interactions were based on summary factors. These include grouping the months into seasons (winter = January, February, March; spring (deleted here) = April, May, June; summer = July, August, September; and fall = October, November, December) and stations into regions (Region 1 (near OCNGS) = Stations 5, 6, 7 and 8; Region 2 (south) = Stations 2, 3, 4 and 4A; Region 3 (east) = Stations 1 and 17; Region 4 (near north) = Stations 9, 10, 10A, 10B and 11; and Region 5 (north) = Stations 12, 13, 14, 15 and 16). This regional grouping is the same as that initiated last year when Station 16 was included in Region 5. Because the program available would not fit main effects in terms of original factors and interactions in terms of summary factors, the following procedure was used. ANOVAs were first calculated with main effects and interactions in terms of the summary factors (season, region and year). The calculation was then repeated for the main effects of month, station and year. The results of the two

ANOVAs were then combined by adding the sums of squares associated with the main effects (full factors), 2-way interactions (summary factors) and 3-way interactions (summary factors). The residual mean square based on the combined fit was used as the error variance estimate and is considered to be more appropriate than the error estimate based on the summary factors. F-ratios and F-tests were recalculated based on the combined fit-error estimates. The program used for ANOVA calculations was that given in "Statistical Package for the Social Sciences" (Nie, Hill, Jenkins, Steinbrenner and Bent, 1975).

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

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

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 $\nu$ 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.

$H_o$ will be rejected at significance level  if

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

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

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 $\mu_1$, $\mu_2$, ..., $\mu_k$, be the corresponding population means. Let $s^2$ denote the error mean square from an analysis of variance, based on $\nu$ 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  .

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

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

then all the means $\mu_i$, $\mu_2$, ..., $\mu_k$ are declared to be equal.

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

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

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

then compare

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

and compare

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

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

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

At the conclusion of this process, the means $\bar{X}_i$, $\bar{X}_j$ are declared significantly different at level $\alpha$ if $\bar{X}_i$, $\bar{X}_j$ 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

$$\text{logit (proportion destruction)} = \log_e \frac{P}{1-P}\ .$$

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:

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

where $\beta$ = the unknown regression coefficient

and E = error or unexplained variability.

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

## Results and Discussion

### Modifications to Panel Exposure

The original site of Station 16, Berkeley Yacht Basin in Seaside Heights was discontinued in December, 1981, and a new site (16A) was located at the Municipal Dock in Seaside Heights. This was discontinued in June, 1982 and Station 16B was established at Bayside Boats in Seaside Heights. These sites are near enough to one another such that water quality parameters are very similar.

The missing rack at Station 13 was found in good condition and rehung in December, 1981.

The panel at Station 1 was missing at the November, 1982 sampling. It is presumed that the panel fell off due to heavy borer attack since the panels in the immediate vicinity also exhibited very heavy attack.

## Species Identified

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

Crustacean woodborers belonging to the genus Limnoria were again found at several stations. These were probably L. cf. tuberculata according to identifications made last year by Dr. J.J. Gonor of Oregon State University.

## Short-term (1-month) Panels

Short-term panels, those exposed for a one-month period, provide data on the time of year when settling occurs, 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 pulled near the beginning of each month, the results reflect activity during the previous month.

The numbers and species of Teredinidae found in short-term panels during this report period are shown in Table A-3. Settlement took place in August and September, and again in November, and was heaviest at Station 1. Last year, settlement began in October, but was very light, so this year's pattern does not represent a major change in settling patterns. More significant is the fact that no settlement was observed at Station 7 this year, whereas last year approximately 17 percent of the short-term set occurred at Station 7 (Maciolek-Blake et al., 1982).

The numbers of teredinids recorded on the panels are relatively low, and the amount of destruction was generally less than 1 percent, except at Station 1 where it was

TABLE A-3. NUMBERS OF TEREDINIDS IN SHORT-TERM PANELS REMOVED MONTHLY FROM DECEMBER, 1981 THROUGH NOVEMBER, 1982*

| Site | Aug | Sep | Nov | Total |
|---|---|---|---|---|
| 1 | 475T | 700Tn,T | 160T | 1335 |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 4A | | | | |
| 5 | | 1T | 1T | 2 |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
| 9 | | | | |
| 10 | | | | |
| 10A | 1T | | | 1 |
| 10B | | | | |
| 11 | 29T | | 4T | 33 |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | 2Bg | | | 2 |
| 16B | | 1Bg | | 1 |
| 17 | 1T | 18Tn,Ts,T | | 19 |

* Short-term panels removed December, 1981 through July, 1982 and October, 1982 were free from Teredinidae.
Bg - Bankia gouldi
Tn - Teredo navalis
Ts - Teredo spp.
T - Teredinidae

15 percent in September (Table A-4). This was very low compared to last year's 75 percent destruction during the same month (Maciolek-Blake et al., 1982).

A comparison of the total number of Teredinidae settling on short-term panels, each year from 1975 through 1982 is shown in Table A-5. There was a slight decrease in the total set in the 1982 short-term panel over that recorded in 1981, due primarily to the complete absence of set at Station 7 in 1982. At the other sites, settlement continued to be low.

**Destruction.** The average percent destruction of short-term panels for each year from 1975 through 1982 is shown in Table A-6. Destruction at Station 1 was higher than at the other stations, but considerably less than the 16.0 percent reported for 1981. Destruction of short-term panels at other stations continued uniformly low.

**Identifications.** Individual species are only infrequently identified from short-term panels because the size of the specimens is very small (10 mm or less). During this report period, Teredo bartschi was not identified from any panels; T. navalis was identified only from September panels from Stations 1 and 17; and Bankia gouldi from August panels at Station 15 and in September at 16B (Table A-3). The remaining identifications were either at the generic (Teredo spp.) or family (Teredinidae) level.

Over 1600 one-month panels have been examined since the beginning of this program in 1975. Table A-7 presents summaries for family, generic and specific identifications made from these collections. Teredo furcifera, which has not been reported since August, 1975 (Richards et al., 1976), has been excluded.

Last year there was a total of 1369 Teredo navalis reported whereas for the previous 6 years only 14 were recorded. In this report period, the number of specific identifications of T. navalis dropped to 61.

Teredo bartschi, which has been reported consistently since 1977 was not found on any short-term panels during this report period, and Bankia, with only 3 specimens, was at its lowest level since the study began.

For the most part, the pattern of occurrence of teredinids on short-term panels during the 1981/1982 report period was similar to the patterns reported in previous years. T. navalis was found only in Regions 2, 3 and 4, especially in Region 3 and especially in the summer.

TABLE A-4. PERCENT DESTRUCTION OF SHORT-TERM PANELS REMOVED MONTHLY FROM DECEMBER, 1981 THROUGH NOVEMBER, 1982*

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

* Teredinids were not present in short-term panels removed from December, 1981 through July, 1982 and October, 1982.

TABLE A-5. TOTAL AMOUNT OF TEREDINID SETTLEMENT IN SHORT-TERM PANELS FROM JULY, 1975 THROUGH NOVEMBER, 1982

| Site | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|---|---|
| 1 | 8199 | 1090 | 654 | 1015 | 535 | 88 | 1396 | 1335 |
| 2 | 17 | 2 | | 1 | 8 | | | |
| 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 | | | | | | |
| 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 |
| 12 | 34 | 1 | 5 | 1 | 13 | 4 | 1 | |
| 13 | 142 | 10 | 9 | 4 | 16 | | 1* | |
| 14 | 308 | 20 | 8 | 8 | 69 | 2 | 12 | |
| 15 | 3 | | | | 5 | 1 | | 3 |
| 16 | 2 | | | | | | | |
| 17 | 117 | | 3 | | 6 | | | 19 |
| Totals | 16667 | 1207 | 957 | 4108 | 5731 | 127 | 1729 | 1393 |

* 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 1982*

| Site | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|---|---|
| 1 | 13.0 | 3.6 | 2.8 | 1.6 | 4.4 | 0.8 | 16.0 | 3.4 |
| 2 | 1.0 | 0.4 | | 0.2 | 0.6 | | | |
| 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 | | | | | | |
| 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 |
| 12 | 2.0 | 0.2 | 0.4 | 0.2 | 1.6 | 0.4 | 0.2 | |
| 13 | 3.6 | 0.6 | 0.4 | 0.2 | 0.6 | | 0.2** | |
| 14 | 11.2 | 0.6 | 0.4 | 0.4 | 2.4 | 0.4 | 0.4 | |
| 15 | 0.6 | | | | 0.4 | 0.2 | | 0.2 |
| 16/16B | 0.2 | | | | | | | 0.2 |
| 17 | 3.8 | | 0.4 | | 0.6 | | | 0.4 |

Station 4A established April, 1977.
Station 10A and 10B established April, 1978.
Station 10B 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 1444 Times

| Year | # | Season | # | Region | # |
|---|---|---|---|---|---|
| 1975 | 0 | Winter | | 1 | 0 |
| 1976 | 2 | Spring | 0 | 2 | 2 |
| 1977 | 1 | Summer | 1444 | 3 | 1436 |
| 1978 | 1 | Fall | 0 | 4 | 6 |
| 1979 | 10 | | | 5 | 0 |
| 1980 | 0 | | | | |
| 1981 | 1369 | | | | |
| 1982 | 61 | | | | |

Teredo bartschi: Identified a Total of 21 Times

| Year | # | Season | # | Region | # |
|---|---|---|---|---|---|
| 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 | | | | |

All Teredo*: Identified a Total of 1512 Times

| Year | # | Season | # | Region | # |
|---|---|---|---|---|---|
| 1975 | 7 | Winter | 0 | 1 | 41 |
| 1976 | 6 | Spring | 0 | 2 | 7 |
| 1977 | 4 | Summer | 1506 | 3 | 1454 |
| 1978 | 7 | Fall | 6 | 4 | 9 |
| 1979 | 21 | | | 5 | 1 |
| 1980 | 2 | | | | |
| 1981 | 1391 | | | | |
| 1982 | 74 | | | | |

TABLE A-7. (continued)

| | Year | # | Season | # | Region | # |
|---|---|---|---|---|---|---|
| All Bankia**: Identified a Total of 76 Times | | | | | | |
| | 1975 | 17 | Winter | 0 | 1 | 13 |
| | 1976 | 6 | Spring | 0 | 2 | 5 |
| | 1977 | 8 | Summer | 76 | 3 | 3 |
| | 1978 | 4 | Fall | 0 | 4 | 23 |
| | 1979 | 13 | | | 5 | 32 |
| | 1980 | 9 | | | | |
| | 1981 | 16 | | | | |
| | 1982 | 3 | | | | |
| Teredinidae***: Identified a Total of 3313 Times | | | | | | |
| | 1975 | 47 | Winter | 1 | 1 | 372 |
| | 1976 | 21 | Spring | 0 | 2 | 21 |
| | 1977 | 26 | Summer | 3032 | 3 | 2786 |
| | 1978 | 23 | Fall | 280 | 4 | 73 |
| | 1979 | 52 | | | 5 | 61 |
| | 1980 | 22 | | | | |
| | 1981 | 1729 | | | | |
| | 1982 | 1393 | | | | |

* 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 fc 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. The numbers and species of Teredinidae found in long-term panels during this report period are shown in Tables A-8 (December, 1981) through A-19 (November, 1982).

Panels submerged in June, July and August, 1981, and examined in December 1981, and January and February, 1982 respectively contained specimens ranging from less than 1 mm up to 240 mm. The 240 mm specimens occurred in December at Station 14. The largest specimen found in January was 225 mm at Station 13, and in February it was only 110 mm at Station 11. This was in contrast to last year when specimens as long as 375 mm were collected. The smallest size range was at Station 1 (1-60 mm in December, 1-35 mm in January, and 1-40 mm in February). The smallest individuals probably represent specimens which set from the late summer, early fall spawning peak by Teredo and which ceased to grow as the water cooled.

Both the number of individuals and the sizes of specimens found in long-term panels in March, 1982 (Table A-11) decreased markedly. Those specimens probably represented the last of the fall-spawned set. The largest specimen was only 35 mm at Station 1. No other specimens collected were over 5 mm. The only stations where teredinids were collected in March were Stations 1 (80 specimens), 5 (9 specimens), 6 (1 specimen), 7 (38 specimens), and 11 (1 specimen).

No specimens were collected during April, May and June, 1982 (Tables A-12 through A-14). In July, one specimen of Teredo navalis, 55 mm in length, was collected at Station 8, and one Teredinidae, 3 mm, was collected at Station 11. The 55-mm specimens at Station 8 in July (Table A-15) could have resulted from spawning in late May or early June, 1982.

By August, the abundance of teredinid specimens and number of stations at which they were collected, increased considerably (Table A-16), reflecting the summer spawning peak. The larger specimens of Teredo navalis collected at Stations 7 and 8 could represent specimens which were spawned in late spring or early summer in the discharge canal area. As with previous years, the large majority of specimens were collected at Station 1, and they were all in the very small ( 1 to 2 mm) range.

## TABLE A-8. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED DECEMBER 8-9, 1981

| Station | Panel | No. of Specimens | Percent Filled | Size Range in mm. | Species Identification | Remarks |
|---|---|---|---|---|---|---|
| 1 | P | 615 | 99 | 1-60 | 65 T. navalis, 550 Teredinidae* | Only 7 alive |
| | C | 0 | | | | |
| 5 | P | 233 | 2 | 1-90 | 3 T. bartschi, 320 Teredinidae* | |
| | C | 0 | | | | |
| 6 | P | 1 | 1 | 55 | 1 T. bartschi | |
| | C | 0 | | | | |
| 7 | P | 803 | 90 | 1-210 | 2 B. gouldi, 200 T. bartschi, 1 T. navalis, 600 Teredinidae* | |
| | C | 0 | | | | |
| 8 | P | 1 | 1 | 55 | 1 B. gouldi | |
| | C | 0 | | | | |
| 10 | P | 3 | 3 | 20-125 | 3 B. gouldi | |
| | C | 0 | | | | |
| 10A | P | 9 | 20 | 1-230 | 5 B. gouldi, 4 Teredinidae* | 1 Teredinidae dead |
| | C | 0 | | | | |
| 11 | P | 3 | 7 | 90-165 | 1 B. gouldi, 1 T. navalis | 1 T. navalis dead |
| | C | 0 | | | | |
| 12 | P | 3 | 8 | 130-140 | 3 B. gouldi | |
| | C | 0 | | | | |
| 13 | P | 3 | 10 | 210-225 | 3 B. gouldi | |
| | C | 0 | | | | |
| 14 | P | 10 | 25 | 1-240 | 8 B. gouldi, 2 Teredinidae* | 2 Teredinidae - empty pits |
| | C | 0 | | | | |

TABLE A-8. (Continued)

| | | | | | |
|---|---|---|---|---|---|
| 15 | P | 2 | 4 | 155-168 | 2 B. gouldi |
| | C | 0 | | | |
| 17 | P | 4 | 3 | 28-135 | 4 T. navalis |
| | C | 0 | | | |

Stations 2-4A, 9, 10B; no Teredinidae present
No panels examined from Station 16

P = Long-term panel, submerged June 1-2, 1981.
C = Short-term panel, submerged November 3-4, 1981.
* = Not speciated due to size or condition.

| Station | Panel | No. of Specimens | Percent Filled | Size Range in mm. | Species Identification | Remarks |
|---|---|---|---|---|---|---|
| 1 | P | 275 | 99 | 1-35 | 45 *T. navalis*, 230 Teredinidae* | 50% of panel broken off, all dead |
| | C | 0 | | | | |
| 5 | P | 84 | 6 | 1-220 | 1 *B. gouldi*, 3 *T. bartschi* | All *T. bartschi* dead |
| | C | 0 | | | | |
| 6 | P | 1 | 1 | 50 | 1 *T. bartschi* | Dead |
| | C | 0 | | | | |
| 7 | P | 600 | 20 | 1060 | 150 *T. bartschi*, 450 Teredinidae* | All dead |
| | C | 0 | | | | |
| 10 | P | 1 | 1 | 110 | 1 *B. gouldi* | |
| | C | 0 | | | | |
| 10B | P | 1 | 2 | 175 | 1 *B. gouldi* | |
| | C | 0 | | | | |
| 11 | P | 6 | 15 | 45-195 | 5 *B. gouldi*, 1 *T. navalis* | |
| | C | 0 | | | | |
| 13 | P | 2 | 6 | 190-225 | 2 *B. gouldi* | |
| | C | 0 | | | | |
| 14 | P | 8 | 15 | 70-160 | 8 *B. gouldi* | |
| | C | 0 | | | | |
| 15 | P | 1 | 1 | 1 | 1 Teredinidae* | |
| | C | 0 | | | | |
| 17 | P | 3 | 1 | 22-60 | 3 *T. navalis* | |
| | C | 0 | | | | |

Stations 2-4A, 8-9, 10A, 12, 16A**: No Teredinidae present

P = Long-term panel, submerged July 7-8, 1981.
C = Short-term panel, submerged December 8-9, 1981.
* = Not speciated due to size or condition.
** = New rack installed in December, 1981.

| Station | Panel | No. of Specimens | Percent Filled | Size Range in mm. | Species Identification | Remarks |
|---|---|---|---|---|---|---|
| 1* | P | 280 | 99 | 1-40 | 60 T. navalis, 220 Teredinidae** | Only 6 alive |
| | C | 0 | | | | |
| 5 | P | 35 | 1 | 1-60 | 2 T. bartschi, 33 Teredinidae** | All dead |
| | C | 0 | | | | |
| 6 | P | 2 | 1 | 1-2 | 2Teredinidae** | Empty tubes |
| | C | 0 | | | | |
| 7 | P | 550 | 20 | 1-40 | 100 T. bartschi, 450 Teredinidae** | All dead |
| | C | 0 | | | | |
| 8 | P | 1 | 1 | 11 | 1 T. bartschi | To be verified |
| | C | 0 | | | | |
| 9 | P | 1 | 1 | 48 | 1 B. gouldi | |
| | C | 0 | | | | |
| 11 | P | 11 | 4 | 2-110 | 8 T. navalis, 3 Teredinidae** | |
| | C | 0 | | | | |
| 14 | P | 1 | 1 | 35 | 1 T. navalis | |
| | C | 0 | | | | |
| 15 | P | 2 | 2 | 78-90 | 2 T. navalis | |
| | C | 0 | | | | |
| 17 | P | 2 | 1 | 21-45 | 2 T. navalis | |
| | C | 0 | | | | |

Stations 2-4A, 10-10B, 12-13, 16A***: No Teredinidae present.

P = Long-term panel, submerged August 4-5, 1981.
C = Short-term panel, submerged January 5-6, 1982.
* = Station #1 long-term panel submerged 5 months, removed in January, 1982 because of excessive deterioration.
** = Not Speciated due to size or condition.
*** = Station #16A long-term submerged only 2 months.

TABLE A-11. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED MARCH 2-3, 1982

| Station | Panel | No. of Specimens | Percent Filled | Size Range in mm. | Species Identification | Remarks |
|---|---|---|---|---|---|---|
| 1 | P | 80 | 3 | 1-35 | 23 T. navalis, 57 Teredinidae* | |
| | C | 0 | | | | |
| 5 | P | 9 | 1 | 1-5 | 1 T. bartschi, 8 Teredinidae* | |
| | C | 0 | | | | |
| 6 | P | 1 | 1 | 2 | 1 Teredinidae* | Tube empty |
| | C | 0 | | | | |
| 7 | P | 38 | 1 | 1-2 | 38 Teredinidae* | |
| | C | 0 | | | | |
| 11 | P | 1 | 1 | 3 | 1 Teredo spp.* | |
| | C | 0 | | | | |

Stations 2-4A, 8-10B, 12-17: No Teredinidae Present.

P = Long-term panels submerged September 9-10, 1981.
C = Short-term panel, submerged February 2, 1982.
* = Not speciated due to size or conditon.

TABLE A-12. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED APRIL 7-8, 1982

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

TABLE A-13. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED MAY 4-5, 1982

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

TABLE A-14. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED JUNE 1-2, 1982

| Station | Panel | No. of Specimens | Percent Filled | Size Range in mm. | Species Identification | Remarks |
|---|---|---|---|---|---|---|

Stations 1-17 No Teredinidae Present.

TABLE A-15. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED JULY 6-7, 1982

| Station | Panel | No. of Specimens | Percent Filled | Size Range in mm. | Species Identification | Remarks |
|---|---|---|---|---|---|---|
| 8 | P | 1 | 1 | 55 | 1 Teredo navalis | |
| | C | 0 | | | | |
| 11 | P | 1 | 1 | 3 | 1 Teredinidae* | |
| | C | 0 | | | | |

Stations 1-7, 9-10B, 12-17 - No Teredinidae Present

P = Long-term panel, submerged January 5-6, 1982 (Station 16B submerged June 2, 1982).
C = Short-term panel, submerged June 1-2, 1982.
* = Too small to speciate.

TABLE A-16. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED August 3-4, 1982

| Station | Panel | No. of Specimens | Percent Filled | Size Range in mm. | Species Identification | Remarks |
|---|---|---|---|---|---|---|
| 1 | P | 280 | 2 | 1-2 | 280 Teredinidae* | |
| | C | 475 | 2 | 1-1 | 475 Teredinidae* | |
| 7 | P | 1 | 1 | 100 | 1 Teredo navalis | |
| | C | 0 | | | | |
| 8 | P | 1 | 2 | 143 | 1 Teredo navalis | Ripening gonads |
| | C | 0 | | | | |
| 10A | P | 0 | | | | |
| | C | 1 | 1 | 2 | 1 Teredinidae* | |
| 11 | P | 8 | 3 | 1-90 | 3 Teredo navalis, 5 Teredinidae* | 3 T. navalis with ripening gonads |
| | C | 29 | 1 | 1-2 | 29 Teredinidae* | |
| 14 | P | 1 | 1 | 70 | 1 Teredo navalis | |
| | C | 0 | | | | |
| 15 | P | 0 | | | | |
| | C | 2 | 1 | 3-7 | 2 Bankia gouldi | |
| 17 | P | 0 | | | | |
| | C | 1 | 1 | 1 | 1 Teredinidae* | |

Stations 2-6, 9-10, 10B, 12-13, 16B - No Teredinidae Present

P = Long-term panel, submerged February 2, 1982 (Station 16B submerged June 2, 1982).
C = Short-term panel, submerged July 6-7, 1982.
* = Too small to speciate.

The abundance of shipworms and the number of stations at which they were collected continued to increase in September (Table A-17), again reflecting the usual summer reproductive activity as well as growth of those specimens which set early in the breeding season. The majority of specimens continued to be collected from Station 1, but the largest specimens were found at Stations 13 (180 mm), 11 (150 mm) and 7 (140 mm), respectively.

By October (Table A-18) shipworms which had set early in the spawning season had shown considerable growth, with some specimens of *Bankia gouldi* from Station 14 and 16B reaching lengths of 205 mm. The panel at Station 1 had over 1000 shipworms in it and was 99 percent filled, and the panel at Station 11, although it contained only 48 specimens, was 80 percent filled.

Attack at Station 1 was so heavy by November (Table A-19) that the panel had fallen off and was not recovered. The short-term panel, however, was still there and contained 160 newly set ( 1 mm) teredinids. Most of the specimens in the long-term panels were relatively large, with specimens up to 260 mm being found at Station 13, and 240 mm at 16B. These larger specimens were *Bankia gouldi*, which usually tends to be larger than *Teredo* by November. Setting in the short-term panels at Stations 1 and 11 in November strengthens the thesis that there are two normal spawning peaks for *Teredo* in Barnegat Bay.

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

***Teredo bartschi*.** One of the more significant aspects of this year's program was the disappearance of *T. bartschi* from our panels after March, 1982 (Table A-20). During December, 1981 and January, 1982, it occurred at Stations 5, 6, and 7, although primarily at Station 7. In February, 1982, it was recovered from panels at Stations 5 and 7, but by March only 1 specimen was collected, and that was at Station 5. Normally, it would be expected to disappear from the panels at about that time and reappear in July or August. This year, however, the reappearance did not happen. One possible explanation is that the water temperatures during the winter months when the plant was down were low enough (see Appendix C, Tables C-2 through C-5) to kill the breeding population of this subtropical species, which was purported to be maintained in the effluent canal by the thermal discharge of the Oyster Creek Nuclear Generating Station (e.g., Hoagland and

TABLE A-17. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED SEPTEMBER 7-8, 1982

| Station | Panel | No. of Specimens | Percent Filled | Size Range in mm. | Species Identification | Remarks |
|---|---|---|---|---|---|---|
| 1 | P | 500 | 95 | 1-80 | 400 T. navalis, 100 Teredinidae* | Several with ripening gonads-few with larvae |
| | C | 700 | 15 | 1-12 | 60 T. navalis, 640 Teredinidae* | |
| 5 | P | 1 | 2 | 130 | 1 B. gouldi | |
| | C | 1 | 1 | 7 | 1 Teredinidae* | |
| 7 | P | 4 | 2 | 10-140 | 4 T. navalis | |
| | C | 0 | | | | |
| 10A | P | 2 | 1 | 1-50 | 2 Teredinidae* | |
| | C | 0 | | | | |
| 11 | P | 56 | 60 | 30-150 | 1 B. gouldi, 55 T. navalis | 1 T. navalis dead |
| | C | 0 | | | | |
| 13 | P | 3 | 5 | 70-180 | B. gouldi | |
| | C | 0 | | | | |
| 14 | P | 4 | 5 | 48-110 | 3 B. gouldi, 1 T. navalis | |
| | C | 0 | | | | |
| 15 | P | 4 | 3 | 5-115 | 1 T. navalis, 3 B. gouldi | |
| | C | 0 | | | | |
| 16B | P | 1 | 2 | 123 | 1 B. gouldi | |
| | C | 1 | 1 | 9 | 1 B. gouldi | |
| 17 | P | 4 | 1 | 1-44 | 3 T. navalis, 1 Teredinidae* | |
| | C | 18 | 1 | 1-7 | 1 T. navalis, 13 Teredo spp., 4 Teredinidae* | |

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

P = Long-term panel submerged March 2-3, 1982 (Station 16B submerged June 2, 1981).
C = Short-term panel submerged August 3-4, 1982.
* = Not speciated due to size or condition.

## TABLE A-18. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED OCTOBER 5-6, 1982

| Station | Panel | No. of Specimens | Percent Filled | Size Range in mm. | Species Identification | Remarks |
|---|---|---|---|---|---|---|
| 1 | P | 1,000± | 99 | 3-60 | 150 T. navalis, 850 Teredinidae* | 10% of specimens dead |
| | C | 0 | | | | |
| 3 | P | 1 | 3 | 150 | 1 B. gouldi | |
| | C | 0 | | | | |
| 7 | P | 2 | 2 | 65-80 | 2 T. navalis | 1 dead, 1 live |
| | C | 0 | | | | |
| 8 | P | 1 | 2 | 130 | 1 T. navalis | |
| | C | 0 | | | | |
| 10B | P | 3 | 8 | 130-170 | 1 B. gouldi, 1 T. navalis | |
| | C | 0 | | | | |
| 11 | P | 48 | 80 | 60-170 | 48 T. navalis | |
| | C | 0 | | | | |
| 13 | P | 1 | 3 | 175 | 1 B. gouldi | |
| | C | 0 | | | | |
| 14 | P | 3 | 7 | 40-205 | 3 B. gouldi | |
| | C | 0 | | | | |
| 15 | P | 3 | 2 | 4-130 | 1 B. gouldi, 1 T. navalis, 1 Teredinidae* | |
| | C | 0 | | | | |
| 16B | P | 1 | 4 | 205 | 1 B. gouldi | |
| | C | 0 | | | | |
| 17 | P | 6 | 3 | 1-105 | 5 T. navalis, 1 Teredinidae* | |
| | C | 0 | | | | |

Stations 2, 4-6, 9-10A, 12 - No Teredinidae present

P = Long-term panel submerged April 7-8, 1982 (Station 16B submerged June 2, 1982).
C = Short-term panel submerged September 7-8, 1982.
* = Not speciated due to size or condition.

## TABLE A-19. INCIDENCE OF TEREDINIDAE IN PANELS REMOVED NOVEMBER 1-2, 1982

| Station | Panel | No. of Specimens | Percent Filled | Size Range in mm. | Species Identification | Remarks |
|---|---|---|---|---|---|---|
| 1 | P (Panel missing from rack due to heavy attack) | | | | | |
| | C | 160 | 1 | 1 | 160 Teredinidae* | |
| 5 | P | 1 | 2 | 180 | 1 T. navalis | |
| | C | 1 | 1 | 1 | 1 Teredinidae* | |
| 7 | P | 2 | 1 | 1-100 | 2 Teredinidae* | empty tube only of 100 mm specimen |
| | C | 0 | | | | |
| 8 | P | 1 | 2 | 150 | 1 T. navalis | |
| | C | 0 | | | | |
| 9 | P | 1 | 1 | 70 | 1 T. navalis | |
| | C | 0 | | | | |
| 10A | P | 4 | 9 | 60-175 | 4 T. navalis | |
| | C | 0 | | | | |
| 11 | P | 82 | 90 | 40-130 | 82 T. navalis | |
| | C | 4 | 1 | 1 | 4 Teredinidae* | |
| 13 | P | 5 | 20 | 180-260 | 5 B. gouldi | |
| | C | 0 | | | | |
| 14 | P | 2 | 7 | 155-190 | B. gouldi | |
| | C | 0 | | | | |
| 15 | P | 5 | 7 | 24-145 | 1 B. gouldi<br>4 T. navalis | |
| | C | 0 | | | | |
| 16B | P | 2 | 9 | 220-240 | 2 B. gouldi | |
| | C | 0 | | | | |
| 17 | P | 5 | 5 | 40-130 | 5 T. navalis | 4 live, 1 dead |
| | C | | | | | |

Stations 2-4A, 6, 10, 10B, 12 - No Teredinidae present

P = Long-term panel submerged May 4-5, 1982 (Station 16B submerged June 2, 1982).
C = Short-term panel submerged October 5-6, 1982.
* = Not speciated due to size or condition.

TABLE A-20. NUMBER OF <u>Teredo</u> <u>bartschi</u> IN 6-MONTH PANELS REMOVED JULY, 1975 THROUGH NOVEMBER, 1982

| tation | 1 | 2 | 3 | 4 | 4A | 5 | 6 | 7* | 8 | 9 | 10 | 10A | 10B | 11 | 12 | 13 | 14 | 15 | 16# | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ul | | | | | - | | | | - | - | | - | - | | | | | | | |
| ug | | | | | - | | | | - | - | | - | - | | | | | | | |
| ep | | | | | - | 2962 | 402 | - | | | | - | - | | | | | | | |
| ct | | | | | - | 46 | 315 | | | | | - | - | | | | | | | |
| ov | | | | | - | 392 | 300 | | | | | - | - | | | | | | | |
| ec | | | | | - | 21 | 7 | | | | | - | - | | | | | | | |
| an | - | | | | - | 46 | 240 | | | | | - | - | | | | | | | |
| eb | | | | | - | 350 | 398 | | | | | - | - | | | - | | | | |
| ar | | | | | - | 14 | 14 | | | | | - | - | | | | | | | |
| pr | | | | | - | | | | | | | - | - | | | | | | | |
| ay | | | | | - | | | | | | | - | - | | | | | | | |
| un | | | | | - | | | | | | | - | - | | | | | | | |
| ul | | | | | - | | | | | | | - | - | | | | | | | |
| ug | | | | | - | | | | | | | - | - | | | | | | | |
| ep | | | | | - | | | | | | | - | - | | | | | | | |
| ct | | | | | - | | | | | | | - | - | | | | | | | |
| ov | | | | | - | | | 11 | | | | - | - | | | | | | | |
| ec | | | | | - | | | | | | | - | - | | | | | | | |
| an | | | | | - | | | | | | | - | - | | | | | | | |
| eb | | | | | | | | 4 | | | | - | - | | | | | | | |
| ar | | | | | - | | | | | | | - | - | | | | | | | |
| pr | | | | | - | | | | | | | - | - | | | | | | | |
| ay | | | | | | | | | | | | - | - | | | | | | | |
| un | | | | | | | | | | | | - | - | | | | | | | |
| ul | | | | | | | | | | | | - | - | | | | | | | |
| ug | | | | | | | | | | | | - | - | | | | | | | |
| ep | | | | | | | | 1 | | | | - | - | | | | | | | |
| ct | | | | | | | | 11 | | | | - | - | | | | | | | |
| ov | | | | | | | | 135 | | | | - | - | | | | | | | |
| ec | | | | | | | | 130 | | | | - | - | | | | | | | |
| an | | | | | | | | 160 | | | | - | - | | | | | | | |
| eb | | | | | | | | 200 | | | | - | - | | | | | | | |
| ar | | | | | | 1 | 2 | 81 | | | | - | - | | | | | | | |
| pr | | | | | | | | | | | | - | - | | | | | | | |
| ay | | | | | | | | | | | | | | | | | | | | |
| un | | | | | | | | | | | | | | | | | | | | |

TABLE A-20. (continued)

| Station | 1 | 2 | 3 | 4 | 4A | 5 | 6 | 7* | 8 | 9 | 10 | 10A | 10B | 11 | 12 | 13 | 14 | 15 | 16# | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jul | | | | | | | | 71 | | | | | | | | | | | | |
| Aug | | | | | | 2 | | 129 | | | | | | | | | | | | |
| Sep | | | | | | 91 | | 536 | | | | | | | | | | | | |
| Oct | | | | | | 90 | 1 | 360 | | | | | | | | | | | | |
| Nov | | | | | | 79 | 22 | 300 | | | | | | | | | | | | |
| Dec | | | | | | 190 | 35 | 400 | | | | | | | | | | | | |
| Jan | | | | | | 73 | 11 | 300 | | | | | | | | | | | | |
| Feb | | | | | | 7 | 18 | 70 | | | | | | | | | | | | |
| Mar | | | | | | | | | | | | | | | | | | | | |
| Apr | | | | | | | | | | | | | | | | | | | | |
| May | | | | | | | | | | | | | | | | | | | | |
| Jun | | | | | | | | | | | | | | | | | | | | |
| Jul | | | | | | | | | | | | | | | | | | | | |
| Aug | | | | | | 17 | | 160 | | | | | | | | | | | | |
| Sep | | | | | | 240 | | 500 | | | | 17 | | | | | | | | |
| Oct | | | | | | 35 | 64 | 100 | | | | 20 | | | | | | | | |
| Nov | | | | | | 1 | 160 | 38 | - | | | 29 | | | | | | | | |
| Dec | | | | | | 10 | 170 | 14 | | | | 47 | | | | | | | | |
| Jan | | | | | | 390 | 39 | 200 | | | | 34 | 1 | | | | | | | |
| Feb | | | | | | 449 | 21 | 55 | | | | 31 | | 1 | | | | | | |
| Mar | | | | | | 22 | 12 | 40 | | | | 1 | | | | | | | | |
| Apr | | | | | | | | | | | | | | | | | | | - | |
| May | | | | | | | | | | | | | | | | | | | | |
| Jun | | | | | | | | | | | | | | | | | | | | |
| Jul | | | | | | | | | | | | | | | | | | | | |
| Aug | | | | | | | | | | | | | | | | | | | | |
| Sep | | | | | | | | | | | | | | | | | | | | |
| Oct | | | | | | | | 2 | | | | | | | | | | | | |
| Nov | | | | | | | | 1 | | | | | | | | | | | | |

TABLE A-20. (continued)

| Station | 1 | 2 | 3 | 4 | 4A | 5 | 6 | 7* | 8 | 9 | 10 | 10A | 10B | 11 | 12 | 13 | 14 | 15 | 16# | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dec | | | | | | | 1 | 6 | | | | | | | | | | | | |
| Jan | | | | | | | 2 | 63 | | | | | | | | | | | | |
| Feb | | | | | | | | 5 | | | | | | | | | | | | |
| Mar | | | | | | | 4 | 19 | | | | | | | | | | | | |
| Apr | | | | | | | | | | | | | | | | | | | | |
| May | | | | | | | | | | | | | | | | | | | | |
| Jun | | | | | | | | | | | | | | | | | | | | |
| Jul | | | | | | | | | | | | | | | | | | | | |
| Aug | | | | | | | | 5 | | | | | | | | | | | | |
| Sep | | | | | | | | 130 | | | | | | | | | | | | |
| Oct | | | | | | 9 | | 130 | | | | | | | | | | | | |
| Nov | | | | | | 90 | | 250 | | | | | | | | | | | | |
| Dec | | | | | | 3 | 1 | 200 | | | | | | | | | | | | |
| Jan | | | | | | 3 | 1 | 150 | | | | | | | | | | | | |
| Feb | | | | | | 2 | | 100 | | | | | | | | | | | | |
| Mar | | | | | | 1 | | | | | | | | | | | | | | |
| Apr | | | | | | | | | | | | | | | | | | | | |
| May | | | | | | | | | | | | | | | | | | | -- | |
| Jun | | | | | | | | | | | | | | | | | | | | |
| Jul | | | | | | | | | | | | | | | | | | | | |
| Aug | | | | | | | | | | | | | | | | | | | | |
| Sep | | | | | | | | | | | | | | | | | | | | |
| Oct | | | | | | | | | | | | | | | | | | | | |
| Nov | - | | | | | | | | | | | | | | | | | | | |

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

Crocket 1981a, 1981b; Maciolek-Blake et al., 1982). The plant was down during the winter months in 1976 and 1980 (see e.g., Maciolek-Blake et al., 1982) and at least some of the breeding population survived.

Another factor contributing to the loss of T. bartschi from the panels in 1982 could be the effects of the haplosporidian parasite described for the Barnegat Bay region by Hillman (1978, 1979). Last year, specimens of T. bartschi examined for gonad condition were infected with the parasite at rates of 92 percent at Station 5 and 100 percent at Station 7 (Maciolek-Blake et al., 1982). Populations infected at rates of 40 percent or higher can be expected to show a decline in abundance during the season following the high infection rate (Maciolek-Blake et al., 1981; Hillman et al., 1982).

The synergistic effect of the cold water and the high parasite burden causing an insurmountable stress is another consideration when trying to assess the disappearance of T. bartschi from the Oyster Creek panels.

As with last year, because of the distinct and limited distribution of this species only in the effluent area, no further statistical analysis of the data on distribution and abundance of this species was made.

**Teredo navalis.** Teredo navalis was recorded from six-month panels from 6 of the 20 stations between December, 1981 and March, 1982, and at 11 stations between July and November, 1982 (Table A-21), thus maintaining the distributional pattern described last year (Maciolek-Blake et al., 1982, p. A-46). It was absent from Station 2, and hasn't been observed there since December, 1980 when one specimen was collected. It was dominant (Table A-23), however, at Stations 1, 8, 11, 15 and 17, and codominant at Station 9, an increase over last year in the number of stations at which it was the dominant shipworm species. It continued to be far more abundant at Station 1, Barnegat Inlet, on the eastern side of the Bay, than any other station (Table A-21).

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

In the last annual report, we initiated a system of grouping the data which corresponded to the breeding season of the Teredinidae rather than to the calendar year. Grouping by calendar year had appeared to artificially enhance the two-way interactions in the analysis of variance and the new grouping proved to be extremely useful in explaining the underlying causes of variation in the data. We have chosen to continue grouping data on the basis of bioyear (i.e., July, Year A to June, Year B) in the present report and thus the most recent data added during this calendar year comprise the last six months of bioyear 81/82 and the first six months of bioyear 82/83.

For the data on Teredo navalis abundance (Table A-24) the results of the ANOVA were similar to those seen in our previous report. All main effects were found to be highly significant for both grouped (region, season, bioyear) and ungrouped (station, month, bioyear) factors. Higher order interactions were calculated for grouped factors only and indicated a pattern of significance similar to that reported last year. The interaction of region and season was highly significant, meaning that the pattern of seasonal change in T. navalis densities differs among regions. The region-bioyear and season-bioyear interactions were not significant. The interaction of all three main factors was also not significant.

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

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

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

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

Comparisons among station means for T. navalis log abundances, using all available data and data from fall and winter months only, resulted in the following groupings (stations connected by an underline were not significantly different at $p = .05$):

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

For the analysis using data from the summer months only (June, July, August), the pattern was essentially similar, with only stations 1 and 11 appearing as significantly different from the large group comprising the remaining stations:

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

These observations are identical to those described in our previous report and continue to indicate a pattern of greater T. navalis densities at Stations 1 and 17, near Barnegat Inlet, and at Stations 2 and 11. Although densities of T. navalis have generally decreased in all areas over the most recent year, this species continues to be dominant at Station 11 in an area which would ordinarily be expected to support greater densities of Bankia gouldi. As we have noted in previous reports, this situation is not fully understood. For the current year, as in previous years, however, densities of T. navalis at stations in Oyster Creek (Stations 5, 6, 7 and 8) were not significantly different from the majority of stations on the western side of Barnegat Bay.

Comparisons among bioyears using all available data indicated few significant differences in the abundance of T. navalis over the course of the study:

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

This arrangement of years is slightly different from that described in our previous report, in which no significant difference among bioyears was found. The most recent bioyear (82/83) falls nearly in the middle of the range of densities observed for this species over the course of the study and does not appear to indicate any important change in the abundance of T. navalis.

The grouping resulting from Region 3 (Stations 1 and 17) data only indicated no significant differences among bioyears. When Region 1 (impacted stations) only is considered, the current bioyear (82/83) was found to have significantly greater densities of T. navalis than all other years. We believe that this is an artifact due to the fact that the data for 82/83 are incomplete at this time and include only the season(s) of greatest annual density for this species. We will, however, reexamine this observation following collection of data from the entire bioyear.

The results of the comparisons among months were essentially similar for all available data:

Jul Mar Aug Dec Feb Jan Sep Nov Oct,

complete bioyears only:

Jul Mar Aug Dec Feb Jan Sep Nov Oct,

and Region 3 data only:

Jul Aug Mar Feb Sep Oct Dec Jan Nov

These results support the observations made in previous reports that T. navalis has a pronounced seasonal cycle in all areas of Barnegat Bay with lowest numbers during the spring (excluded from this analysis) and summer seasons followed by annual peaks during fall and early winter.

**Bankia gouldi**. Bankia gouldi was recorded from 6-month panels from 11 of 20 stations between December, 1981 and March, 1982, and at 8 stations between September and November, 1982. This was two fewer stations than reported for the same time period in 1981. Although the species continues to be most abundant at stations north of Oyster Creek along the western shore of Barnegat Bay (Tables A-22 and A-23), there has been a continual and significant decline in abundance of this species throughout the study area over the past few years (Table A-22).

As has been the case in previous years, both the presence/absence and abundance data produced similar though not identical results. All main effects were highly significant for both the grouped (region, season, bioyear) and ungrouped (station, month, bioyear) analysis. Comparison of the mean squares attributable to each of the main factors indicates that month/season was the most important determining factor for

TABLE A-21. NUMBER OF Teredo navalis IN 6-MONTH PANELS REMOVED JULY, 1975 THROUGH NOVEMBER, 1982

| Station | 1 | 2 | 3 | 4 | 4A | 5 | 6 | 7* | 8 | 9 | 10 | 10A | 10B | 11 | 12 | 13 | 14 | 15 | 16# | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jul | | | | | - | | | | - | - | | - | - | | | | | | | |
| Aug | | | | | - | | | | - | - | | - | - | | | | | | | |
| 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 | | | | | - | | | | | | | - | - | | | | | | | |
| 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 | | | | | - | | | | | | | - | - | | | | | | | |
| Jul | | | | | - | | | | | | | - | - | | | | | | | |
| Aug | | | | | - | | | | | | | - | - | | | | | | | |
| Sep | 160 | | | | | | | | | | | - | - | | | | 1 | 1 | | |
| Oct | 300 | 1 | | | | | | | | | | - | - | 1 | | | 1 | | | |
| Nov | 390 | | | | | | | | | | | - | - | 6 | | | | 1 | | |
| Dec | 380 | | | | | | | | | 1 | | - | - | 1 | | | | | | 4 |

TABLE A-21. (Continued)

| Station | 1 | 2 | 3 | 4 | 4A | 5 | 6 | 7* | 8 | 9 | 10 | 10A | 10B | 11 | 12 | 13 | 14 | 15 | 16# | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 400 | 3 | | | | | | | | | | - | - | 2 | | | | | | 4 |
| Feb | 375 | | | | | | | | | | | - | - | | | | | | | 1 |
| Mar | 220 | | | | | | | | | | | - | - | | | | | | | |
| Apr | | | | | | | | 2 | | | | - | - | | | | | | | |
| May | | | | | | | | | | | | | | | | | | | | |
| Jun | | | | | | | | | | | | | | | | | | | | |
| Jul | | | | | | | | | | | | | | 1 | | | | | | |
| Aug | 1 | | | | | | | | | | | | | | | | | | | |
| Sep | 115 | | | | | | | | | | | | | 1 | | | | | | 1 |
| Oct | 329 | 3 | | | | | | | | | | | | | | | | | | |
| Nov | 430 | 5 | | | | | | | | | | | | 2 | | | | | | 4 |
| Dec | 400 | 3 | | | | | | | | | | | | 8 | | | | | | |
| 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 |
| 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 | | | | | | |

ABLE A-21. (Continued)

| tation | 1 | 2 | 3 | 4 | 4A | 5 | 6 | 7* | 8 | 9 | 10 | 10A | 10B | 11 | 12 | 13 | 14 | 15 | 16# | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ug | 1 | 6 | | | | | | 1 | | | | | | 29 | 1 | | 1 | | | |
| ep | 35 | 7 | | | | 1 | | 1 | 1 | | | | | 4 | | | 1 | | 1 | |
| ct | 200 | 11 | | 1 | | | | 3 | | | | | | 8 | | | 1 | | | 2 |
| ov | 300 | 11 | | | | | | | | | | | | 11 | | | | | | 6 |
| ec | 300 | 1 | | | | | | | | | | | 1 | 8 | | | | | | |
| an | 350 | | | | | | | | | | | | | | | | | | | |
| eb | 72 | | | | | | | | | | | 1 | | 8 | | | 2 | | | 6 |
| ar | 3 | | | | | | | | | | | 1 | | | | | | | | |
| pr | | | | | | | | 1 | 1 | | | | | | | | | | | |
| ay | | | | | | | | | | | | | | | | | | | | |
| un | | | | | | | | | | | | | | | | | | | | |
| ul | | | | | | | | | 1 | | | | | | | | 2 | | | |
| ug | 135 | | | | | | | | | | | | | 7 | | | 3 | | | |
| ep | 800 | | | | | | | | | | | | | 5 | | | 4 | 1 | | |
| ct | 100 | | | | | | | | 1 | 1 | | | | 5 | | -- | 3 | | | 1 |
| ov | 190 | | | | | | | | 2 | | | | | 2 | | -- | | 1 | | |
| ec | 65 | | | | | | | 1 | | | | | | 2 | | | | | -- | 4 |
| an | 45 | | | | | | | | | | | | | 1 | | | | | | 3 |
| eb | 60 | | | | | | | | | | | | | 8 | | | 1 | 2 | | 2 |
| ar | 23 | | | | | | | | | | | | | | | | | | | |
| pr | | | | | | | | | | | | | | | | | | | | |
| ay | | | | | | | | | | | | | | | | | | | | |
| un | | | | | | | | | | | | | | | | | | | -- | |
| ul | | | | | | | | | 1 | | | | | | | | | | | |
| ug | | | | | | | | 1 | 1 | | | | | 3 | | | 1 | | | |
| ep | 400 | | | | | | | 4 | | | | | | 55 | | | 1 | 1 | | 3 |
| ct | 150 | | | | | | | 2 | 1 | | | | 1 | 48 | | | | 1 | | 5 |
| ov | -- | | | | | 1 | | | 1 | 1 | | 4 | | 82 | | | | 4 | | 5 |

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

TABLE A-22. NUMBER OF Bankia gouldi IN 6-MONTH PANELS REMOVED JULY, 1975 THROUGH NOVEMBER, 1982

| 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 | |
| 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 | | | | | - | | | | | | | - | - | | | | | | | |
| Jul | | | | | - | 1 | | 2 | | | | - | - | 4 | | | 2 | | | |
| Aug | | | | 2 | - | 2 | | 2 | 2 | 1 | | - | - | 6 | 2 | 24 | 7 | 3 | | |
| Sep | | | | 3 | - | 1 | 2 | 2 | 3 | | 1 | - | - | 23 | 5 | 31 | 11 | 7 | | |
| Oct | | | | 1 | - | 3 | 1 | 4 | 1 | 1 | 1 | - | - | 11 | 8 | 26 | 19 | 1 | | |
| Nov | 1 | | | 5 | - | 4 | | 5 | 1 | | | - | - | 33 | 7 | 20 | 17 | 2 | | |
| Dec | | | | 4 | - | | 1 | 3 | 5 | | 2 | - | - | 31 | 6 | 21 | 10 | 3 | | |
| Jan | | | | | - | | 1 | 2 | | | | - | - | 42 | 6 | 5 | 2 | | | |
| Feb | | | | 2 | - | 1 | 1 | 1 | | | | - | - | 31 | 2 | 2 | | | | |
| Mar | | | | | - | | | | | | | - | - | | | | | | | |
| Apr | | | | | - | | | | | | | - | - | | | | | | | |
| May | | | | | | | | | | | | - | - | | | | | | | |
| Jun | | | | | | | | | | | | - | - | | | | | | | |
| Jul | | | | | | | | | | | | - | - | | | | | | | |
| 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 | | | | | | | | | | | | | | | | | | | | |

TABLE A-22. (Continued)

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

TABLE A-22. (Continued)

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

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

TABLE A-23. PRESENCE AND DOMINANCE OF SPECIES OF TEREDINIDAE IN LONG-TERM PANELS REMOVED FROM DECEMBER, 1981 THROUGH NOVEMBER, 1982

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

* = Specimens too small or in condition too poor for speciating.
√ = Species present.

TABLE A-24. ANALYSIS OF VARIANCE OF $LOG_e$ (1 + ABUNDANCE) OF *Teredo navalis* BASED ON LONG-TERM (6-MONTH) PANELS REMOVED JANUARY, 1976 THROUGH NOVEMBER, 1982, WITH THE EXCEPTION OF PANELS REMOVED IN APRIL, MAY OR JUNE

| Source of Variation | Sum of Squares | DF | Mean Square | F | Significance of F | Source of Variation | Sum of Squares | DF | Mean Square | F | Significance of F |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MAIN EFFECTS | 503.941 | 11 | 45.813 | 51.109 | 0.000 | MAIN EFFECTS | 951.911 | 32 | 29.747 | 60.516 | 0.000 |
| Region | 462.523 | 4 | 115.631 | 128.999 | 0.000 | Station | 882.179 | 19 | 46.430 | 94.455 | 0.000 |
| Season | 13.904 | 2 | 6.952 | 7.756 | 0.000 | Month | 42.142 | 8 | 5.268 | 10.716 | 0.000 |
| Bioyear | 27.173 | 5 | 5.435 | 6.063 | 0.000 | Bioyear | 28.606 | 5 | 5.721 | 11.639 | 0.000 |
| 2-WAY INTERACTIONS | 84.144 | 38 | 2.214 | 2.470 | 0.000 | | | | | 5.173 | 0.000 |
| Region/Season | 61.015 | 8 | 7.627 | 8.509 | 0.000 | | | | | 17.820 | 0.000 |
| Region/Bioyear | 19.346 | 20 | 0.967 | 1.079 | 0.366 | | | | | 2.259 | 0.001 |
| Season/Bioyear | 3.466 | 10 | 0.347 | 0.387 | 0.953 | | | | | .811 | 0.600 |
| 3-WAY INTERACTIONS | 12.138 | 40 | 0.303 | 0.339 | 1.000 | | | | | .708 | 0.750 |
| Region/Season/Bioyear | 12.138 | 40 | 0.303 | 0.339 | 1.000 | | | | | | |
| EXPLAINED | 600.223 | 89 | 6.744 | 7.524 | 0.000 | EXPLAINED | 1048.193 | 110 | 9.529 | 22.264 | |
| RESIDUAL | 840.792 | 938 | 0.896 | | | RESIDUAL | 392.822 | 917 | 0.428 | | |
| TOTAL | 1441.015 | 1027 | 1.403 | | | | | | | | |

TABLE A-25. ANALYSIS OF VARIANCE OF PRESENCE/ABSENCE OF *Teredo navalis* BASED ON LONG-TERM (6-MONTH) PANELS REMOVED JANUARY, 1976 THROUGH NOVEMBER, 1982, 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 | 37.162 | 11 | 3.378 | 27.369 | 0.000 |
| Region | 25.266 | 4 | 6.317 | 51.173 | 0.000 |
| Season | 2.300 | 2 | 1.150 | 9.315 | 0.000 |
| Bioyear | 9.411 | 5 | 1.882 | 15.248 | 0.000 |
| 2-WAY INTERACTIONS | 9.412 | 38 | 0.248 | 2.007 | 0.000 |
| Region/Season | 3.927 | 8 | 0.491 | 3.977 | 0.000 |
| Region/Bioyear | 4.096 | 20 | 0.205 | 1.659 | 0.034 |
| Season/Bioyear | 1.402 | 10 | 0.140 | 1.136 | 0.332 |
| 3-WAY INTERACTIONS | 3.557 | 40 | 0.089 | 0.720 | 0.902 |
| Region/Season/Bioyear | 3.557 | 40 | 0.089 | 0.720 | 0.902 |
| EXPLAINED | 50.131 | 89 | 0.563 | 4.563 | 0.000 |
| RESIDUAL | 115.783 | 938 | 0.123 | | |
| TOTAL | 165.914 | 1027 | 0.162 | | |

| Source of Variation | Sum of Squares | DF | Mean Square | F | Significance of F |
|---|---|---|---|---|---|
| MAIN EFFECTS | 69.645 | 32 | 2.176 | 22.494 | 0.000 |
| Station | 52.233 | 19 | 2.749 | 28.408 | 0.000 |
| Month | 7.808 | 8 | 0.976 | 10.087 | 0.000 |
| Bioyear | 9.809 | 5 | 1.962 | 20.277 | 0.000 |
| | | | | 2.730 | 0.000 |
| | | | | 5.405 | 0.000 |
| | | | | 2.257 | 0.001 |
| | | | | 1.541 | 0.150 |
| | | | | 0.980 | 0.500 |
| EXPLAINED | 82.614 | 110 | 0.751 | 8.268 | |
| RESIDUAL | 83.300 | 917 | 0.091 | | |

the presence/absence data while station/region was most important when abundances were analyzed.

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

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

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

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

2) Bioyears
   a) all data

3) Months
   a) all data
   b) complete bioyears only (7/76 - 6/82)
   c) regions 4 and 5 only

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

TABLE A-26. ANALYSIS OF VARIANCE OF $LOG_e$ (1 + ABUNDANCE) OF *Bankia gouldi* BASED ON LONG-TERM (6-MONTH) PANELS REMOVED JANUARY, 1976, THROUGH NOVEMBER, 1982, 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 | 190.840 | 11 | 17.349 | 24.331 | 0.000 |
| Region | 101.486 | 4 | 25.372 | 35.583 | 0.000 |
| Season | 45.236 | 2 | 22.618 | 31.721 | 0.000 |
| Bioyear | 44.424 | 5 | 8.885 | 12.461 | 0.000 |
| 2-WAY INTERACTIONS | 50.683 | 38 | 1.334 | 1.871 | 0.001 |
| Region/Season | 19.197 | 8 | 2.400 | 3.365 | 0.001 |
| Region/Bioyear | 25.050 | 20 | 1.253 | 1.757 | 0.021 |
| Season/Bioyear | 6.355 | 10 | 0.636 | 0.891 | 0.541 |
| 3-WAY INTERACTIONS | 15.888 | 40 | 0.397 | 0.557 | 0.989 |
| Region/Season/Bioyear | 15.888 | 40 | 0.397 | 0.557 | 0.989 |
| EXPLAINED | 257.412 | 89 | 2.892 | 4.056 | 0.000 |
| RESIDUAL | 668.826 | 938 | 0.713 | | |
| TOTAL | 926.238 | 1027 | 0.902 | | |

| Source of Variation | Sum of Squares | DF | Mean Square | F | Significance of F |
|---|---|---|---|---|---|
| MAIN EFFECTS | 481.827 | 32 | 15.057 | 33.712 | 0.000 |
| Station | 332.477 | 19 | 17.499 | 39.178 | 0.000 |
| Month | 106.184 | 8 | 13.273 | 29.717 | 0.000 |
| Bioyear | 46.559 | 5 | 9.312 | 20.849 | 0.000 |
| | | | | 3.238 | 0.000 |
| | | | | 5.825 | 0.000 |
| | | | | 3.041 | 0.000 |
| | | | | 1.544 | 0.150 |
| | | | | 0.964 | 0.500 |
| EXPALINED | 548.398 | 110 | 4.985 | 12.098 | |
| RESIDUAL | 377.840 | 917 | 0.412 | | |

TABLE A-27. ANALYSIS OF VARIANCE OF PRESENCE/ABSENCE OF Bankia gouldi BASED ON LONG-TERM (6-MONTH) PANELS REMOVED JANUARY, 1976, THROUGH NOVEMBER, 1982 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 | 42.224 | 11 | 3.839 | 21.078 | 0.000 |
| Region | 21.740 | 4 | 5.435 | 29.844 | 0.000 |
| Season | 12.580 | 2 | 6.290 | 34.540 | 0.000 |
| Bioyear | 8.029 | 5 | 1.606 | 8.818 | 0.000 |
| 2-WAY INTERACTIONS | 10.897 | 38 | 0.287 | 1.575 | 0.016 |
| Region/Season | 1.749 | 8 | 0.219 | 1.200 | 0.295 |
| Region/Bioyear | 7.103 | 20 | 0.355 | 1.950 | 0.008 |
| Season/Bioyear | 2.109 | 10 | 0.211 | 1.158 | 0.316 |
| 3-WAY INTERACTIONS | 4.282 | 40 | 0.107 | 0.588 | 0.981 |
| Season/Region/Bioyear | 4.282 | 40 | 0.107 | 0.588 | 0.981 |
| EXPLAINED | 57.402 | 39 | 0.645 | 3.542 | 0.000 |
| RESIDUAL | 170.820 | 938 | 0.182 | | |
| TOTAL | 228.222 | 1027 | 0.222 | | |

| Source of Variation | Sum of Squares | DF | Mean Square | F | Significance of F |
|---|---|---|---|---|---|
| MAIN EFFECTS | 102.341 | 32 | 3.198 | 25.279 | 0.000 |
| Station | 60.683 | 19 | 3.194 | 25.245 | 0.000 |
| Month | 33.932 | 8 | 4.241 | 33.526 | 0.000 |
| Bioyear | 9.144 | 5 | 1.829 | 14.456 | 0.000 |
| | | | | 2.377 | 0.000 |
| | | | | 1.814 | 0.015 |
| | | | | 2.941 | 0.000 |
| | | | | 1.748 | 0.050 |
| EXPLAINED | 117.520 | 110 | 1.068 | 8.847 | |
| RESIDUAL | 110.702 | 917 | 0.121 | | |

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

These results are very similar to those reported last year and continue to indicate that Station 11 is unique, particularly in view of the T. navalis results. The stations within Oyster Creek (Stations 5, 6, 7 and 8) are included within one or both of the large homogeneous groups and therefore do not appear to differ from the majority of Barnegat Bay stations in their abundance of B. gouldi.

Repeating the analysis for data from fall months only produced the following pattern:

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

Although there are some differences in the patterns of significance between the combined data and the fall season only data, the overall conclusions are essentially the same. Station 11 appears to have significantly greater densities of B. gouldi than the remaining stations. Stations 13 and 14 are also distinguishable from the other stations but do not reach the densities found at Station 11.

Analysis of data grouped by bioyear, using all data collected from January 1976 to December, 1982 indicated a series of overlapping significantly different groups:

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

Although the number of overlapping groups in this analysis precludes determining a clear pattern of change, a trend toward decreasing densities of B. gouldi over the eight years of data is apparent. This is certainly the case for the present partial bioyear (82/83) even though a disproportionately greater percentage of the data were collected in months which (as will be seen below) typically have higher B. gouldi densities.

The analysis by month, using all data, indicated a clear seasonal cycle of B. gouldi densities:

Mar Jul Aug Feb Nov Sep Oct Dec Jan

Of the nine months analyzed (APR, MAY and JUN are months in which Teredo is never found in the panels) significantly lower densities occur during the two months bordering the spring lows while next lowest densities occur during the next two bordering months. The fall/early winter period historically has been the annual period of peak abundance for this species.

Excluding bioyears 1 and 8 (75/76 and 82/83), for which the data are incomplete, produced a similar pattern:

Mar Jul Feb Aug Jan Nov Sep Oct Dec

as did the analysis using data from Regions 1, 2, and 3 only:

Mar Jul Aug Feb Nov Sep Oct Dec Jan

**Destruction.** Percent destruction (= percent filled) of panels was recorded for both short-term (Table A-4) and long-term panels (Tables A-8 through A-19). The average percent destruction to long-term panels (Figure A-5) over each breeding season (July, Year A, through April, Year B) is given in Table A-28. Values given for the 1982 season are based on data collected from July through November, 1982 and may change slightly when the data set is complete. Several trends are obvious, however.

Attack was highest at Station 1 again this year, although it was down by over 10 percent from last year. This year, there was a considerable increase in attack at Station 11, and only slightly more activity at Station 1 than at Station 11. The absence of Teredo bartschi over much of this report period was responsible for the decrease in attack recorded for Stations 5, 6 and 7, especially Stations 5 and 7. There was also a sharp drop in attack at Station 14, and minor variations up and down at the other sites. Based on the average values in Table A-28, stations were ranked in Table A-29 in descending order of amount of attack. Station 1, near Barnegat Inlet, was again ranked first, with Station 11 second. Station 16, which has been ranked last for every year of the study except the first when it was still in the lowest third of all stations, ranked fifth. This could be due to the change in location, however slight that was geographically.

Analyses presented in the last two annual reports indicated that the abundances of woodborers are the first order effect in accounting for the destruction data, and that temporal factors outweigh spatial factors (Maciolek-Blake et al., 1981, 1982). Analyses performed this year continue to support these conclusions.

**TABLE A-28. AVERAGE PERCENT DESTRUCTION TO LONG-TERM PANELS OVER BREEDING SEASONS (JULY THROUGH APRIL)**

| Station | Breeding Season* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
| 1 | 72.7** | 61.1 | 58.8 | 52.7 | 60.7 | 40.2 | 60.6 | 49.0 |
| 2 | 23.7 | 0.4 | 1.1 | 8.8 | 19.4 | 8.4 | 0.0 | 0.0 |
| 3 | 15.4 | 0.1 | 0.9 | 0.0 | 2.7 | 0.0 | 0.0 | 0.6 |
| 4 | 33.0 | 5.1 | 1.3 | 2.6 | 4.8 | 0.2 | 0.0 | 0.0 |
| 4A | - | - | 3.1 | 0.6 | 8.2 | 0.0 | 0.0 | 0.0 |
| 5 | 67.9 | 7.2 | 9.9 | 21.9 | 61.1 | 8.5 | 6.5 | 0.8 |
| 6 | 65.1 | 3.1 | 0.9 | 4.7 | 14.9 | 2.3 | 0.5 | 0.0 |
| 7 | 2.1** | 18.1 | 36.5 | 53.0 | 67.5 | 6.9 | 29.9 | 1.2 |
| 8 | 3.5** | 7.4 | 2.1 | 3.3 | 2.5** | 1.1 | 0.7 | 1.4 |
| 9 | 2.3** | 1.1 | 1.4 | 0.8 | 4.2 | 1.3 | 0.3 | 0.2 |
| 10 | 23.7 | 1.6 | 3.3 | 0.2 | 3.9 | 0.2 | 0.5 | 0.0 |
| 10A | - | - | - | 8.0 | 49.6 | 22.4 | 3.2 | 2.0 |
| 10B | - | - | - | 2.4 | 14.4 | 2.1 | 0.4 | 1.6 |
| 11 | 64.5 | 24.5 | 43.1 | 24.7 | 66.6 | 40.5 | 7.7 | 46.8 |
| 12 | 39.6 | 15.7 | 12.4 | 0.8 | 35.6 | 18.3 | 2.0 | 0.0 |
| 13 | 57.2** | 38.2 | 24.9 | 13.7 | 42.2 | 2.8 | 3.1** | 5.6 |
| 14 | 56.3 | 32.4 | 19.2 | 24.3 | 48.5 | 2.2 | 10.2 | 4.0 |
| 15 | 15.4 | 5.1 | 0.5 | 0.7 | 5.6 | 2.9 | 1.2 | 2.4 |
| 16/16B | 6.6 | 0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0** | 3.0** |
| 17 | 44.4 | 8.5 | 0.8 | 1.8 | 3.5 | 2.0 | 0.8 | 1.8 |

* 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-November, 1982

** = Incomplete data.

\- = Panel not exposed.

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

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

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

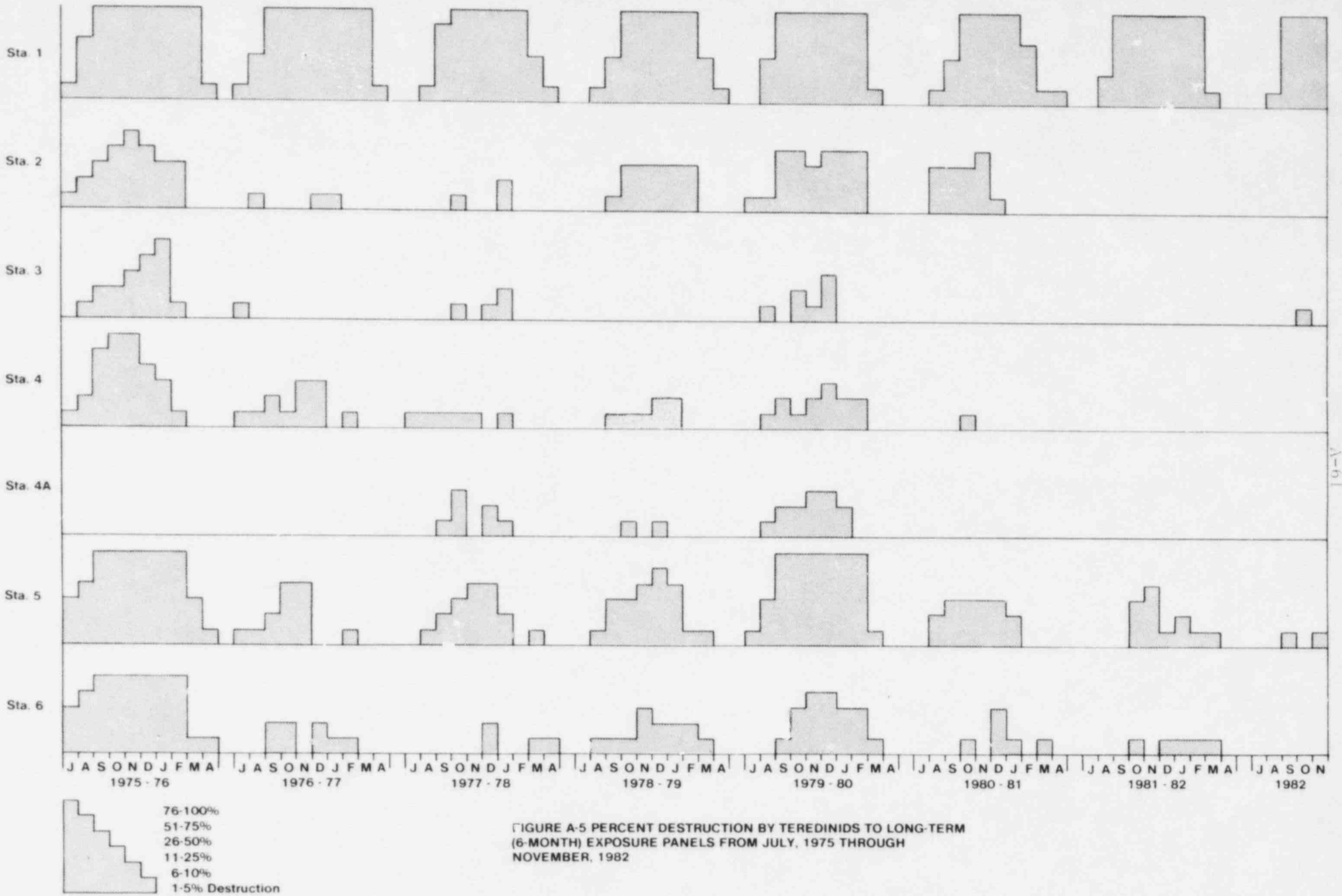



FIGURE A-5 PERCENT DESTRUCTION BY TEREDINIDS TO LONG-TERM (6-MONTH) EXPOSURE PANELS FROM JULY, 1975 THROUGH NOVEMBER, 1982

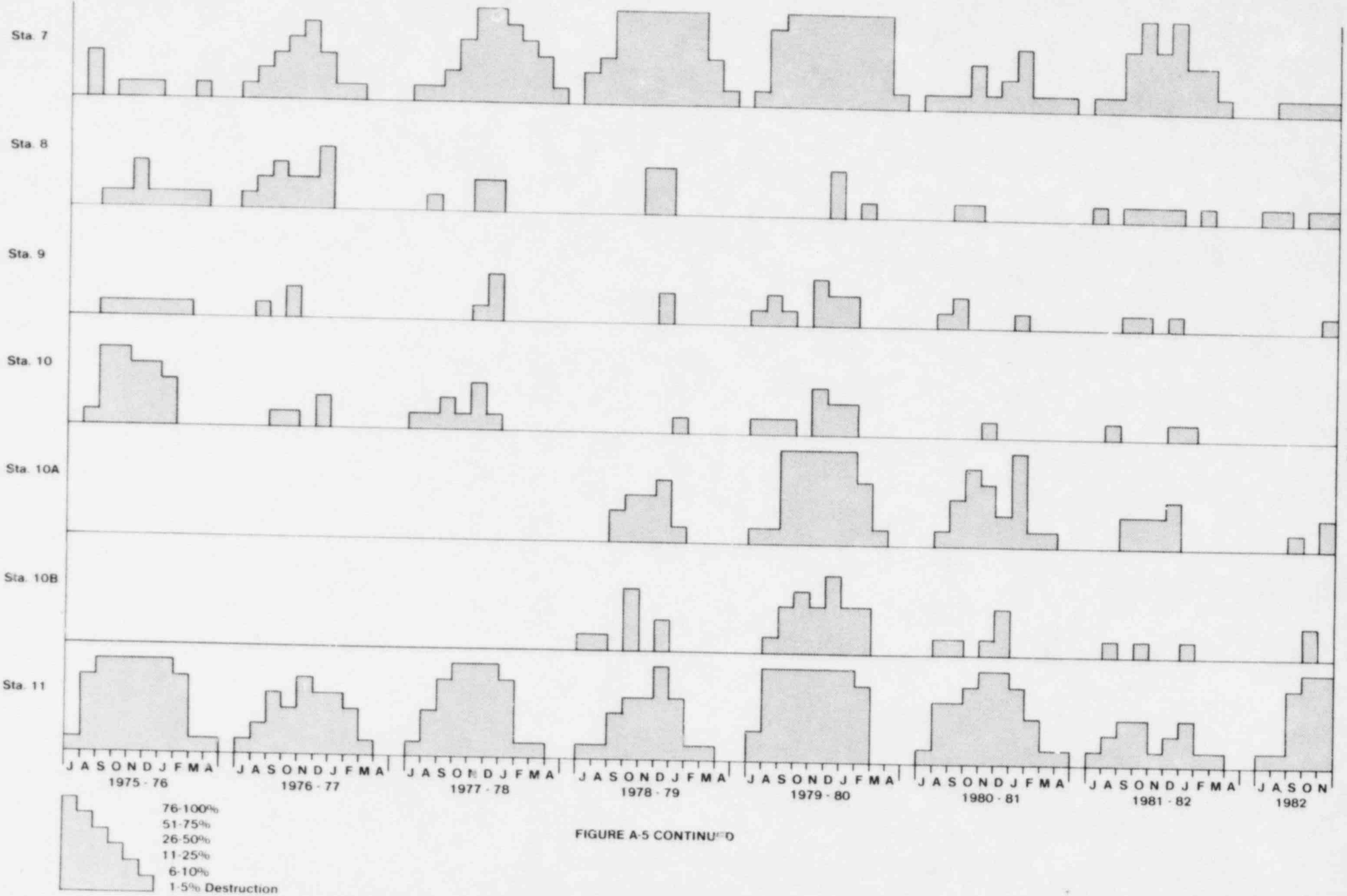



FIGURE A-5 CONTINU⁼D

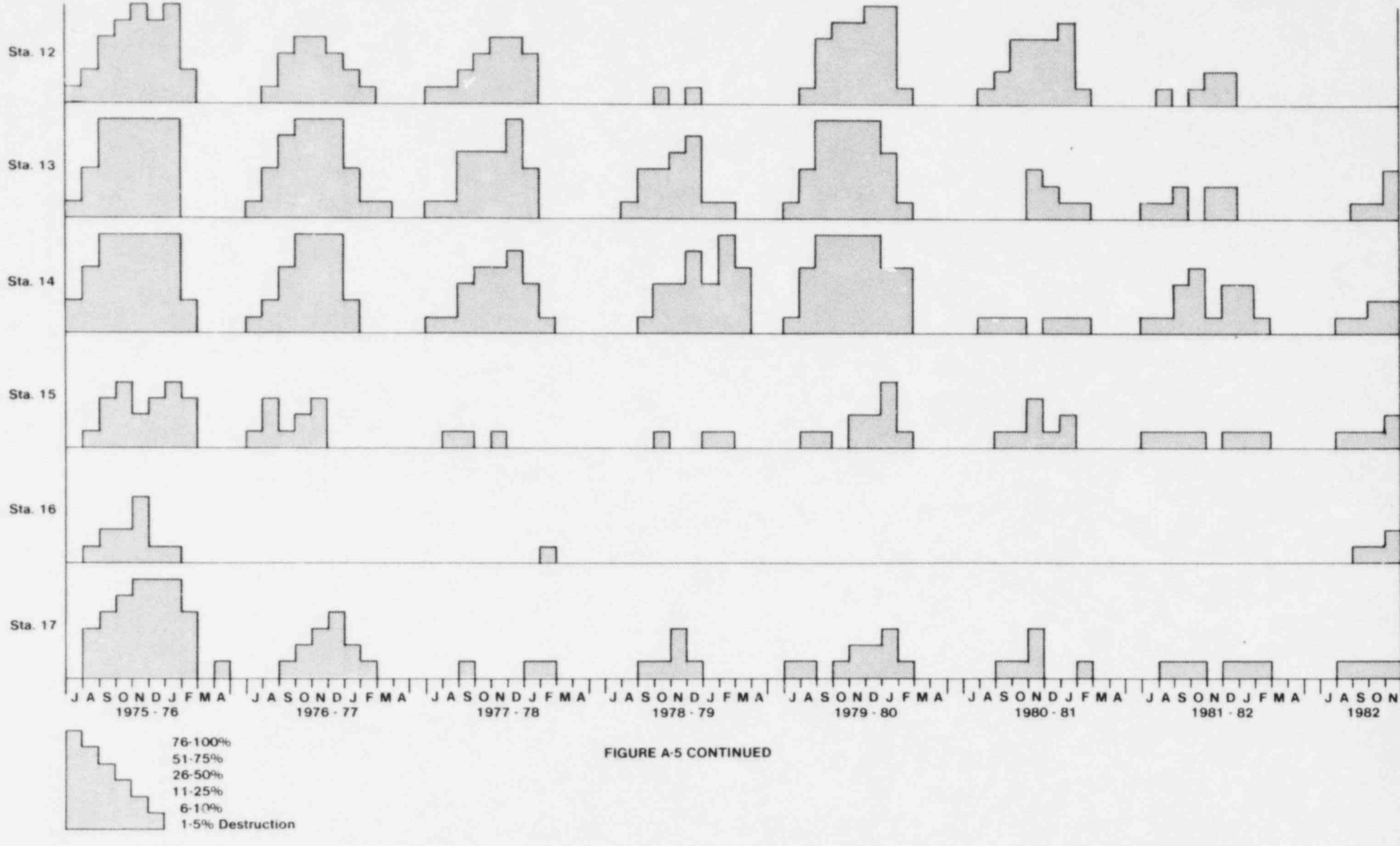



FIGURE A-5 CONTINUED

An unweighted least squares regression model of logit (proportion destruction) was fitted to the abundance data, and solved for the regression coefficient for each species. Several data points, all in 1975, were determined to be atypical and were eliminated from the model. The estimated coefficients thus calculated are as follows:

| | Unstandardized | Standardized |
|---|---|---|
| $\hat{\beta}_0$ | -5.06 | |
| $\hat{\beta}_1$ (Teredo navalis) | 1.20 | 0.48 |
| $\hat{\beta}_2$ (Bankia gouldi) | 1.40 | 0.57 |
| $\hat{\beta}_3$ (Teredo spp.) | 0.50 | 0.11 |
| $\hat{\beta}_4$ (Teredo bartschi) | 0.69 | 0.26 |
| $\hat{\beta}_5$ (Teredinidae) | 0.22 | 0.11 |

The relative size ordering of the coefficients reflects the relative size ordering of the species or taxa considered here: Bankia gouldi has the largest coefficient, implying that B. gouldi does the most destruction per individual. The taxon Teredinidae, which are the smallest specimens, have the smallest coefficients. The multiple "R square" value for this fit was 0.7484, implying that this regression analysis explained approximately 75 percent of the variation in the data.

In order to determine if any spatial or temporal factors other than abundance of teredinids had an effect on percent destruction, we fitted an analysis of variance model to the residuals, using station, month and bioyear as main effects. The results of this ANOVA are given in Table A-30. All main effects and two-factor interactions were statistically significant, though only marginally so for region vs. season. The temporal factors of month and bioyear were the strongest main effects, and season vs. bioyear was the strongest of the interactions. This ANOVA accounted for about 12.7 percent of the variation in the residuals, above the 74 percent explained by the abundances. Therefore, as reported last year abundances were a first order effect in determining destruction, and spatial and temporal factors were second order.

## Long-term (12-Month) Panels

Beginning in August, 1976, we placed two "special panels" on the exposure racks at every station. With the exception of 1976-77 when they were exposed for only 9

TABLE A-30. ANALYSIS OF VARIANCE OF RESIDUALS OF LEAST SQUARES REGRESSION MODEL OF LOGIT (PROPORTION DESTRUCTION)

| Source of Variation | Sum of Squares | DF | Mean Square | F | Significance of F |
|---|---|---|---|---|---|
| MAIN EFFECTS | 119.547 | 11 | 10.868 | 15.363 | 0.000 |
| Region | 7.754 | 4 | 1.939 | 2.740 | 0.028 |
| Season | 48.728 | 2 | 24.364 | 34.441 | 0.000 |
| Bioyear | 61.654 | 5 | 12.331 | 17.431 | 0.000 |
| 2-WAY INTERACATIONS | 125.243 | 38 | 3.296 | 4.659 | 0.000 |
| Region/Season | 10.881 | 8 | 1.360 | 1.923 | 0.053 |
| Region/Bioyear | 55.417 | 20 | 2.771 | 3.917 | 0.000 |
| Season/Bioyear | 59.257 | 10 | 5.926 | 8.377 | 0.000 |
| 3-WAY INTERACTIONS | 30.111 | 40 | 0.753 | 1.064 | 0.365 |
| Region/Season/Bioyear | 30.111 | 40 | 0.753 | 1.064 | 0.365 |
| EXPLAINED | 274.901 | 89 | 3.089 | 4.366 | 0.000 |
| RESIDUAL | 663.548 | 938 | 0.707 | | |
| TOTAL | 938.449 | 1627 | 0.914 | | |

| Source of Variation | Sum of Squares | DF | Mean Square | F | Significance of F |
|---|---|---|---|---|---|
| MAIN EFFECTS | 202.231 | 32 | 6.320 | 8.541 | 0.000 |
| Station | 38.633 | 19 | 2.033 | 2.748 | 0.000 |
| Month | 100.176 | 8 | 12.522 | 16.924 | 0.000 |
| Bioyear | 63.299 | 5 | 12.660 | 17.110 | 0.000 |
| | | | | 5.203 | 0.000 |
| | | | | 2.147 | 0.025 |
| | | | | 4.374 | 0.000 |
| | | | | 9.355 | 0.000 |
| | | | | 1.188 | 0.250 |
| EXPLAINED | 357.567 | 110 | 3.251 | 5.132 | |
| RESIDUAL | 580.882 | 917 | 0.633 | | |

or 10 months, these panels are removed and replaced in May and June of 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). Additional information on species present in these 12-month panels, their size range and the percent of panel filled has also been recorded; however, these data are not as extensive as those collected from the regular 1- and 6-month panels. The incidence of Teredinidae in 12-month panels from May, 1977 through June, 1981 were first presented last year (Maciolek-Blake et al., 1982). The incidence in panels submerged in May, 1981, and retrieved in May, 1982, is shown in Table A-31, and the June, 1981, to June, 1982 data are shown in Table A-32.

In general, these data confirm what was reported from the 6-month panels in terms of abundance and distribution of the borers in Barnegat Bay. The maximum size, and consequently size ranges tend to be larger in the 12-month panels, but this is to be expected.

**Limnoria**

Table A-33 shows the incidence of the crustacean woodborer Limnoria in 6-month and 1-month panels removed December, 1981 through November, 1982.

During the present report period, Limnoria were present at Stations 1, 2, 3, 4, 4A, 11 and 17. No attack by Limnoria was recorded from Stations 11 and 17 last year. By the same token, no attack was recorded this year at Station 15 whereas it was a station at which Limnoria were collected in 1981/1982.

Attack continued to be very high at Station 4A this year, and increased over the last part of the year at Station 4. It was down sharply at Station 1 this year, and decreased somewhat at Station 2 (Figure A-6).

FIGURE A-6 AVERAGE NUMBER OF LIMNORIA TUNNELS IN LONG-TERM (6-MONTH) PANELS FROM 1976-1982

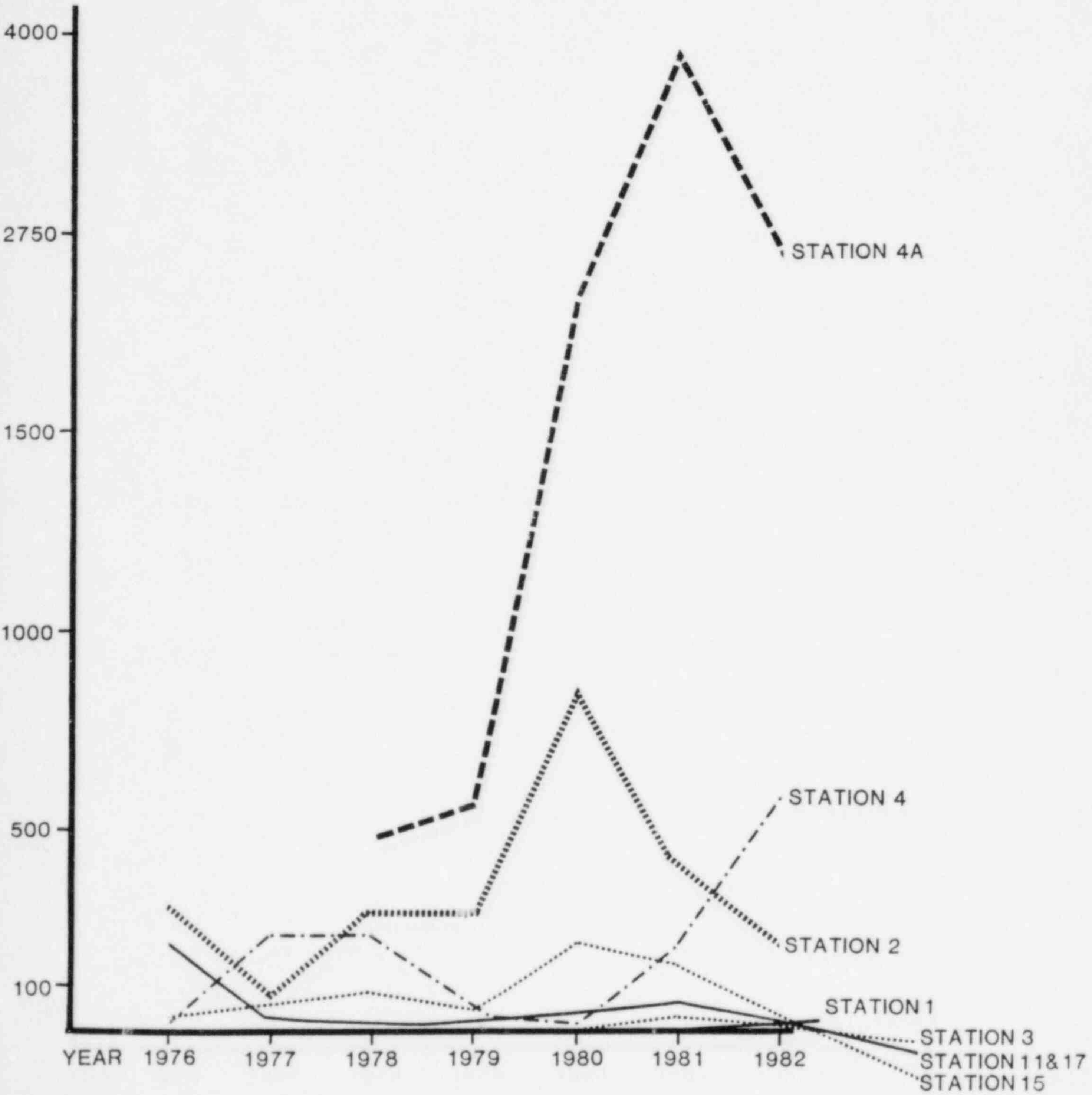


TABLE A-31. INCIDENCE OF TEREDINIDAE IN 12-MONTH PANELS SUBMERGED MAY 4-5, 1981 AND REMOVED MAY 4-5, 1982

| Station | No. of Specimens | Percent Filled | Size Range in mm. | Species Identification | Remarks |
|---|---|---|---|---|---|
| 1 | 400 | 99 | | 38 T. navalis, 362 Teredinidae | All dead except for 6 T. navalis ripening gonads. |
| 5 | 18 | <1 | <1-2 | 18 Teredinidae | All dead. |
| 7 | 600 | 95 | <1-55 | 200 T. bartschi, 400 Teredinidae | All dead. |
| 10A | 2 | 4 | 145-150 | 2 B. gouldi | 1 live, 1 dead. |
| 10B | 1 | 2 | 125 | 1 B. gouldi | |
| 11 | 1 | <1 | 55 | 1 Teredinidae | Dead. |
| 14 | 6 | 18 | 105-210 | 4 B. gouldi, 2 T. navalis | Ripening gonads. |
| 15 | 1 | 4 | 220 | 1 B. gouldi | |
| 17 | 1 | <1 | 30 | 1 T. navalis | Dead. |

No Teredinidae in panels from Stations 2-4A, 6, 8-10, 12-13. No panel examined from Station 16.

TABLE A-32. INCIDENCE OF TEREDINIDAE IN 12-MONTH PANELS SUBMERGED JUNE 1-2, 1981 - REMOVED JUNE 1-2, 1982

| Station | No. of Specimens | Percent Filled | Size Range in mm. | Species Identification | Remarks |
|---|---|---|---|---|---|
| 1* | 500 | 99 | 2-110 | 500 T. navalis | |
| 5 | 73 | 2 | <1-24 | 3 T. bartschi, 70 Teredinidae | All dead. |
| 7 | 650 | 95 | <1-80 | 100 T. bartschi, 550 Teredinidae | All dead. |
| 8 | 1 | 6 | 310 | 1 B. gouldi | Ripe gonads. |
| 10 | 1 | 5 | 260 | 1 B. gouldi | |
| 11 | 1 | 3 | 170 | 1 B. gouldi | Dead. Tube empty. |
| 12 | 1 | 4 | 210 | 1 Teredinidae | Dead. Tube empty. |
| 14 | 1 | 5 | 300 | 1 T. navalis | Ripening gonads. |
| 15 | 2 | 10 | 200-310 | 1 B. gouldi, 1 Teredinidae | 1 live, 1 dead. |
| 17 | 1 | <1 | 32 | 1 Teredinidae | Dead. Tube empty. |

No Teredinidae in panels from Stations 2-4A, 6, 9, 10A-10B, 13. No panel examined from Station 16.

* Panel removed after 7 months exposure due to heavy teredinid attack.

TABLE A-33. INCIDENCE OF LIMNORIA IN 6-MONTH (P) AND 1-MONTH (C) EXPOSURE PANELS REMOVED DECEMBER, 1981 THROUGH NOVEMBER, 1982

| Station | Panel | Dec 1981 Tunnels/* Specimens | Jan 1982 Tunnels/ Specimens | Feb 1982 Tunnels/* Specimens | Mar 1982 Tunnels/ Specimens | Apr 1982 Tunnels/ Specimens | May 1982 Tunnels/ Specimens | Jun 1982 Tunnels/** Specimens | Jul 1982 Tunnels/*** Specimens | Aug 1982 Tunnels/*** Specimens | Sep 1982 Tunnels/*** Specimens | Oct 1982 Tunnels/*** Specimens | Nov 1982 Tunnels/*** Specimens |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | P | 49/26 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 3/5 | 13/17 | 31/36 | 48/13 | 200/150 | -- |
| | C | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 7/11 | 5/8 | 8/11 | 4/3 | 3/3 |
| 2 | P | 35/5 | 25/10 | 17/18 | 0/0 | 0/0 | 0/0 | 5/9 | 120/170 | 315/375 | 70/75 | 950/1000 | 650/400 |
| | C | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 7/13 | 4/8 | 9/13 | 0/0 | 5/3 | 2/2 |
| 3 | P | 0/0 | 1/1 | 13/13 | 0/0 | 0/0 | 0/0 | 2/2 | 7/3 | 9/12 | 70/75 | 7/2 | 3/2 |
| | C | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 1/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 |
| 4 | P | 60/16 | 3/2 | 1/0 | 0/0 | 0/0 | 1/0 | 26/41 | 275/355 | 400/450 | 1600/1650 | 2000/1700 | 2700/2400 |
| | C | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 5/7 | 23/36 | 12/13 | 16/10 | 0/0 | 0/0 |
| 4A | P | 5400/4000 | 1200/1000 | 870/700 | 0/0 | 0/0 | 6/0 | 680/1000 | 1700/2200 | 4500/5500 | 5000/6000 | 6300/4000 | 7000/6000 |
| | C | 1/1 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 80/94 | 105/130 | 75/130 | 260/300 | 110/100 | 7/2 |
| 11 | P | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 1/0 | 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 |
| 17 | P | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 1/0 | 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 |
| 5-10B 12-16B | | No | Limnoria present | | | | | | | | | | |

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

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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, 1981 did not suggest any major alterations in breeding patterns within the study area. The studies have continued and the data reported here summarize the results of observations made from August, 1975 through November, 1982.

The occurrence of species of protozoans parasitic in the shipworms in the study area have been discussed in previous reports to Jersey Central Power & Light and GPU Nuclear (see e.g., Richards et al., 1980; Maciolek-Blake et al., 1981, 1982). Because of the often extensive tissue damage to the shipworms, it was felt that these parasites could have an effect on the abundance and distribution of the borers in Barnegat Bay, and could help to explain some of the variations in abundance observed during the overall program. For that reason, more extensive observations of the histopathology of the shipworms collected for gonad analysis were begun in January, 1977 and were completed in 1982 (Maciolek-Blake et al., 1982). These studies indicated that, at least, a haplosporidian parasite (Haplosporidium sp.) could decrease the abundance of Teredo species in the year following a heavy infection (Maciolek-Blake et al., 1982; Hillman et al., 1982).

## Materials and Methods

Teredine borers were removed in the laboratory from exposure panels retrieved from Barnegat Bay. Details of the retrieval schedule for standard panels are given in Appendix A. With the six-month retrieval schedule, there were three months of the year (April through June) when no borers were recovered from the panels because the panels were immersed when no larvae were settling. In order to obtain gonad information during those critical spring periods, two special panels, retrieved on an annual basis, were installed in May and June of 1976 at each station. This enabled us to obtain some information on the early spring gonadal patterns. In addition, separate racks were installed at Stations 2, 7, 11, 12 and 17 to provide additional information on the parasites of Teredo. The panels on these racks are exposed for a 12 month cycle.

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

The specimens were fixed for 24 hours, followed by rinsing with 70 percent denatured ethanol. The gonad-containing portion of each shipworm was excised, dehydrated further in ethanol, placed in two changes of methylbenzoate and cleared in three changes of xylene. They were then embedded in Paraplast and sectioned at six microns. From January, 1978 through November, 1982, at least two slides of each specimen were prepared. One slide was stained in hematoxylin and eosin for gonad analysis; the second slide was stained with Masson's trichrome or Whipf's polychrome stain and used with the hematoxylin and eosin stained slides for pathological analysis.

The slides were examined microscopically to determine the stage of gonad development at the time the specimens were removed from the water. Because the Teredinidae are bivalve molluscs, the characteristics of gonad development are similar to those of other bivalves, and a classification of developmental stages used by other investigators examining gonads of various bivalves (e.g., Ropes and Stickney, 1965; Ropes, 1968; Holland and Chew, 1974) was suitable. The various phases of gonad development were characterized as follows:

Female Gonads

1. Early active phase - Oogonia occurred at the periphery and within the alveolar walls; nuclei of oogonia contained basophilic nucleoli. The alveolar walls were not completely contracted and lumina were evident in most gonads.

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

3. Ripe phase - The shipworm was considered ripe when the number of oocytes that had become detached from the alveolar wall and were free in the lumen of the alveolus exceeded the number still attached to the alveolar wall.

4. Partially spawned phase - A few oocytes were still attached to the thickened alveolar wall, and some residual ripe ova remained in the alveolar lumen.

5. Spent phase - Alveoli were usually empty of ripe oocytes and those that remained were undergoing cytolysis.

Male Gonads

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

2. Late active phase - This phase was characterized by the proliferation and maturation of spermatocytes, most of which have migrated toward the center of the alveolus. A central lumen was present in the alveolus and occasionally a small number of spermatozoa were present in the lumen.

3. Ripe phase - In the ripe phase, the alveolar lumen was crowded with darkly-stained spermatozoa.

4. Partially spawned phase - A small number of spermatozoa remained in the alveolar lumen.

5. Spent phase - Alveoli in the spent phase contained very few or no spermatozoa.

Hermaphroditic gonads were characterized according to the conditions of both the oocytes and spermatocytes within the various alveoli. The slides were numbered consecutively according to sample number, and gonad condition was noted for each sample. The phase designations of the gonads were correlated with species and station designations only after the gonads were characterized. This tended to eliminate any possible bias for station or season.

## Results and Discussion

From August, 1975 through November, 1981, a total of 3700 teredinid borers were examined histologically for gonad condition. This included 1377 Teredo navalis, 484 T. bartschi, 24 T. furcifera, 57 immature Teredo too small to be identified to species, and 1806 Bankia gouldi. The data from those observations were included in the annual report to GPU Nuclear Corporation for the period December 1, 1980 through November 30, 1981. From December 1, 1981 through November 30, 1982, an additional 230 T. navalis, 50 T. bartschi, 2 immature Teredinidae and 141 B. gouldi were examined. The results of these examinations are tabulated in Tables B-1 through B-4.

No effect of plant operations on gonadal development was observed. In previous reports (e.g., Maciolek-Blake et al., 1982) an extended breeding season for Teredo bartschi in the discharge canal was discussed. During the present reporting period, too few T. bartschi were examined to suggest that during the past year there was anything unusual about the reproductive cycle of T. bartschi in the vicinity of the Oyster Creek Nuclear Generating Station.

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

Teredo navalis. During the present study, Teredo navalis occurred at 13 of the 20 stations at which panels are exposed (Table B-1), an increase of one station from the previous year's collection. The earliest that ripe gonads were observed was May, and one specimen with ripe gonads was collected at Station 8, within the thermally-affected area, as late as November. Partially spawned specimens were also found in November at Stations 10A, 11 and 15.

As in previous years, early and late active stages were observed in the winter months of December and January, but it is felt that development was arrested in those

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, 1981 THROUGH NOVEMBER, 1982.

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

| Gonad Stage | 1981 Dec | Jan | Feb | Mar | Apr | May | 1982 June | Jul | Aug | Sep | Oct | Nov | Station |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EA | 2 | 4 | | | | | | | | 6 | | | |
| LA | | 9 | | | | 3 | | | | | | | |
| R | | | | | | 1 | | | | 2 | | | 1 |
| PS | | | | | | 1 | | | | | | | |
| S | 2 | 3 | | | | | | | | 10 | | | |
| NG | 1 | 5 | | | | 1 | | | | 6 | | | |
| EA | | | | | | | | | | 1 | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | 1 | | |
| PS | | | | | | | | | | | | | 7 |
| S | 1 | | | | | | | | 1 | 3 | 1 | | |
| NG | | | | | | | | | | | 1 | | |
| EA | | | | | | | | | | | | | |
| LA | | | | | | | | 1 | | | | | |
| R | | | | | | | | | 1 | | | 1 | 8 |
| PS | | | | | | | | | | | | | |
| S | | | | | | | | | | | 1 | | |
| NG | | | | | | | | | | | | | |
| EA | | | | | | | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 9 |
| PS | | | | | | | | | | | | | |
| S | | | | | | | | | | | | 1 | |
| NG | | | | | | | | | | | | | |
| EA | | | | 8 | | | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 10 |
| PS | | | | | | | | | | | | | |
| S | | | | | | | | | | | | | |
| NG | | | | 2 | | | | | | | | | |

TABLE B-1. (continued)

| Gonad Stage | 1981 Dec | Jan | Feb | Mar | Apr | May | 1982 June | Jul | Aug | Sep | Oct | Nov | Station |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EA | | | | | | | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 10A |
| PS | | | | | | | | | | | | 1 | |
| S | | | | | | | | | | | | 3 | |
| NG | | | | | | | | | | | | | |
| EA | | | | | | | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 10B |
| PS | | | | | | | | | | | | | |
| S | | | | | | | | | | | | | |
| NG | | | | | | | | | | | 1 | | |
| EA | | 1 | 7 | 2 | | | | | | 2 | 1 | | |
| LA | | 1 | | | | | | | | | | | |
| R | | | | | | 1 | 1 | | 3 | | | | 11 |
| PS | | | | | | 1 | | | 3 | 2 | 18 | 4 | |
| S | 1 | 3 | 1 | | | | | | | 13 | 1 | 16 | |
| NG | | 1 | 1 | | | | 1 | | | | | | |
| EA | | | | | | | | | | | | | |
| LA | | 1 | | | | | | | | | | | |
| R | | | | | | | | | | | | | 12 |
| PS | | | | | | | | | | | | | |
| S | | | | | | | | | | | | | |
| NG | | | | | | | | | | | | | |
| EA | | | | | | | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 13 |
| PS | | | | | | | | | | | | | |
| S | 1 | | | | | | | | | | | | |
| NG | | | | | | | | | | | | | |

TABLE B-1. (continued)

| Gonad Stage | 1981 Dec | Jan | Feb | Mar | Apr | May | 1982 June | Jul | Aug | Sep | Oct | Nov | Station |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EA | | | | | | | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | 2 | | | | | | | 14 |
| PS | | | | | | | | | | | | | |
| S | | | 1 | | | | | | | 1 | | | |
| NG | | | | | | | 1 | | 1 | | | | |
| EA | | | 2 | | | | | | | | | 1 | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 15 |
| PS | | | | | | | | | | | | 1 | |
| S | | | | | | | | | | 1 | | 1 | |
| NG | | | | | | | | | | | | 1 | |
| EA | 3 | 2 | 1 | | | 1 | | | | 1 | 1 | | |
| LA | | 2 | | | | | | | | | | 1 | |
| R | | | | | | | | | | | | | 17 |
| PS | | | | | | 1 | | | 3 | | | | |
| S | 1 | | 2 | | | | | | 1 | 1 | 4 | 10 | |
| NG | | | 1 | | | | | | | 2 | 2 | 3 | |

TABLE B-2. NUMBERS OF SPECIMENS AND STAGE OF GONAD DEVELOPMENT OF Teredo bartschi IN EXPOSURE PANELS AT STATIONS IN BARNEGAT BAY, NEW JERSEY, FROM DECEMBER, 1981 THROUGH NOVEMBER, 1982

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

| Gonad Stage | 1981 Dec | Jan | Feb | Mar | Apr | May | 1982 June | Jul | Aug | Sep | Oct | Nov | Station |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EA | | | | | | | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 5 |
| PS | | | | | | | | | | | | | |
| S | 2 | 1 | 2 | | | | | | | | | | |
| NG | | 2 | | | | | | | | | | | |
| EA | | | | | | | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 6 |
| PS | | | | | | | | | | | | | |
| S | 1 | 1 | | | | | | | | | | | |
| NG | | | | | | | | | | | | | |
| EA | | | | | | | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 7 |
| PS | 1 | 1 | | | | | | | | | | | |
| S | 23 | 2 | 3 | | | | | | | | | | |
| NG | 6 | 3 | 2 | | | | | | | | | | |

TABLE B-3. NUMBERS OF SPECIMENS AND STAGE OF GONAD DEVELOPMENT OF IMMATURE TEREDINIDS IN EXPOSURE PANELS AT STATIONS IN BARNEGAT BAY, NEW JERSEY, FROM DECEMBER, 1981 THROUGH NOVEMBER, 1982

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

| Gonad | 1981 | | | | | | 1982 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stage | Dec | Jan | Feb | Mar | Apr | May | June | Jul | Aug | Sep | Oct | Nov | Station |
| EA | | | | | | | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 5 |
| PS | | | | | | | | | | | | | |
| S | | | | | | | | | | | | | |
| NG | | | | | | | | | | 1 | | | |
| EA | | | | | | | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 10A |
| PS | | | | | | | | | | | | | |
| S | | | | | | | | | | | | | |
| NG | | | | | | | | | | 1 | | | |

TABLE B-4. NUMBERS OF SPECIMENS AND STAGE OF GONAD DEVELOPMENT OF Bankia gouldi IN EXPOSURE PANELS AT STATIONS IN BARNEGAT BAY, NEW JERSEY, FROM DECEMBER, 1981 THROUGH NOVEMBER, 1982

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

| Gonad | 1981 | | | | | | 1982 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stage | Dec | Jan | Feb | Mar | Apr | May | June | Jul | Aug | Sep | Oct | Nov | Station |
| EA | | 1 | | | | | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 5 |
| PS | | | | | | | | | | | | | |
| S | | | | | | | | | | | | | |
| NG | | | | | | | | | | 1 | | | |
| EA | | | | | | | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 7 |
| PS | | | | | | | | | | | | | |
| S | 2 | | | | 1 | | | | | | | | |
| NG | | | | | | | | | | 1 | | | |
| EA | 1 | | | | | | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 8 |
| PS | | | | | | | | | | | | | |
| S | | | | | | | 1 | | | | | | |
| NG | | | | | | | | | | | | | |
| EA | | 1 | | | | | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 10 |
| PS | | | | | | | | | | | | | |
| S | 3 | | | | | | | | | | | | |
| NG | | | | | | | 1 | | | | | | |
| EA | | | | | | | | | | | | | |
| LA | | | | | | 1 | | | | | | | |
| R | | | | | | | | | | | | | 10A |
| S | 2 | | | | | | | | | | | | |
| NG | 3 | | | | | | | | | | | | |

TABLE B-4. (continued)

| Gonad Stage | 1981 Dec | Jan | Feb | Mar | Apr | May | 1982 June | Jul | Aug | Sep | Oct | Nov | Station |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EA | | 1 | | | | | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 10B |
| PS | | | | | | | | | | | | | |
| S | | | | | | | | | | | 2 | | |
| NG | | | | | | 1 | | | | | | | |
| EA | | 7 | | | | | | | | 1 | | | |
| LA | | | | | | 1 | | | | | | | |
| R | | | | | | | | | | | | | 11 |
| PS | | | | | | | | | | | | | |
| S | 2 | | 1 | 1 | | | | | | 1 | | 2 | |
| NG | 1 | 1 | 2 | 2 | 1 | 1 | | | | | | 2 | |
| EA | | 1 | | | | 2 | | | | | | | |
| LA | | | | | | 1 | | | | | | | |
| R | | | | | | | 1 | | | | | | 12 |
| PS | | | | | | | | | | | | | |
| S | 2 | 5 | 3 | 4 | | | | | | | | 1 | |
| NG | 1 | 1 | | 3 | 1 | 1 | 1 | | | | | 1 | |
| EA | | 1 | | | | | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 13 |
| PS | | | | | | | | | | 1 | | | |
| S | 2 | | | | | | | | | 1 | 1 | 4 | |
| NG | 4 | 1 | | | | | | | | 1 | | 1 | |
| EA | 2 | 8 | | | | 3 | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 14 |
| PS | | | | | | | | | | | | | |
| S | 5 | | | | | | | | | 2 | 3 | 2 | |
| NG | 1 | | | | | 1 | | | | 1 | | | |

TABLE B-4. (continued)

| Gonad Stage | 1981 Dec | Jan | Feb | Mar | Apr | May | 1982 June | Jul | Aug | Sep | Oct | Nov | Station |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EA | | | | | | 1 | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 15 |
| PS | | | | | | | | | | | | | |
| S | 2 | | | | | | | | | 5 | | | |
| NG | | | | | | | 1 | | 1 | 1 | 1 | 1 | |
| EA | | | | | | | | | | | | | |
| LA | | | | | | | | | | | | | |
| R | | | | | | | | | | | | | 16B |
| PS | | | | | | | | | | | | | |
| S | | | | | | | | | | | | 2 | |
| NG | | | | | | | | | | 2 | 1 | | |

stages in late fall. Development toward spawning in early summer would normally begin by February, and early active gonads can be expected at that time.

The occurrence of two spawning peaks in Barnegat Bay, reported in last year's report (Maciolek-Blake, et al., 1982) was evident again this year (Figure B-1). One peak occurred in May and June and the other in August. By September, however, most gonads observed were in the spent condition. The usual development of those larvae setting from the September spawn was evident in October and November, but this development was probably arrested with the cooling of the water during those months.

Teredo bartschi. T. bartschi are found in Barnegat Bay within the thermally affected area. During this report period, T. bartschi were examined from Stations 5, 6 and 7, with most of them occurring at Station 7 (Table B-2) with the exception of one partially spent specimen from Station 7 in each of December and January, all specimens collected were either spent (35 specimens) or had no discernable gonad (13 specimens). No specimens of T. bartschi were collected after the first week of February, 1982, so it is not useful to speculate on the possibility of an extended breeding period for this species during the 1981-1982 collection period. No extended breeding season is obvious when the percentage of specimens in each stage of development during 1981/1982 is plotted and compared with patterns of previous years (Figure B-2). The reasons for the sudden decline of the T. bartschi population in the effluent area are not clear.

Bankia gouldi. B. gouldi was collected for gonad observations from only 12 of the 20 exposure panel stations during the present study period, a decrease of two sites since the previous reporting period (Table B-4). Most of the specimens (approximately 70%) occurred at Stations 11, 12, 13 and 14.

Gonadal development patterns in B. gouldi continued to be similar to those discussed in previous reports, except that there was no clear pattern of ripening and spawning. The only ripe specimen occurred at Station 12 in June, when it could be expected. Most specimens observed throughout the report period were already in the spent phase.

To determine whether the thermal effluent from the Oyster Creek Nuclear Generating Station might be having an effect on reproductive cycles of B. gouldi, the gonadal development found pattern within the thermally affected area was compared with the pattern shown by specimens from Region 1 (Figure B-3), and with the pattern from Regions 2, 4 and 5 combined (Figure B-4). No differences were apparent.

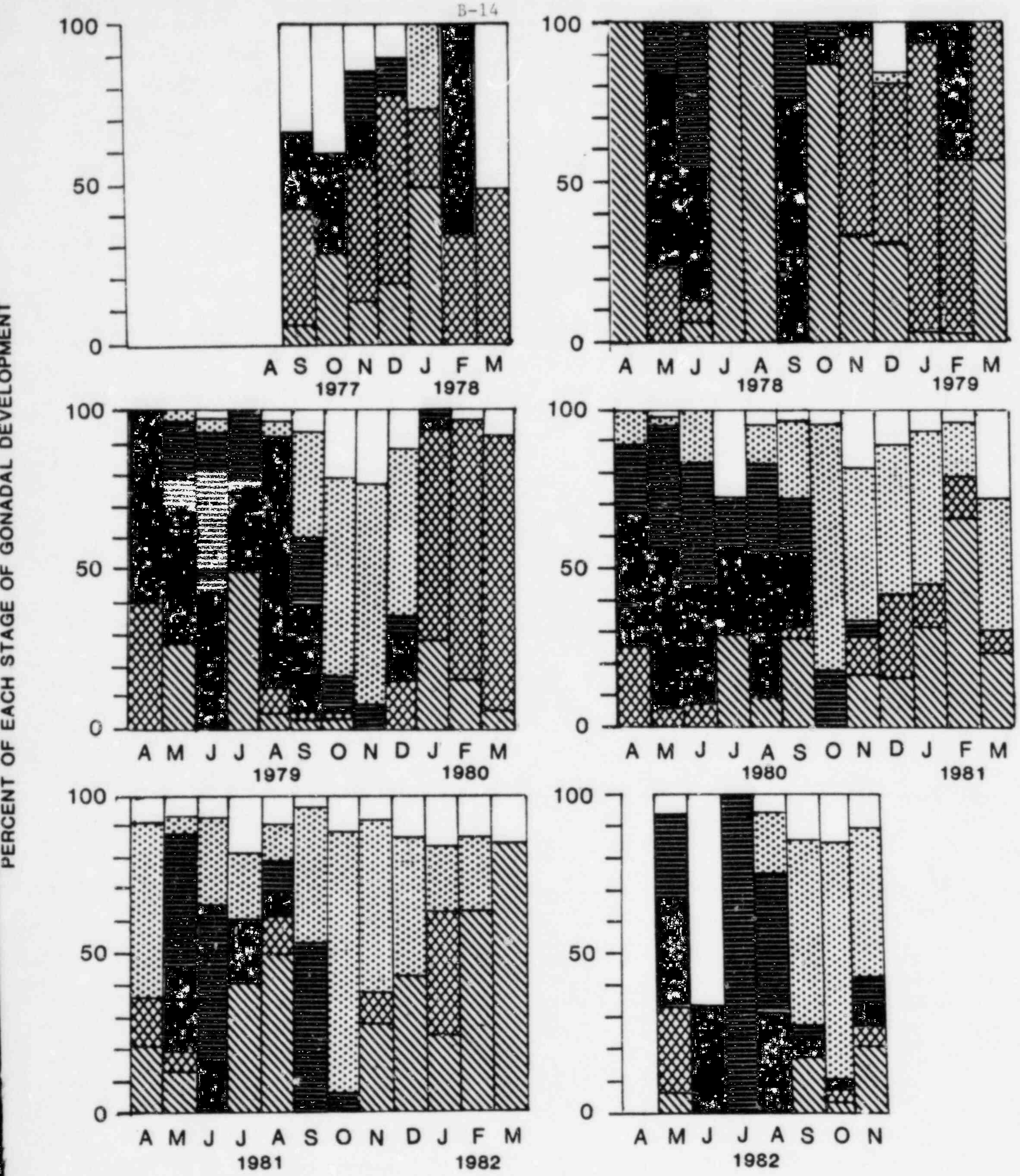


FIGURE B-1. PERCENT OF ALL SPECIMENS OF *Teredo navalis* IN EACH STAGE OF GONAD DEVELOPMENT FROM AUGUST, 1977 THROUGH NOVEMBER, 1982

= Early active; = Late active; = Ripe;

= Partially spawned; = Spent; = No discernable gonad.

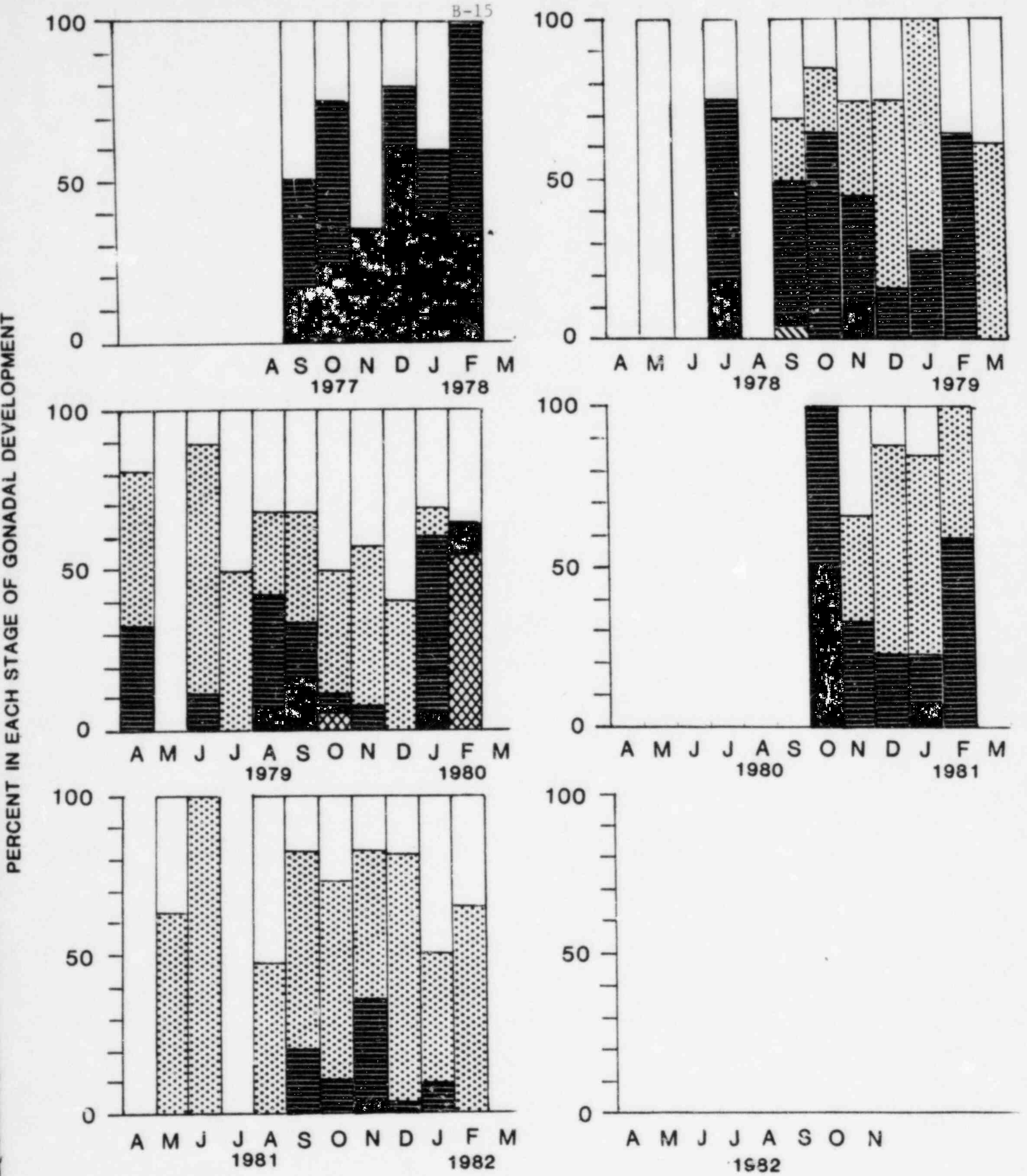


FIGURE B-2. PERCENT OF ALL SPECIMENS OF *Teredo bartschi* IN EACH STAGE OF GONAD DEVELOPMENT FROM AUGUST, 1977 THROUGH NOVEMBER, 1982

= Early active; = Late active; = Ripe;

= Partially spawned; = Spent; = No discernable gonad.

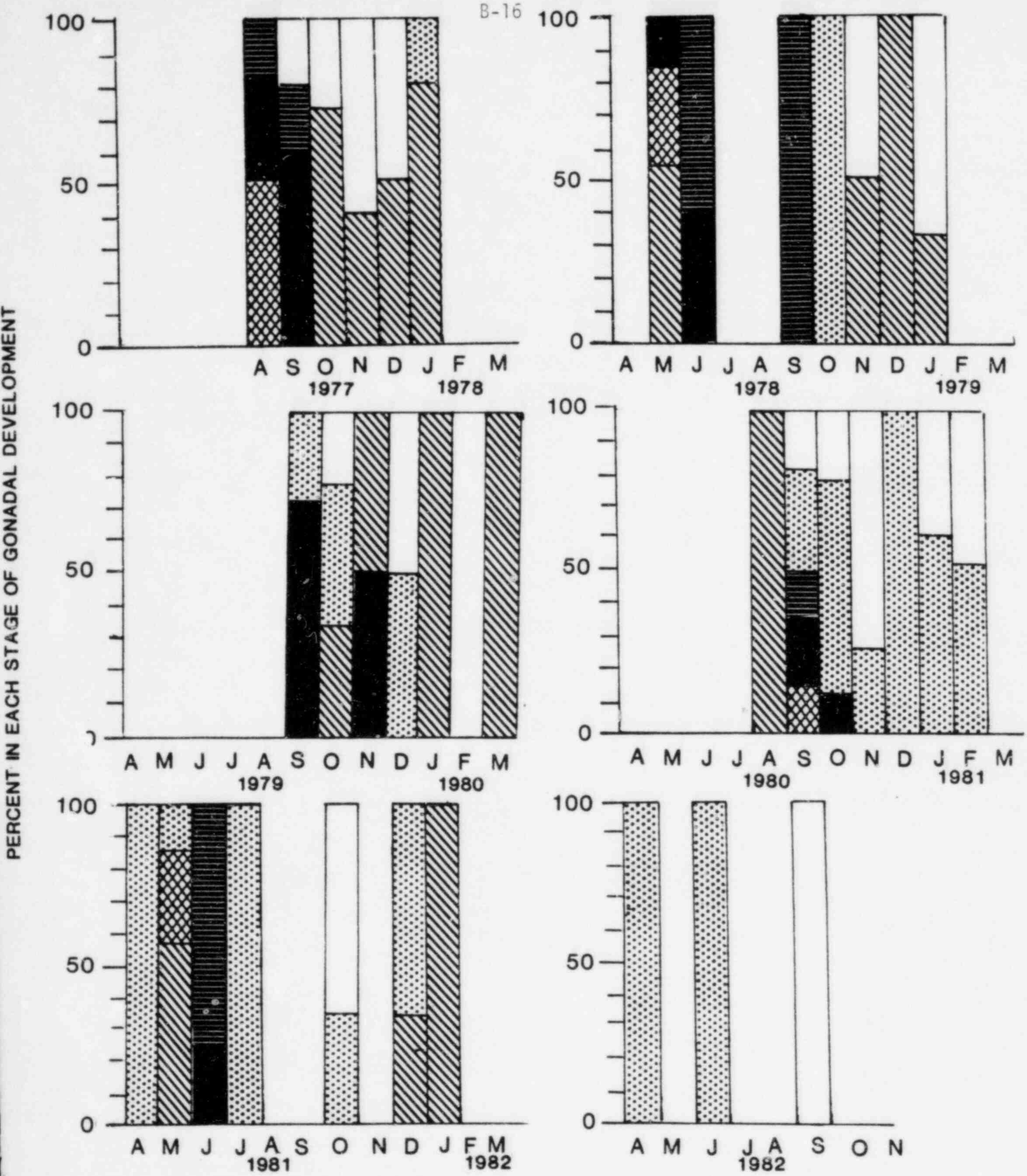


FIGURE B-3. PERCENT OF SPECIMENS OF *Bankia gouldi* FROM REGION I IN EACH STAGE OF GONAD DEVELOPMENT FROM AUGUST, 1977 THROUGH NOVEMBER, 1982

= Early active; = Late active; = Ripe; = Partially spawned; = Spent; = No discernable gonad.

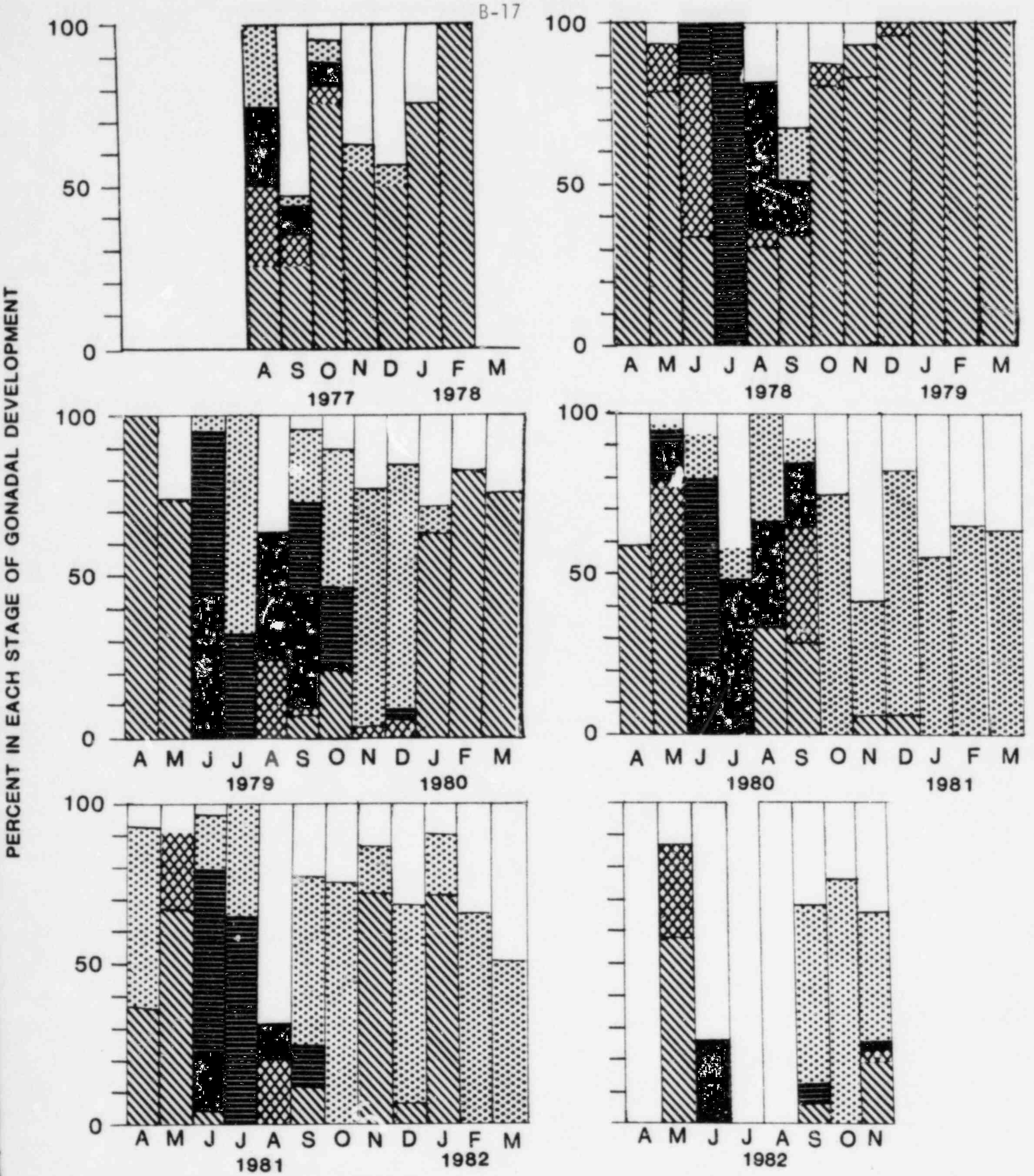


FIGURE B-4. PERCENT OF SPECIMENS OF *Bankia gouldi* FROM REGIONS 2, 4, AND 5 IN EACH STAGE OF GONAD DEVELOPMENT FROM AUGUST, 1977 THROUGH NOVEMBER, 1982

= Early active; = Late active; = Ripe; = Partially spawned; = Spent; = No discernable gonad.

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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, 1981 through November, 1982, and a synthesis of the data collected since the initiation of the study in June, 1975.

## Materials and Methods

### Field

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

### Analysis

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

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

B). For temperature and salinity, average values for each biological year from July, 1975 through June, 1982 were calculated and plotted for each station. A biological

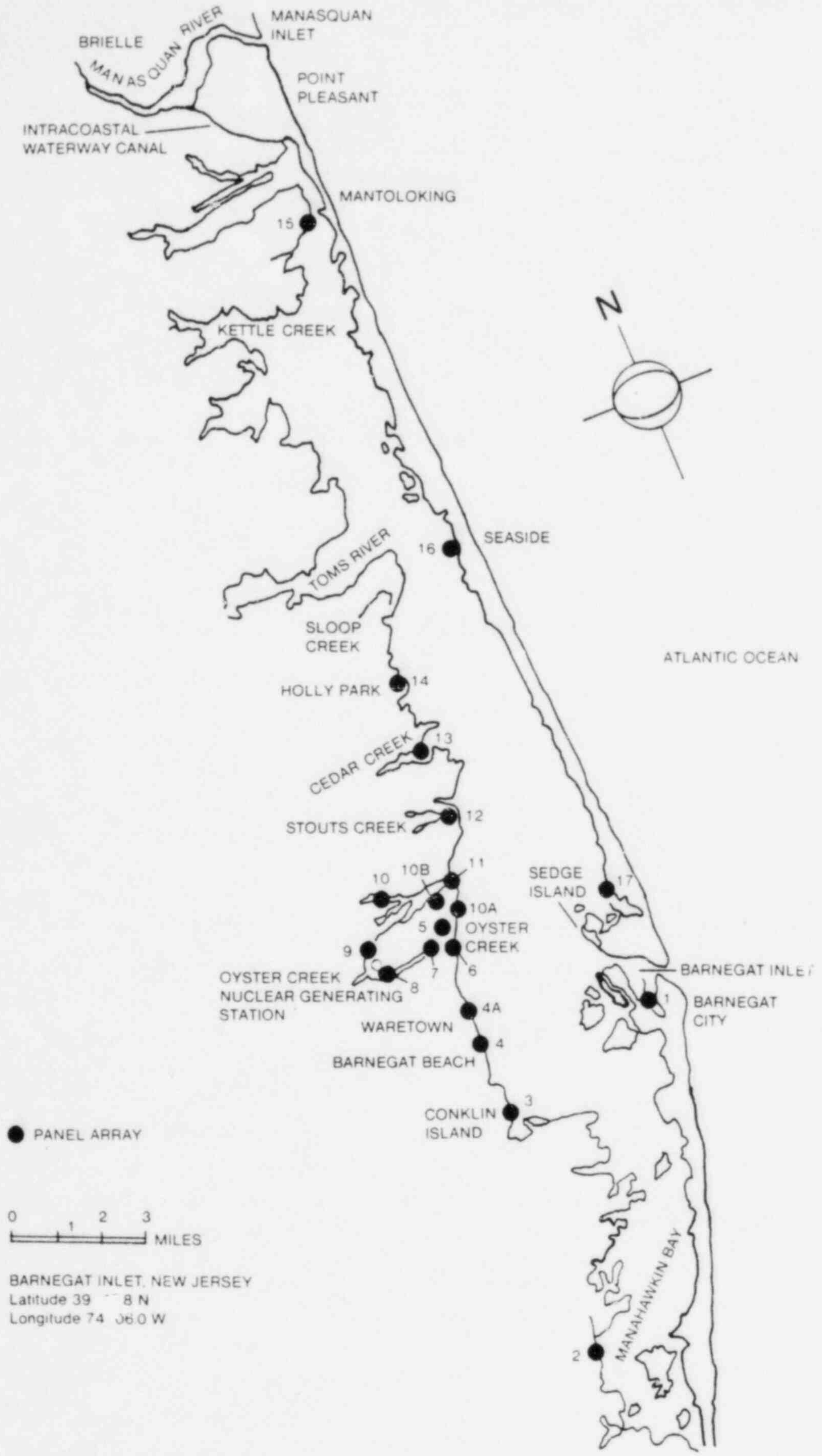


FIGURE 1. OUTLINE OF BARNEGAT BAY SHOWING GEOGRAPHIC LOCATIONS OF EXPOSURE PANELS

year is defined as July, Year A through June, Year B, and corresponds to the breeding season of the teredinids. The period of July, 1982 through November, 1982 was not included because it represents only 5 months of a 12 month period, and average values over this period are not comparable to the other averages calculated.

C). Stations were grouped into regions, and average values of temperature and salinity were calculated and plotted for each biological year since July, 1975. Regions are as follows: Region 1 (near OCNGS discharge), Stations 5, 6, 7, and 8; Region 2 (south of OCNGS), Stations 2, 3, 4, and 4A; Region 3 (east side of bay), Stations 1 and 17; Region 4 (near north), Stations 9, 10, 10A, !0B, and 11; Region 5 (north of OCNGS), Stations 12, 13, 14, 15, and 16.

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

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

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

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

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

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

Let $\bar{X}_1$, $\bar{X}_2$, ...$\bar{X}_k$ be k sample means based on $N_1$, $N_2$, ...$N_k$ observations respectively. Let $M_1$, $M_2$, ...,$M_k$ be the corresponding population means. These sample averages might originate as the average values in k levels of a factor under study.

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

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

$H_o$ will be rejected at significance level $\alpha$ if

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

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

This procedure leads to the condidence intervals

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

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

## Results and Discussion

The water quality values recorded each month at each of the exposure panel stations from December, 1981, through November, 1982 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, 1981 (Table C-1) were considerably lower throughout the study area than during December 1980. The highest temperature recorded in December, 1981, was 9.0°C at Station 8 and the lowest was 2.4°C at Station 16A. Last year, Station 7 had a temperature of 12°C, while the lowest temperature, 6.8°C, occurred at Station 4A. The mean temperature for the study area in December 1981 was 4.8°C (Table C-13) as compared with 8.8°C last year. In January 1982, however, water temperature dropped only slightly, with a mean temperature of 4.6°C being recorded over the study area, as compared to a mean of only 1.1°C last year.

One of the sharpest contrasts between last year's water temperature readings and those recorded for this year was comparisons for the month of April. This year's mean temperature in April around the Bay was only 3.5°C as compared to 12°C last year. The highest temperature recorded at any station during April this year was 5°C at Station 13, whereas last year, the lowest temperature during April was at Station 13 when a reading of 8.5°C was recorded. The uniformly low temperatures in April, 1982 around the bay, at a critical point in the maturation of gonads, may have had an effect on reducing spawning at some stations, resulting in the lowered recruitment this year.

Temperatures in May, 1982, were up sharply over what they were during the same period last year, with mean temperatures of 20.0°C or more at Stations 5, 6, 7 and 8 as compared to only 13.3°C at Station 1.

Temperatures in October and November, 1982, were also warmer than for the same months last year.

Ice occurred over the region during February, 1982, at Stations 2, 3, 4, 4A, 6, 12, 16/16B and 17 (Table C-14). It was as thick as 12 inches at Station 3, and at least 8 inches at Stations 6 and 17. Generally the ice cover at those stations where ice occurred

TABLE C-1. WATER QUALITY AT EXPOSURE PANEL STATIONS DECEMBER, 1981

| Station | Date | Time | Depth in Feet | Salinity (o/oo) | Temperature (oC) | $O_2$ (mg.l) | pH |
|---|---|---|---|---|---|---|---|
| 1 | 12/8/81 | 1700 | 3.0 | 30.7 | 5.8 | 11.8 | 7.6 |
| 2 | 12/8/81 | 1630 | 1.0 | 27.1 | 3.4 | 12.4 | 7.7 |
| 3 | 12/8/81 | 1615 | 1.0 | 27.6 | 4.0 | 12.4 | 7.7 |
| 4 | 12/8/81 | 1545 | 2.0 | 27.2 | 4.5 | 11.8 | 7.6 |
| 4A | 12/8/81 | 1550 | 2.0 | 27.1 | 4.4 | 12.4 | 7.8 |
| 5 | 12/9/81 | 1050 | 2.0 | 25.6 | 7.2 | 11.0 | 7.5 |
| 6 | 12/9/81 | 1030 | 2.0 | 23.1 | 4.6 | 11.2 | 7.6 |
| 7 | 12/9/81 | 1020 | 1.0 | 25.8 | 7.5 | 11.0 | 7.6 |
| 8 | 12/8/81 | 1515 | 1.0 | 21.8 | 9.0 | 12.0 | 7.5 |
| 9 | 12/8/81 | 1500 | 3.0 | 24.5 | 4.1 | 12.8 | 7.6 |
| 10 | 12/8/81 | 1410 | 2.0 | 21.9 | 4.1 | 12.2 | 7.5 |
| 10A | 12/8/81 | 1430 | 2.0 | 25.5 | 4.9 | 12.8 | 7.6 |
| 10B | 12/8/81 | 1440 | 2.0 | 25.6 | 4.7 | 13.0 | 7.6 |
| 11 | 12/8/81 | 1500 | 2.0 | 25.5 | 4.2 | 12.6 | 7.6 |
| 12 | 12/8/81 | 1350 | 2.0 | 23.9 | 4.5 | 12.4 | 7.5 |
| 13 | 12/8/81 | 1320 | 2.0 | 21.7 | 4.0 | 13.2 | 7.5 |
| 14 | 12/8/81 | 1300 | 2.0 | 23.7 | 4.5 | 12.8 | 7.5 |
| 15 | 12/8/81 | 1210 | 2.0 | 26.2 | 4.2 | 12.2 | 7.2 |
| 16A | 12/9/81 | 1210 | 3.0 | 21.0 | 2.4 | 12.6 | 7.9 |
| 17 | 12/9/81 | 1240 | 2.0 | 29.7 | 3.2 | 12.4 | 7.7 |

TABLE C-2. WATER QUALITY AT EXPOSURE PANEL STATIONS JANUARY, 1982

| Station | Date | Time | Depth in Feet | Salinity (o/oo) | Temperature (oC) | $0_2$ (mg.l) | pH |
|---|---|---|---|---|---|---|---|
| 1 | 1/5/82 | 1718 | 3.0 | 24.4 | 4.4 | 7.7 | 7.7 |
| 2 | 1/5/82 | 1645 | 2.5 | 23.6 | 4.7 | 8.7 | 7.7 |
| 3 | 1/6/82 | 0930 | 2.5 | 23.5 | 5.1 | 8.7 | 7.0 |
| 4 | 1/6/82 | 0949 | 3.0 | 25.2 | 4.4 | 9.0 | 7.3 |
| 4A | 1/6/82 | 1002 | 3.0 | 25.0 | 3.8 | 9.9 | 7.6 |
| 5 | 1/6/82 | 1015 | 3.0 | 22.1 | 4.3 | 9.7 | 7.5 |
| 6 | 1/6/82 | 1023 | 2.5 | 22.4 | 4.8 | 9.6 | 7.4 |
| 7 | 1/6/82 | 1030 | 2.5 | 21.7 | 3.9 | 9.8 | 7.5 |
| 8 | 1/5/82 | 1618 | 3.0 | 23.9 | 4.7 | 7.7 | 7.7 |
| 9 | 1/5/82 | 1600 | 2.5 | 25.0 | 4.9 | 8.8 | 7.8 |
| 10 | 1/5/82 | 1501 | 3.0 | 17.3 | 5.1 | 9.8 | 7.6 |
| 10A | 1/5/82 | 1516 | 2.5 | 23.7 | 4.9 | 9.5 | 7.6 |
| 10B | 1/5/82 | 1530 | 2.5 | 23.8 | 4.7 | 9.7 | 7.7 |
| 11 | 1/5/82 | 1542 | 2.0 | 25.3 | 4.8 | 9.1 | 7.8 |
| 12 | 1/5/82 | 1438 | 3.0 | 21.1 | 5.0 | 9.3 | 7.2 |
| 13 | 1/5/82 | 1417 | 2.5 | 9.3 | 5.5 | 10.0 | 7.2 |
| 14 | 1/5/82 | 1357 | 2.5 | 19.3 | 4.7 | 9.3 | 7.1 |
| 15 | 1/6/82 | 1306 | 2.5 | 21.1 | 5.0 | 9.2 | 7.1 |
| 16A | 1/6/82 | 1135 | 2.5 | 17.5 | 3.6 | 10.0 | 7.5 |
| 17 | 1/6/82 | 1200 | 2.0 | 15.4 | 3.9 | 9.3 | 7.2 |

TABLE C-3. WATER QUALITY AT EXPOSURE PANEL STATIONS FEBRUARY, 1982

| Station | Date | Time | Depth in Feet | Salinity (o/oo) | Temperature (oC) | $0_2$ (mg.l) | pH |
|---|---|---|---|---|---|---|---|
| 1 | 2/2/82 | 0807 | 3.0 | 15.1 | 0.9 | 10.8 | 7.7 |
| 2 | 2/2/82 | 0850 | 3.0 | 13.6 | 0.4 | 11.3 | 7.7 |
| 3 | 2/2/82 | 0913 | 2.0 | 12.6 | 1.8 | 10.6 | 7.7 |
| 4 | 2/2/82 | 0929 | 2.5 | 15.3 | 2.2 | 11.0 | 7.7 |
| 4A | 2/2/82 | 0935 | 2.5 | 13.7 | 0.2 | 10.8 | 7.8 |
| 5 | 2/2/82 | 0952 | 1.5 | 11.1 | 1.3 | 10.4 | 7.4 |
| 6 | 2/2/82 | 1004 | 1.5 | 12.2 | 1.1 | 10.3 | 7.4 |
| 7 | 2/2/82 | 1013 | 2.0 | 12.0 | 1.2 | 11.2 | 7.6 |
| 8 | 2/2/82 | 1025 | 2.0 | 12.5 | 1.1 | 11.6 | 7.7 |
| 9 | 2/2/82 | 1037 | 1.0 | 11.7 | 1.5 | 11.4 | 7.5 |
| 10 | 2/2/82 | 1143 | 3.5 | 11.7 | 2.8 | 10.6 | 7.4 |
| 10A | 2/2/82 | 1055 | 1.5 | 10.8 | 0.9 | 10.2 | 7.3 |
| 10B | 2/2/82 | 1105 | 2.0 | 13.2 | 1.7 | 10.9 | 7.5 |
| 11 | 2/2/82 | 1115 | 1.0 | 15.1 | 1.5 | 12.1 | 7.8 |
| 12 | 2/2/82 | 1204 | 4.0 | 12.8 | 3.6 | 8.8 | 7.5 |
| 13 | 2/2/82 | 1224 | 2.0 | 5.1 | 2.1 | 10.3 | 7.6 |
| 14 | 2/2/82 | 1243 | 3.5 | 11.9 | 2.3 | 10.4 | 7.4 |
| 15 | 2/2/82 | 1445 | 3.5 | 11.1 | 0.9 | 11.9 | 7.5 |
| 16A | 2/2/82 | 1503 | 4.0 | 9.1 | 2.3 | 11.6 | 7.3 |
| 17 | 2/2/82 | 1531 | 0.6 | 9.2 | 2.0 | 7.2 | 7.4 |

TABLE C-4. WATER QUALITY AT EXPOSURE PANEL STATIONS MARCH, 1982

| Station | Date | Time | Depth in Feet | Salinity (o/oo) | Temperature (oC) | $0_2$ (mg.l) | pH |
|---|---|---|---|---|---|---|---|
| 1 | 3/2/82 | 0947 | 3.0 | 25.8 | 3.5 | 12.3 | 8.0 |
| 2 | 3/2/82 | 1037 | 1.5 | 21.8 | 3.6 | 9.8 | 7.6 |
| 3 | 3/2/82 | 1106 | 1.5 | 21.3 | 3.9 | 10.9 | 8.1 |
| 4 | 3/2/82 | 1125 | 2.0 | 23.8 | 3.6 | 11.7 | 8.1 |
| 4A | 3/2/82 | 1153 | 1.5 | 22.8 | 4.2 | 13.3 | 8.1 |
| 5 | 3/2/82 | 1212 | 1.0 | 17.6 | 3.9 | 12.7 | 7.9 |
| 6 | 3/2/82 | 1232 | 1.5 | 17.3 | 4.2 | 12.5 | 7.8 |
| 7 | 3/2/82 | 1250 | 1.3 | 16.0 | 4.7 | 12.4 | 7.8 |
| 8 | 3/2/82 | 1410 | 2.5 | 18.6 | 4.5 | 12.3 | 7.6 |
| 9 | 3/2/82 | 1434 | 2.5 | 18.2 | 3.6 | 13.0 | 7.7 |
| 10 | 3/2/82 | 1620 | 2.5 | 17.5 | 4.1 | 12.9 | 7.8 |
| 10A | 3/2/82 | 1453 | 1.5 | 19.1 | 4.2 | 13.1 | 7.6 |
| 10B | 3/2/82 | 1515 | 2.0 | 20.0 | 3.9 | 13.0 | 7.6 |
| 11 | 3/2/82 | 1530 | 1.3 | 19.7 | 4.2 | 12.9 | 7.8 |
| 12 | 3/2/82 | 1640 | 2.5 | 18.4 | 4.2 | 12.7 | 7.7 |
| 13 | 3/2/82 | 1705 | 2.5 | 15.4 | 4.6 | 12.6 | 8.3 |
| 14 | 3/2/82 | 1730 | 1.7 | 18.0 | 3.6 | 12.9 | 8.8 |
| 15 | 3/3/82 | 0942 | 2.0 | 23.8 | 1.8 | 11.4 | 7.4 |
| 16A | 3/3/82 | 1043 | 6.5 | 17.5 | 4.0 | 10.4 | 7.4 |
| 17 | 3/3/82 | 1130 | 1.0 | 25.1 | 4.9 | 10.1 | 7.7 |

TABLE C-5. WATER QUALITY AT EXPOSURE PANEL STATIONS APRIL, 1982

| Station | Date | Time | Depth in Feet | Salinity (o/oo) | Temperature (oC) | $O_2$ (mg.l) | pH |
|---|---|---|---|---|---|---|---|
| 1 | 4/7/82 | 0900 | 2.5 | 25.0 | 2.3 | 12.4 | 7.9 |
| 2 | 4/7/82 | 1000 | 1.0 | 23.5 | 2.3 | 9.3 | 8.0 |
| 3 | 4/7/82 | 1030 | 0.5 | 22.6 | 3.5 | 9.6 | 7.9 |
| 4 | 4/7/82 | 1045 | 1.2 | 23.0 | 3.8 | 10.4 | 7.9 |
| 4A | 4/7/82 | 1055 | 0.3 | 23.3 | 4.0 | 10.8 | 7.9 |
| 5 | 4/7/82 | 1200 | 0.2 | 17.3 | 3.5 | 11.3 | 7.6 |
| 6 | 4/7/82 | 1215 | 0.2 | 15.3 | 2.8 | 11.7 | 7.5 |
| 7 | 4/7/82 | 1225 | 0.8 | 16.3 | 4.5 | 10.8 | 7.5 |
| 8 | 4/7/82 | 1120 | 2.5 | 16.0 | 4.2 | 10.6 | 7.5 |
| 9 | 4/7/82 | 1140 | 2.5 | 17.7 | 3.2 | 10.7 | 7.8 |
| 10 | 4/7/82 | 1440 | 2.5 | 10.5 | 4.1 | 11.1 | 7.3 |
| 10A | 4/7/82 | 1350 | 0.2 | 21.5 | 4.8 | 11.2 | 7.8 |
| 10B | 4/7/82 | 1425 | 1.0 | 21.8 | 3.5 | 11.6 | 7.8 |
| 11 | 4/7/82 | 1400 | 0.0 | 20.3 | 4.0 | 11.2 | 7.8 |
| 12 | 4/7/82 | 1505 | 1.0 | 19.4 | 4.8 | 11.0 | 7.7 |
| 13 | 4/7/82 | 1530 | 1.5 | 4.0 | 5.0 | 11.0 | 7.1 |
| 14 | 4/7/82 | 1550 | 1.0 | 16.5 | 3.5 | 11.7 | 7.7 |
| 15 | 4/8/82 | 0830 | 1.5 | 21.0 | 1.8 | 12.4 | 8.0 |
| 16A | 4/8/82 | 0855 | 3.0 | 16.5 | 1.8 | 13.2 | 8.0 |
| 17 | 4/8/82 | 0930 | 0.0 | 22.5 | 2.9 | 9.2 | 7.9 |

TABLE C-6. WATER QUALITY AT EXPOSURE PANEL STATIONS MAY, 1982

| Station | Date | Time | Depth in Feet | Salinity (o/oo) | Temperature (oC) | $0_2$ (mg.l) | pH |
|---|---|---|---|---|---|---|---|
| 1 | 5/4/82 | 0900 | 3.5 | 25.5 | 13.3 | 9.1 | 8.2 |
| 2 | 5/4/82 | 0949 | 2.0 | 23.7 | 18.0 | 7.3 | 8.2 |
| 3 | 5/4/82 | 1020 | 1.5 | 23.5 | 18.7 | 7.8 | 8.1 |
| 4 | 5/4/82 | 1046 | 1.8 | 24.6 | 17.7 | 6.7 | 7.8 |
| 4A | 5/4/82 | 1105 | 1.5 | 23.8 | 17.8 | 7.6 | 8.0 |
| 5 | 5/4/82 | 1122 | 1.0 | 21.8 | 20.0 | 7.5 | 8.0 |
| 6 | 5/4/82 | 1138 | 1.0 | 21.7 | 20.0 | 7.5 | 7.9 |
| 7 | 5/4/82 | 1155 | 1.8 | 21.6 | 20.8 | 7.4 | 7.9 |
| 8 | 5/4/82 | 1323 | 3.0 | 20.7 | 21.2 | 7.4 | 8.0 |
| 9 | 5/4/82 | 1345 | 3.0 | 22.3 | 19.2 | 7.6 | 8.1 |
| 10 | 5/4/82 | 1540 | 2.0 | 15.7 | 19.7 | 7.8 | 7.6 |
| 10A | 5/4/82 | 1442 | 1.0 | 22.4 | 19.8 | 7.8 | 8.0 |
| 10B | 5/4/82 | 1456 | 1.5 | 22.5 | 19.5 | 7.8 | 8.0 |
| 11 | 5/4/82 | 1512 | 0.8 | 22.6 | 19.9 | 8.2 | 8.1 |
| 12 | 5/5/82 | 1245 | 1.0 | 20.5 | 18.9 | 8.0 | 8.0 |
| 13 | 5/5/82 | 1215 | 2.0 | 15.7 | 19.8 | 7.1 | 7.9 |
| 14 | 5/5/82 | 1148 | 2.0 | 15.6 | 18.5 | 7.6 | 8.2 |
| 15 | 5/5/82 | 0850 | 2.5 | 17.7 | 16.9 | 8.3 | 8.2 |
| 16A | 5/5/82 | 0918 | 4.0 | 15.2 | 17.2 | 7.5 | 8.1 |
| 17 | 5/5/82 | 1005 | 1.0 | 24.6 | 17.5 | 6.7 | 8.1 |

TABLE C-7. WATER QUALITY AT EXPOSURE PANEL STATIONS JUNE, 1982

| Station | Date | Time | Depth in Feet | Salinity (o/oo) | Temperature (oC) | $0_2$ (mg.l) | pH |
|---|---|---|---|---|---|---|---|
| 1 | 6/1/82 | 0955 | 3.0 | 23.5 | 17.5 | 7.6 | 8.3 |
| 2 | 6/1/82 | 1040 | 2.5 | 22.9 | 19.4 | 6.7 | 8.2 |
| 3 | 6/1/82 | 1115 | 1.5 | 20.3 | 19.1 | 6.6 | 8.1 |
| 4 | 6/1/82 | 1140 | 1.5 | 21.3 | 19.5 | 6.8 | 8.2 |
| 4A | 6/1/82 | 1200 | 1.5 | 20.7 | 19.9 | 6.8 | 8.1 |
| 5 | 6/1/82 | 1315 | 1.0 | 19.4 | 22.5 | 6.2 | 8.0 |
| 6 | 6/1/82 | 1328 | 1.0 | 19.4 | 22.7 | 7.4 | 8.1 |
| 7 | 6/1/82 | 1350 | 1.5 | 19.4 | 22.9 | 6.5 | 8.0 |
| 8 | 6/1/82 | 1410 | 2.0 | 19.8 | 24.0 | 6.4 | 8.0 |
| 9 | 6/1/82 | 1430 | 2.5 | 19.8 | 20.2 | 6.8 | 8.1 |
| 10 | 6/1/82 | 1600 | 3.0 | 18.1 | 20.2 | 5.4 | 7.7 |
| 10A5 | 6/1/82 | 1455 | 1.0 | 20.2 | 21.3 | 7.2 | 8.2 |
| 10B | 6/1/82 | 1520 | 2.0 | 20.4 | 21.0 | 7.4 | 8.2 |
| 11 | 6/1/82 | 1525 | 1.0 | 20.0 | 20.1 | 8.1 | 8.4 |
| 12 | 6/2/82 | 1420 | 1.0 | 16.4 | 23.0 | 8.0 | 8.1 |
| 13 | 6/2/82 | 1345 | 2.0 | 12.0 | 21.9 | 6.8 | 7.6 |
| 14 | 6/2/82 | 1320 | 2.0 | 19.8 | 21.8 | 6.6 | 8.0 |
| 15 | 6/2/82 | 0850 | [illegible] | 18.7 | 18.8 | 7.4 | 8.1 |
| 16B | 6/2/82 | 1115 | [illegible] | 15.3 | 20.1 | 6.6 | 7.9 |
| 17 | 6/2/82 | [illegible] | [illegible] | 23.7 | 22.4 | 8.0 | 8.3 |

TABLE C-8. WATER QUALITY AT EXPOSURE PANEL STATIONS JULY, 1982

| Station | Date | Time | Depth in Feet | Salinity (o/oo) | Temperature (oC) | $0_2$ (mg.l) | pH |
|---|---|---|---|---|---|---|---|
| 1 | 7/6/82 | 0955 | 3.0 | 24.9 | 21.0 | 5.7 | 7.9 |
| 2 | 7/6/82 | 1035 | 1.8 | 24.6 | 23.2 | 6.1 | 8.4 |
| 3 | 7/6/82 | 1100 | 1.0 | 20.8 | 23.8 | 7.0 | 8.2 |
| 4 | 7/6/82 | 1120 | 0.8 | 22.3 | 23.8 | 6.6 | 8.1 |
| 4A | 7/6/82 | 1135 | 0.7 | 22.0 | 24.2 | 7.0 | 8.1 |
| 5 | 7/6/82 | 1155 | 0.2 | 20.4 | 26.3 | 5.7 | 7.7 |
| 6 | 7/6/82 | 1205 | 0.5 | 20.4 | 26.7 | 5.8 | 7.8 |
| 7 | 7/6/82 | 1215 | 0.5 | 20.0 | 26.5 | 6.2 | 7.8 |
| 8 | 7/6/82 | 1320 | 2.0 | 20.1 | 26.5 | 6.5 | 8.0 |
| 9 | 7/6/82 | 1340 | 2.0 | 20.9 | 24.3 | 7.1 | 8.1 |
| 10 | 7/6/82 | 1445 | 2.0 | 14.0 | 25.5 | 6.4 | 7.5 |
| 10A | 7/6/82 | 1356 | 0.5 | 20.8 | 26.3 | 7.0 | 8.0 |
| 10B | 7/6/82 | 1415 | 2.0 | 20.8 | 25.9 | 7.3 | 8.0 |
| 11 | 7/6/82 | 1425 | 0.2 | 21.1 | 25.5 | 8.5 | 8.3 |
| 12 | 7/6/82 | 1530 | 1.5 | 19.7 | 25.5 | 7.5 | 8.1 |
| 13 | 7/6/82 | 1605 | 1.2 | 14.6 | 26.3 | 7.0 | 7.8 |
| 14 | 7/6/82 | 1640 | 1.0 | 15.1 | 24.2 | 7.2 | 8.0 |
| 15 | 7/7/82 | 0925 | 2.0 | 16.7 | 23.1 | 6.7 | 8.0 |
| 16B | 7/7/82 | 1050 | 2.0 | 13.7 | 24.0 | 6.7 | 8.1 |
| 17 | 7/7/82 | 1130 | 0.1 | 25.6 | 23.9 | 6.7 | 8.2 |

TABLE C-9. WATER QUALITY AT EXPOSURE PANEL STATIONS AUGUST, 1982

| Station | Date | Time | Depth in Feet | Salinity (o/oo) | Temperature (oC) | $O_2$ (mg.l) | pH |
|---|---|---|---|---|---|---|---|
| 1 | 8/3/82 | 0850 | 3.0 | 26.0 | 22.7 | 5.8 | 7.9 |
| 2 | 8/3/82 | 0935 | 3.5 | 23.9 | 25.0 | 5.4 | 8.2 |
| 3 | 8/3/82 | 1005 | 1.0 | 22.0 | 25.0 | 5.5 | 8.1 |
| 4 | 8/3/82 | 1025 | 1.5 | 22.5 | 25.3 | 4.8 | 7.7 |
| 4A | 8/3/82 | 1040 | 1.0 | 22.5 | 25.5 | 6.1 | 8.1 |
| 5 | 8/3/82 | 1120 | 0.7 | 19.9 | 27.6 | 5.1 | 7.8 |
| 6 | 8/3/82 | 1130 | 0.7 | 19.9 | 28.1 | 6.0 | 8.0 |
| 7 | 8/3/82 | 1145 | 1.0 | 19.7 | 28.4 | 5.1 | 7.8 |
| 8 | 8/3/82 | 1200 | 3.0 | 20.0 | 28.4 | 5.6 | 8.0 |
| 9 | 8/3/82 | 1100 | 3.0 | 20.7 | 25.7 | 6.0 | 8.1 |
| 10 | 8/3/82 | 1350 | 2.0 | 16.4 | 26.9 | 6.0 | 7.8 |
| 10A | 8/3/82 | 1300 | 0.8 | 21.0 | 27.2 | 6.6 | 8.2 |
| 10B | 8/3/82 | 1315 | 2.0 | 21.1 | 27.2 | 6.6 | 8.2 |
| 11 | 8/3/82 | 1325 | 0.7 | 21.0 | 26.8 | 6.6 | 8.2 |
| 12 | 8/3/82 | 1425 | 0.7 | 18.9 | 26.9 | 7.3 | 8.3 |
| 13 | 8/3/82 | 1455 | 1.5 | 15.0 | 27.0 | 6.7 | 8.1 |
| 14 | 8/3/82 | 1515 | 1.5 | 14.3 | 26.9 | 6.3 | 8.1 |
| 15 | 8/4/82 | 0830 | 2.0 | 15.6 | 25.1 | 6.2 | 8.0 |
| 16B | 8/4/82 | 0900 | 2.0 | 12.0 | 26.0 | 5.3 | 7.7 |
| 17 | 8/4/82 | 0940 | 0.5 | 26.9 | 26.0 | 4.8 | 7.6 |

TABLE C-10. WATER QUALITY AT EXPOSURE PANEL STATIONS SEPTEMBER, 1982

| Station | Date | Time | Depth in Feet | Salinity (o/oo) | Temperature (oC) | $0_2$ (mg.l) | pH |
|---|---|---|---|---|---|---|---|
| 1 | 9/7/82 | 0945 | 3.0 | 26.0 | 20.0 | 6.8 | 8.0 |
| 2 | 9/7/82 | 1020 | 0.2 | 26.8 | 21.5 | 6.8 | 8.0 |
| 3 | 9/7/82 | 1055 | 0.5 | 24.4 | 22.1 | 6.6 | 8.1 |
| 4 | 9/7/82 | 1110 | 1.0 | 24.4 | 21.9 | 6.0 | 7.8 |
| 4A | 9/7/82 | 1127 | 1.0 | 24.9 | 22.5 | 7.1 | 8.1 |
| 5 | 9/7/82 | 1145 | 0.5 | 22.4 | 24.7 | 6.5 | 8.1 |
| 6 | 9/7/82 | 1200 | 0.8 | 22.4 | 24.2 | 6.9 | 8.1 |
| 7 | 9/7/82 | 1210 | 1.0 | 22.4 | 24.7 | 6.2 | 7.9 |
| 8 | 9/7/82 | 1330 | 2.5 | 23.3 | 24.8 | 6.4 | 8.0 |
| 9 | 9/7/82 | 1315 | 2.5 | 23.3 | 21.6 | 6.8 | 8.1 |
| 10 | 9/7/82 | 1445 | 2.5 | 19.9 | 22.5 | 7.8 | 8.1 |
| 10A | 9/7/82 | 1350 | 0.8 | 23.7 | 23.0 | 7.1 | 8.1 |
| 10B | 9/7/82 | 1405 | 2.0 | 23.9 | 22.3 | 7.6 | 8.2 |
| 11 | 9/7/82 | 1415 | 0.8 | 24.0 | 21.6 | 6.9 | 8.1 |
| 12 | 9/7/82 | 1525 | 1.5 | 21.7 | 21.8 | 7.2 | 3.1 |
| 13 | 9/7/82 | 1548 | 1.5 | 18.0 | 22.1 | 7.6 | 8.2 |
| 14 | 9/8/82 | 1110 | 2.0 | 17.3 | 20.0 | 6.9 | 7.6 |
| 15 | 9/8/82 | 0900 | 2.0 | 16.7 | 19.0 | 7.1 | 7.7 |
| 16 | 9/8/82 | 0920 | 2.0 | 15.3 | 19.9 | 6.6 | 7.7 |
| 17 | 9/8/82 | 1000 | 0.2 | 25.0 | 19.5 | 6.0 | 7.5 |

TABLE C-11. WATER QUALITY AT EXPOSURE PANEL STATIONS OCTOBER, 1982

| Station | Date | Time | Depth in Feet | Salinity (o/oo) | Temperature (oC) | $O_2$ (mg.l) | pH |
|---|---|---|---|---|---|---|---|
| 1 | 10/5/82 | 0900 | 3.0 | 24.7 | 19.0 | 6.8 | 8.0 |
| 2 | 10/5/82 | 0930 | 1.0 | 24.8 | 19.2 | 6.4 | 7.8 |
| 3 | 10/5/82 | 1000 | 1.2 | 23.9 | 19.3 | 6.8 | 8.0 |
| 4 | 10/5/82 | 1015 | 1.5 | 24.4 | 19.3 | 7.3 | 8.0 |
| 4A | 10/5/82 | 1035 | 1.7 | 24.4 | 20.2 | 7.1 | 8.0 |
| 5 | 10/5/82 | 1055 | 0.7 | 24.0 | 22.3 | 7.0 | 8.0 |
| 6 | 10/5/82 | 1105 | 1.0 | 23.1 | 22.5 | 7.1 | 8.0 |
| 7 | 10/5/82 | 1125 | 0.7 | 22.0 | 24.8 | 6.6 | 7.9 |
| 8 | 10/5/82 | 1140 | 4.5 | 22.7 | 23.9 | 6.5 | 7.9 |
| 9 | 10/5/82 | 1200 | 4.0 | 23.1 | 20.3 | 7.1 | 8.1 |
| 10 | 10/5/82 | 1355 | 2.0 | 21.5 | 21.0 | 6.5 | 7.8 |
| 10A | 10/5/82 | 1305 | 1.0 | 23.0 | 21.9 | 7.6 | 8.1 |
| 10B | 10/5/82 | 1320 | 2.0 | 23.1 | 21.9 | 7.6 | 8.1 |
| 11 | 10/5/82 | 1330 | 1.0 | 22.7 | 21.0 | 7.5 | 8.0 |
| 12 | 10/5/82 | 1435 | 1.0 | 21.9 | 21.5 | 7.5 | 8.0 |
| 13 | 10/5/82 | 1500 | 1.5 | 20.0 | 21.9 | 7.8 | 8.1 |
| 14 | 10/5/82 | 1525 | 2.5 | 17.8 | 20.9 | 7.8 | 8.2 |
| 15 | 10/6/82 | 0830 | 2.0 | 17.8 | 19.1 | 7.4 | 8.2 |
| 16 | 10/6/82 | 0855 | 2.5 | 15.9 | 19.3 | 7.0 | 8.2 |
| 17 | 10/6/82 | 0935 | 0.7 | 22.4 | 20.8 | 6.0 | 7.9 |

TABLE C-12. WATER QUALITY AT EXPOSURE PANEL STATIONS NOVEMBER, 1982

| Station | Date | Time | Depth in Feet | Salinity (o/oo) | Temperature (oC) | $O_2$ (mg.l) | pH |
|---|---|---|---|---|---|---|---|
| 1 | 11/1/82 | 1008 | 3.0 | 25.0 | 16.6 | 7.9 | 8.1 |
| 2 | 11/1/82 | 1104 | 3.0 | 23.5 | 15.4 | 8.5 | 8.2 |
| 3 | 11/1/82 | 1200 | 1.5 | 23.0 | 16.7 | 9.3 | 8.2 |
| 4 | 11/1/82 | 1235 | 1.0 | 23.0 | 16.9 | 9.6 | 8.3 |
| 4A | 11/1/82 | 1300 | 1.0 | 23.2 | 17.6 | 9.4 | 8.3 |
| 5 | 11/1/82 | 1415 | 0.5 | 21.9 | 19.6 | 9.0 | 8.1 |
| 6 | 11/1/82 | 1435 | 0.5 | 22.0 | 20.0 | 9.5 | 8.2 |
| 7 | 11/1/82 | 1450 | 0.3 | 21.7 | 19.9 | 9.0 | 8.1 |
| 8 | 11/1/82 | 1522 | 3.0 | 20.9 | 20.0 | 9.1 | 8.1 |
| 9 | 11/1/82 | 1603 | 3.0 | 21.9 | 17.7 | 9.4 | 8.2 |
| 10 | 11/2/82 | 1454 | 2.0 | 19.7 | 17.5 | 8.9 | 8.2 |
| 10A | 11/2/82 | 1538 | 1.0 | 21.9 | 18.1 | 9.2 | 8.3 |
| 10B | 11/2/82 | 1602 | 1.5 | 22.1 | 18.3 | 9.0 | 8.3 |
| 11 | 11/2/82 | 1620 | 0.7 | 22.6 | 18.0 | 8.7 | 8.3 |
| 12 | 11/2/82 | 1421 | 1.3 | 21.5 | 17.6 | 9.0 | 8.2 |
| 13 | 11/2/82 | 1349 | 1.5 | 20.5 | 16.8 | 8.8 | 8.3 |
| 14 | 11/2/82 | 1314 | 2.5 | 19.7 | 16.3 | 8.7 | 8.3 |
| 15 | 11/2/82 | 1008 | 2.5 | 20.5 | 16.1 | 9.9 | 8.3 |
| 16 | 11/2/82 | 1047 | 3.0 | 17.8 | 16.0 | 9.0 | 8.4 |
| 17 | 11/2/82 | 1135 | 0.3 | 24.1 | 17.8 | 9.2 | 8.4 |

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, 1981 THROUGH NOVEMBER, 1982

| Parameter | Date | Maximum | Minimum | Mean | + Standard Deviation |
|---|---|---|---|---|---|
| | Dec 1981 | 9.0 | 2.4 | 4.8 | 1.55 |
| | Jan 1982 | 5.5 | 3.6 | 4.6 | 0.50 |
| | Feb | 3.6 | 0.4 | 1.6 | 0.82 |
| | Mar | 4.9 | 1.8 | 4.0 | 0.78 |
| | Apr | 5.0 | 1.8 | 3.5 | 0.96 |
| Temperature | May | 21.2 | 13.3 | 18.7 | 1.75 |
| (°C) | Jun | 24.0 | 17.5 | 20.9 | 1.70 |
| | Jul | 26.7 | 21.0 | 24.8 | 1.47 |
| | Aug | 28.4 | 22.7 | 26.4 | 1.39 |
| | Sep | 24.8 | 19.0 | 22.0 | 1.69 |
| | Oct | 24.8 | 19.0 | 21.0 | 1.62 |
| | Nov | 20.0 | 15.4 | 17.7 | 1.34 |
| | Dec 1981 | 30.7 | 21.0 | 25.3 | 2.62 |
| | Jan 1982 | 25.3 | 9.3 | 21.5 | 4.05 |
| | Feb | 15.3 | 5.1 | 12.0 | 2.36 |
| | Mar | 25.8 | 15.4 | 19.9 | 3.05 |
| | Apr | 25.0 | 4.0 | 18.7 | 5.02 |
| Salinity | May | 25.5 | 15.2 | 21.1 | 3.31 |
| (o/oo) | Jun | 23.7 | 12.0 | 19.6 | 2.79 |
| | Jul | 25.6 | 13.7 | 19.9 | 3.48 |
| | Aug | 26.9 | 12.0 | 20.0 | 3.70 |
| | Sep | 26.8 | 15.3 | 22.3 | 3.21 |
| | Oct | 24.8 | 15.9 | 22.2 | 2.47 |
| | Nov | 25.0 | 17.8 | 21.8 | 1.67 |
| | Dec 1981 | 7.9 | 7.2 | 7.6 | 0.14 |
| | Jan 1982 | 7.8 | 7.1 | 7.5 | 0.25 |
| | Feb | 7.8 | 7.3 | 7.6 | 0.16 |
| | Mar | 8.8 | 7.4 | 7.8 | 0.34 |
| | Apr | 8.0 | 7.1 | 7.7 | 0.24 |
| pH | May | 8.2 | 7.6 | 8.0 | 0.15 |
| | Jun | 8.4 | 7.6 | 8.1 | 0.20 |
| | Jul | 8.4 | 7.5 | 8.0 | 0.21 |
| | Aug | 8.3 | 7.6 | 8.0 | 0.20 |
| | Sep | 8.2 | 7.5 | 8.0 | 0.20 |
| | Oct | 8.2 | 7.8 | 8.0 | 0.12 |
| | Nov | 8.4 | 8.1 | 8.2 | 0.09 |

TABLE C-13. (Continued)

| Parameter | Date | Maximum | Minimum | Mean | + Standard Deviation |
|---|---|---|---|---|---|
| | Dec 1981 | 13.2 | 11.0 | 12.3 | 0.63 |
| | Jan 1982 | 10.0 | 7.7 | 9.2 | 0.67 |
| | Feb | 11.9 | 7.2 | 10.7 | 1.09 |
| | Mar | 13.3 | 9.8 | 12.2 | 1.06 |
| | Apr | 13.2 | 9.2 | 11.1 | 0.98 |
| Dissolved Oxygen (mg/l) | May | 9.1 | 6.7 | 7.6 | 0.52 |
| | Jun | 8.1 | 5.4 | 7.0 | 0.67 |
| | Jul | 8.5 | 5.7 | 6.7 | 0.69 |
| | Aug | 7.3 | 4.8 | 5.9 | 0.67 |
| | Sep | 7.8 | 6.0 | 6.9 | 0.47 |
| | Oct | 7.8 | 6.0 | 7.1 | 0.50 |
| | Nov | 9.9 | 7.9 | 9.1 | 0.46 |

TABLE C-14. ICE COVER (inches) AT EXPOSURE PANEL STATIONS IN BARNEGAT BAY DURING THE PERIOD DECEMBER, 1981 THROUGH NOVEMBER, 1982

February, 1982

| | | |
|---|---|---|
| Station | 1 | No ice |
| Station | 2 | Thin sheet ice |
| Station | 3 | 12" ice |
| Station | 4 | Thin sheet ice |
| Station | 4A | 1/2" ice |
| Station | 5 | Ice 2' from shore |
| Station | 6 | 8" ice |
| Station | 7 | Ice away from shore |
| Station | 8 | No ice |
| Station | 9 | No ice |
| Station | 10 | No ice |
| Station | 10A | Ice away from shore |
| Station | 10B | Ice away from shore |
| Station | 11 | No ice |
| Station | 12 | 5" ice |
| Station | 13 | No ice |
| Station | 14 | No ice |
| Station | 15 | No ice |
| Station | 16/16B | 1" ice |
| Station | 17 | 8" ice |

was heavier than in February last year. However there was no ice in January, 1982 whereas in January 1981, there was quite a bit of ice cover at several stations.

The average temperature at each station is plotted in Figure C-2 for each biological year for the 6 complete bioyears during the period July, 1975, through June, 1982. A biological year corresponds to the breeding season of the Teredinidae (e.g. Richards et al., 1979). As expected, stations closest to the discharge from OCNGS (Stations 5 through 8) continue to show elevated temperatures as compared to those temperatures recorded at other stations.

Table C-15 compares temperatures recorded at Station 8 in Oyster Creek with those recorded at Stations 2, 9, 12, 15 and 17, which are outside Oyster Creek. Since 1975, Station 8 has had temperatures elevated over ambient between 78 and 90% of the time, with the elevation being 3° to 5.9°C from 35 to 47% of the time.

The results of the analyses of variance of temperatures is shown in Table C-16. All three main effects of month, station and bioyear were highly significant, with the month to month variation being the strongest effect by far. Station and bioyear effects were second order and approximately equal. The two-factor interactions are also statistically significant, with the interaction between season and bioyears being the most significant. These results are similar to those reported for the previous two years, even though calendar years rather than bioyears were used for the 1980-81 report period (Maciolek-Blake et al., 1981).

Although the ANOVA results show that there are significant effects and interactions, they do not provide information about the nature and magnitude of such interactions. Significant F-values are an indication of the presence of some systematic effects, but with the large amount of data being analyzed, relatively small effects can appear highly statistically significant. Interaction plots and multiple comparison procedures were prepared to determine the nature and magnitude of the effects observed in the analyses of variance. Monthly averages were plotted for each bioyear; station averages were plotted for each season, and also for each bioyear. These plots showed that the month to month variation is indeed the predominant effect, as suggested by the ANOVA calculation. Station effects are essentially the same in each season, i.e. region by season interactions are statistically significant but minor. Station effects are also similar in each bioyear, therefore the region by bioyear interaction is minor.

Multiple comparison procedures were carried out on the temperature data for stations averaged over all years, months averaged over all stations and bioyears averaged

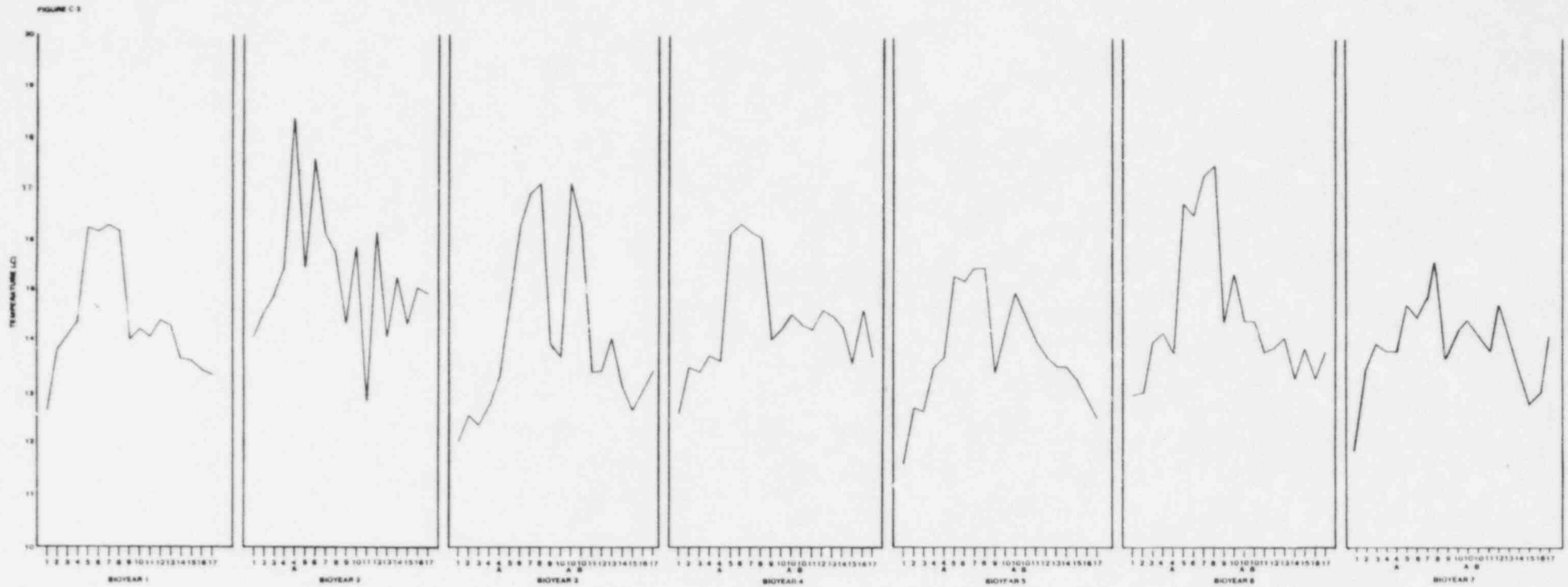

FIGURE C-2. AVERAGE TEMPERATURE AT EACH EXPOSURE PANEL STATION CALCULATED FOR BIOLOGICA YEARS FROM JULY, 1975 THROUGH JUNE, 1982. [Bioyear 1 = July, 1975 through June, 1976; bioyear 2 = July, 1976 through June, 1977; etc.] Number of observations is 12 for each bioyear except bioyear 2, when N=8-12.

TABLE C-15. TEMPERATURES RECORDED AT STATION 8 COMPARED TO FIVE OTHER EXPOSURE PANEL STATIONS IN VARIOUS REGIONS OF BARNEGAT BAY

| Station 8 Compared To: | Station 2 | Station 9 | Station 12 | Station 15 | Station 17 |
|---|---|---|---|---|---|
| Number of Observations | | | | | |
| Lower Than | 8 | 7 | 16 | 7 | 10 |
| Equal To | 1 | 11 | 3 | 5 | 2 |
| 0.1 to 0.9°C Higher | 10 | 4 | 3 | 5 | 7 |
| 1.0 to 1.9°C Higher | 6 | 10 | 13 | 7 | 11 |
| 2.0 to 2.9°C Higher | 6 | 13 | 9 | 10 | 12 |
| 3.0 to 3.9°C Higher | 16 | 18 | 21 | 12 | 10 |
| 4.0 to 4.9°C Higher | 21 | 17 | 7 | 20 | 15 |
| 5.0 to 5.9°C Higher | 10 | 5 | 9 | 14 | 10 |
| 6.0 to 6.9°C Higher | 4 | 2 | 4 | 4 | 4 |
| 7.0 to 8.5°C Higher | 4 | 0 | 0 | 2 | 4 |
| 78.5°C Higher | 0 | 0 | 0 | 0 | 1 |
| Missing Pairs | 3 | 2 | 4 | 3 | 3 |

| Summary | | | | | |
|---|---|---|---|---|---|
| Total Observations | 86 | 87 | 85 | 86 | 86 |
| Number of Times Elevated | 77 | 69 | 66 | 74 | 74 |
| Percent of Times Elevated | 90 | 79 | 78 | 86 | 86 |
| Number of Times 3.0-5.9°C | 47 | 40 | 37 | 46 | 35 |
| Percent of Times 3.0-5.9°C | 55 | 46 | 44 | 53 | 41 |

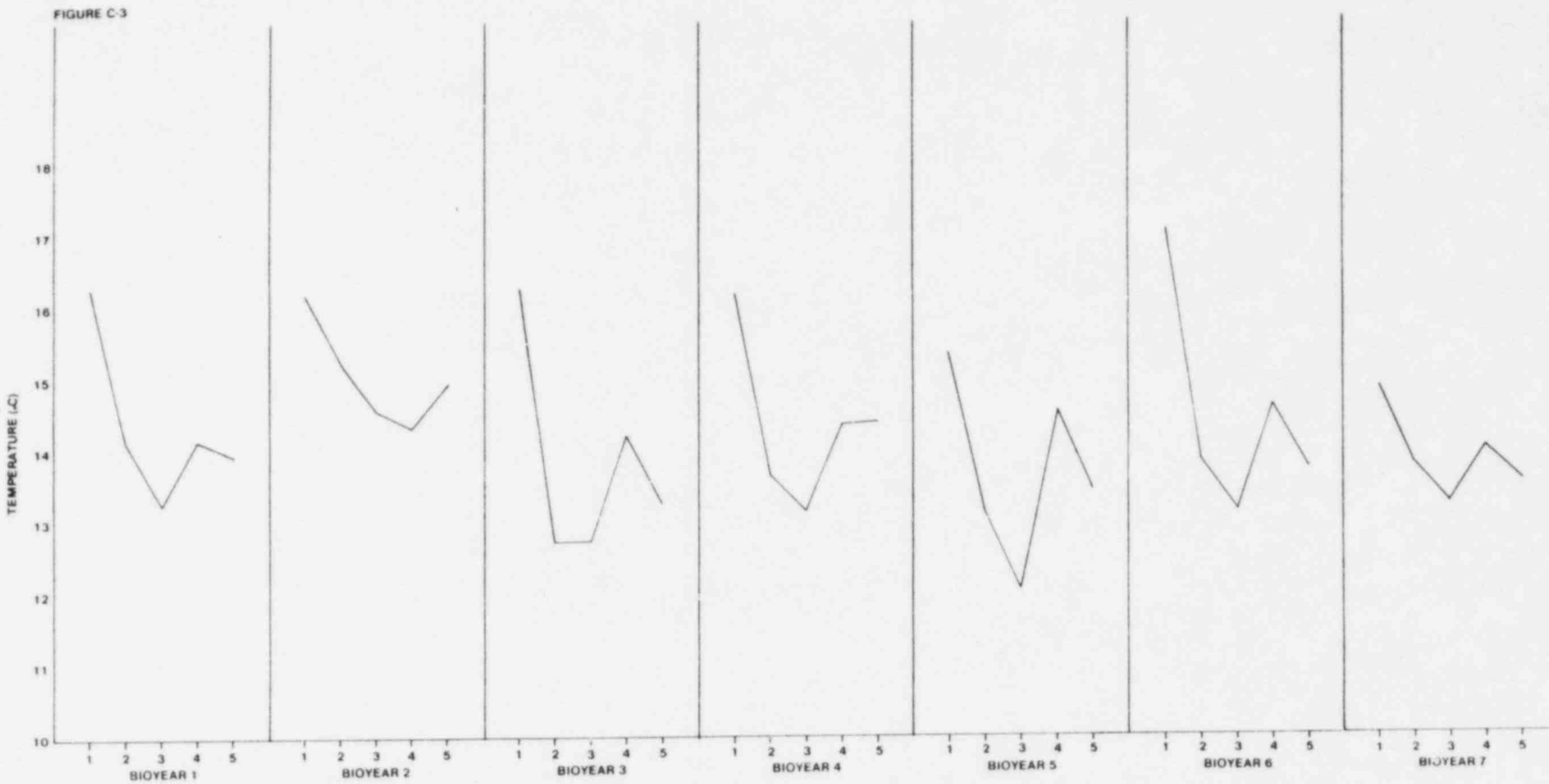


FIGURE C-3. AVERAGE BIOYEAR TEMPERATURES FOR STATIONS GROUPED INTO REGIONS FOR BIOLOGICAL YEARS FROM JULY, 1975 THROUGH JUNE, 1982 (Region 1 = Stations 5, 6, 7, 8; Region 2 = Stations 2, 3, 4, 4A; Region 3 = Stations 1, 17; Region 4 = Stations 9, 10, 10A, 10B, 11; Region 5 = Stations 12, 13, 14, 15, 16).

TABLE C-16. ANALYSIS OF VARIANCE OF TEMPERATURES RECORDED AT EXPOSURE PANEL STATIONS IN BARNEGAT BAY FROM JULY, 1975 THROUGH NOVEMBER, 1982

Stations are grouped into Regions: Region 2 (near OCGS): Stas. 5, 6, 7, 8; Rc 'south): Stas. 2, 3, 4, 4A; Region 3 (east): Stas. 1, 17; Region 4 (near north): Stas. 9, 10, 10A, 10B, 11; Region 5 (north): Stas. 12, ), 16.

Months are grouped by season: Winter = Jan, Feb, Mar; Spring = Apr, May, June; Summer = July, Aug, Sep; Autumn = Oct, Nov, Dec.

Bioyear = July Year A through June Year B.

| Source of Variation | Sum of Squares | DF | Mean Square | F | Significance of F | Source of Variation | Sum of Squares | DF | Mean Square | F | Significance of F |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MAIN EFFECTS | 92545.523 | 12 | 7712.127 | 464.716 | 0.000 | MAIN EFFECTS | 107056.797 | 35 | 3058.766 | 510.817 | 0.000 |
| Region | 1555.395 | 4 | 388.849 | 23.431 | 0.000 | Station | 1716.198 | 19 | 90.326 | 15.085 | 0.000 |
| Season | 91108.516 | 3 | 30369.506 | 1829.999 | 0.000 | Month | 105442.164 | 11 | 9585.651 | 1600.814 | 0.000 |
| Bioyear | 432.508 | 5 | 86.502 | 5.212 | 0.000 | Bioyear | 432.640 | 5 | 86.528 | 14.450 | 0.000 |
| 2-WAY INTERACTIONS | 1425.180 | 47 | 30.323 | 1.827 | 0.001 | | | | | | |
| Region/Season | 116.344 | 12 | 9.695 | 0.584 | 0.856 | | | | | 6.166 | .001 |
| Region/Bioyear | 159.411 | 20 | 7.971 | 0.480 | 0.974 | | | | | 1.971 | .001 |
| Season/Bioyear | 1139.758 | 15 | 75.984 | 4.579 | 0.000 | | | | | 1.6208 | .02 |
| | | | | | | | | | | 15.450 | .001 |
| 3-WAY INTERACTIONS | 504.195 | 59 | 8.546 | 0.515 | 0.999 | | | | | | |
| Region/Season/Bioyear | 504.195 | 59 | 8.546 | 0.515 | 0.999 | | | | | 1.7376 | .02 |
| EXPLAINED | 94474.898 | 118 | 800.635 | 48.244 | 0.000 | EXPLAINED | 108986.170 | 141 | | | |
| RESIDUAL | 20462.086 | 1233 | 16.595 | | | RESIDUAL | 5950.814 | 1210 | 4.9180 | | |
| TOTAL | 114936.984 | 1351 | 85.075 | | | | | | | | |

over all stations. Because this procedure does not correct for variation explained by other factors (i.e. seasonal variation in temperature) the results of the analysis for stations indicated no significant differences. The Region 1 stations, however, are positioned at the top of the range of mean temperatures.

For a similar analysis conducted by month, each of the nine months examined was found to be significantly different from all others. The test comparing mean temperatures by bioyear indicated that only the current year (82/83) is significantly different. This is clearly an artifact due to the incomplete data set for the current year, and no general increase in Barnegat Bay temperatures should be inferred from this result. Overall, these results are generally similar to those reported previously.

## Salinity

The minimum salinities at which Teredo navalis will grow and reproduce have been reported as 5-10 o/oo (Turner, 1973; Richards, 1978), 10-14 o/oo for Bankia gouldi (Allen, 1924; Turner, 1973) and 7-10 o/oo for T. bartschi (Hoagland et al., 1980). During the period December, 1981, through November, 1982, salinities below 10 % were recorded at Station 13 in January (9.3; Table C-2), February (5.1; Table C-3) and April (4.0; Table C-5); at Station 16A in February (9.1; Table C-3); and at Station 17 in February (9.2; Table C-3). Otherwise, salinities were well within the limits for adult survival and reproduction, although they were somewhat lower on the whole during the present report period than during the same period last year.

Average salinities at each exposure panel station, calculated for each biological year from July, 1975 through June, 1982, are plotted as Figure C-4. Stations were grouped into regions, and the average salinities for each bioyear were calculated and plotted (Figure C-5). The salinity pattern from station to station (Figure C-4) is similar to what has been reported previously, although salinities tended to be somewhat lower this year. They were generally highest at Station 1 and lowest at Station 13. Salinities were highest again in Region 3 this year, and lowest in Region 5, a pattern which has been consistent for the 7 bioyears of data (Figure C-5).

The results of the analyses of variance for salinity are shown in Table C-17. All three main effects of station, month and bioyear are statistically significant, with the bioyear effect again being the strongest. Season by bioyear interaction was again the strongest of the 2-factor interactions, and was the only significant interaction.

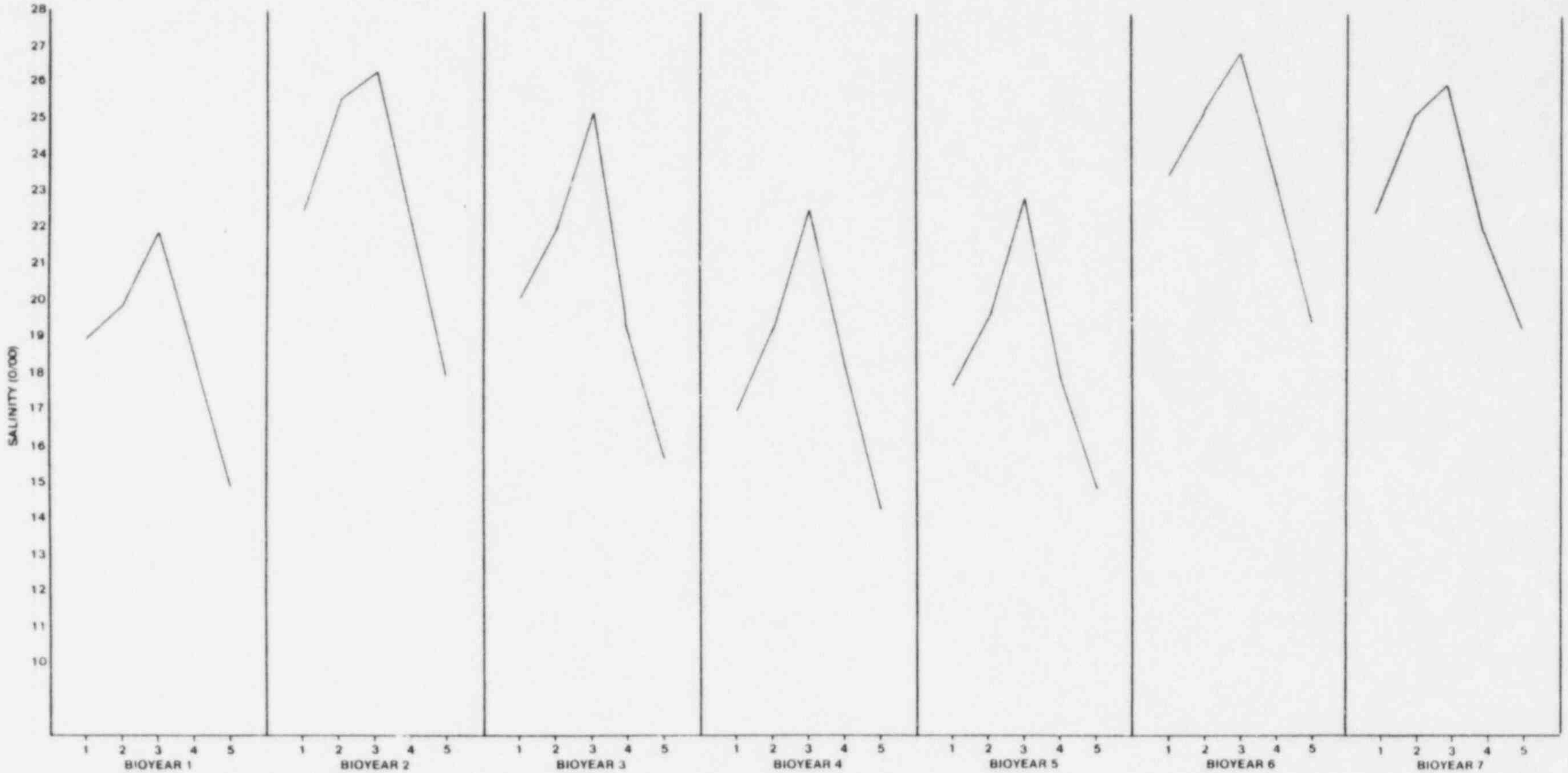


FIGURE C-5. AVERAGE BIOYEAR SALINITIES FOR STATIONS GROUPED INTO REGIONS FOR BIOLOGICAL YEARS FROM JULY, 1975 THROUGH JUNE, 1982. (Region 1 = Stations 5, 6, 7, 8; Region 2 = Stations 2, 3, 4, 4A; Region 3 = Stations 1, 17; Region 4 = Stations 9, 10, 10A 10B, 11; Region 5 = Station 12, 13, 14, 15, 16).

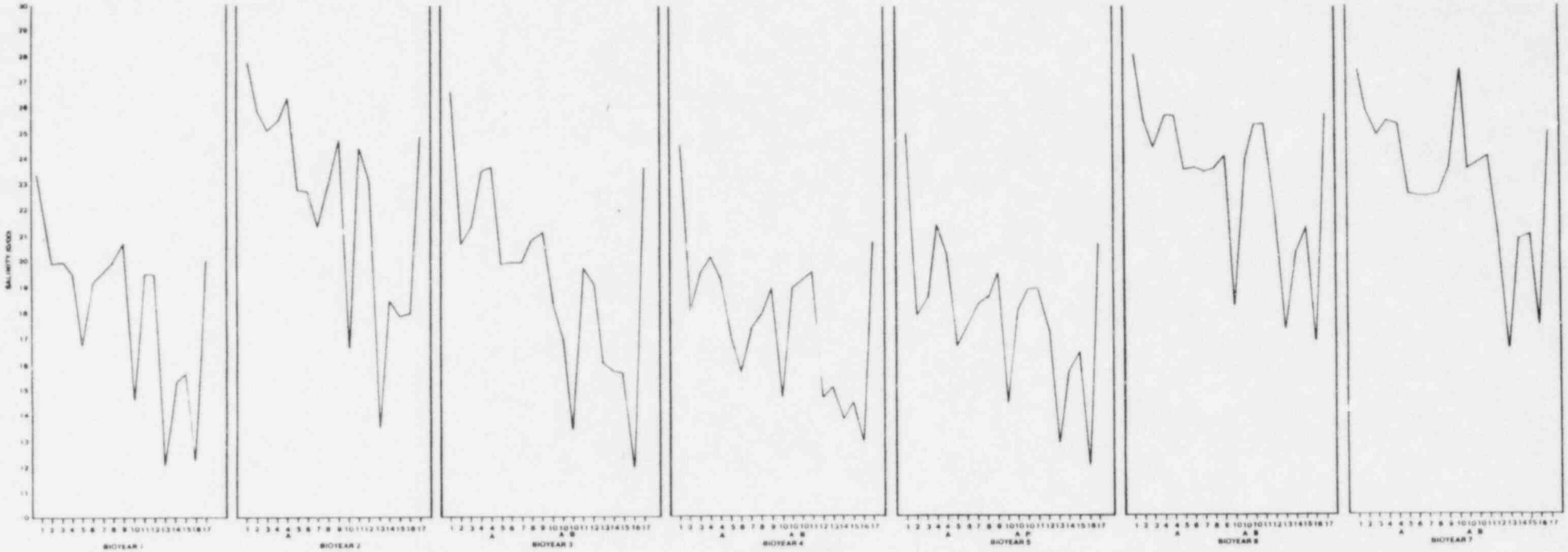


FIGURE C-4. AVERAGE SALINITY AT EACH EXPOSURE PANEL STATION CALCULATED FOR BIOLOGICAL YEARS FROM JULY, 1975 THROUGH JUNE, 1982. [Bioyear 1 = July, 1975 through June, 1976; bioyear 2 = July, 1976 through June, 1977; etc.]. Number of observations is 12 for each bioyear except bioyear 2, when N=8-12.

TABLE C-17. ANALYSIS OF VARIANCE OF SALINITIES RECORDED AT EXPOSURE PANEL STATIONS IN BARNEGAT BAY FROM JULY, 1975 THROUGH NOVEMBER, 1982

Stations are grouped into Regions: Region 2 (near OCGS): Stas. 5, 6, 7, 8; Region 2 (south): Stas. 2, 3, 4, 4A; Region 3 (east): Stas. 1, 17; Region 4 (near north): Stas. 9, 10, 10A, 10B, 11; Region 5 (north): Stas. 12, 13, 14, 15, 16.

Months are grouped by season: Winter = Jan, Feb, Mar; Spring = Apr, May, June; Summer = July, Aug, Sep; Autumn = Oct, Nov, Dec.

Bioyear = July Year A through June Year B.

| Source of Variation | Sum of Squares | DF | Mean Square | F | Significance of F | Source of Variation | Sum of Squares | DF | Mean Square | F | Significance of F |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MAIN EFFECTS | 22157.938 | 12 | 1846.495 | 114.818 | 0.000 | Main Effects | 27117.799 | 35 | 774.794 | 44.069 | 0.000 |
| Region | 8577.283 | 4 | 2144.321 | 133.337 | 0.000 | Station | 11216.326 | 19 | 590.333 | 33.577 | 0.000 |
| Season | 6525.369 | 3 | 2175.123 | 135.252 | 0.000 | Month | 8778.318 | 11 | 798.029 | 45.390 | 0.000 |
| Bioyear | 6816.642 | 5 | 136.328 | 84.774 | 0.000 | Bioyear | 6839.560 | 5 | 1367.912 | 77.804 | 0.000 |
| 2-WAY INTERACTIONS | 7161.760 | 47 | 152.378 | 9.475 | 0.000 | | | | | 12.419 | .001 |
| Region/Season | 214.256 | 12 | 17.855 | 1.110 | 0.347 | | | | | 1.455 | .20 |
| Region/Bioyear | 271.385 | 20 | 13.569 | 0.844 | 0.661 | | | | | 1.106 | .40 |
| Season/Bioyear | 6622.746 | 15 | 441.516 | 27.454 | 0.000 | | | | | 2.2375 | .005 |
| 3-WAY INTERACTIONS | 1097.164 | 59 | 18.596 | 1.156 | 0.199 | | | | | | |
| Region/Season/Bioyear | 1097.163 | 59 | 18.596 | 1.156 | 0.199 | | | | | 1.516 | .01 |
| EXPLAINED | 30416.861 | 118 | 257.770 | 16.029 | 0.000 | Explained | 35376.723 | 141 | | | |
| RESIDUAL | 19732.588 | 1227 | 16.082 | | | Residual | 14772.726 | 1204 | 12.2697 | | |
| TOTAL | 50149.449 | 1345 | 37.286 | | | | | | | | |

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

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

These differences in salinity appear related to the position of the stations within the Bay. The five stations which tended to have lower salinities are located in the northern portion of Barnegat Bay where there is apparently greater freshwater input. Stations in the vicinity of OCNGS and those in the southern portion of the Bay form a large homogeneous group with moderate salinities. Station 17, near Barnegat Inlet is at the most saline extreme of this group. Finally, Station 1 which is located at Barnegat Inlet has significantly higher salinities than all other stations.

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

FEB JAN MAR DEC JUL NOV AUG SEP OCT

This pattern appears related to increased precipitation in the winter and spring resulting in lowered salinities in the Bay. Analysis of salinity by bioyear resulted in a pattern of significance believed to be related to annual rainfall:

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

Although this pattern is generally indicative of increased precipitation in recent years, the magnitude of the differences is not believed to be sufficient to influence the distribution and abundance of teredinids.

## pH

The results of the analysis of variance of pH are given in Table C-18. All main effects were highly statistically significant with bioyear being the first order effect, and month a second order effect. As has been noted in previous reports (Maciolek-Blake et al., 1981, 1982) the actual range of pH values is small, with most station averages falling

TABLE C-18. ANALYSIS OF VARIANCE OF pH RECORDED AT EXPOSURE PANEL STATIONS IN BARNEGAT BAY FROM JULY, 1975 THROUGH NOVEMBER, 1982

Stations are grouped into Regions: Region 2 (near OCGS): Stas. 5, 6, 7, 8; Region 2 (south): Stas. 2, 3, 4, 4A; Region 3 (east): Stas. 1, 17; Region 4 (near north): Stas. 9, 10, 10A, 10B, 11; Region 5 (north): Stas. 12, 13, 14, 15, 16.

Months are grouped by season: Winter = Jan, Feb, Mar; Spring = Apr, May, June; Summer = July, Aug, Sep; Autumn = Oct, Nov, Dec.

Bioyear = July Year A through June Year B.

| Source of Variation | Sum of Squares | DF | Mean Square | F | Significance of F | Source of Variation | Sum of Squares | DF | Mean Square | F | Significance of F |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MAIN EFFECTS | 73.642 | 12 | 6.137 | 28.254 | 0.000 | MAIN EFFECTS | 120.031 | 35 | 3.429 | 15.512 | 0.000 |
| Region | 4.256 | 4 | 1.064 | 4.899 | 0.001 | Station | 14.336 | 19 | 0.755 | 3.413 | 0.000 |
| Season | 12.718 | 3 | 4.239 | 19.518 | 0.000 | Month | 48.974 | 11 | 4.452 | 20.137 | 0.000 |
| Bioyear | 56.170 | 5 | 11.234 | 51.721 | 0.000 | Bioyear | 52.910 | 5 | 10.582 | 47.863 | 0.000 |
| 2-WAY INTERACTIONS | 55.166 | 47 | 1.174 | 5.404 | 0.000 | | | | | 6.479 | .001 |
| Region/Season | 2.841 | 12 | 0.237 | 1.090 | 0.364 | | | | | 1.308 | .20 |
| Region/Bioyear | 6.268 | 20 | 0.313 | 1.443 | 0.093 | | | | | 1.727 | .02 |
| Season/Bioyear | 46.590 | 15 | 3.106 | 14.300 | 0.000 | | | | | 17.140 | .001 |
| 3-WAY INTERACTIONS | 13.909 | 58 | 0.240 | 1.104 | 0.279 | | | | | 1.324 | .05 |
| Region/Season/Bioyear | 13.909 | 58 | 0.240 | 1.104 | 0.279 | | | | | | |
| EXPLAINED | 142.717 | 117 | 1.220 | 5.616 | 0.000 | | 189.106 | 140 | | | |
| RESIDUAL | 254.782 | 1173 | 0.217 | | | | 208.393 | 0.181 | | | |
| TOTAL | 397.499 | 1290 | 0.308 | | | | | | | | |

between 7.7 and 7.9, a range which is not considered biologically significant for teredinids.

Multiple comparisons indicated no significant groups of stations for this parameter. When pH was analyzed by month, however, a clear pattern of significantly different groups was obvious:

JAN FEB SEP OCT DEC NOV AUG MAR JUL

Although some relationships between pH and salinity might be expected, this pattern is not sufficiently similar to that described for salinity to suggest that this is the case. Calculation of the correlation coefficient for this relationship confirms this ($r = .0961$); although the coefficient was statistically significant ($p < .001$), the relationship was extremely weak.

Examination of changes in mean pH by bioyear also revealed significant differences:

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

No trend over the course of the study is suggested by these results, however.

## Dissolved Oxygen

The results of the analysis of variance of dissolved oxygen are given in Table C-19. All three main effects were highly significant, as were the two-factor interactions, with the exception of region by bioyear. Month to month variation appeared to be the strongest effect, with bioyear to bioyear variation a second order effect. Station effects appeared minor compared to the temporal factors.

Multiple comparison procedures confirmed that result, indicating no significant differences between stations. As was the case for temperature, however, potential regional differences may well have been obscured by the side range of annual variation in this parameter.

Analysis by month produced the following groupings:

JUL SEP AUG OCT NOV DEC JAN FEB

TABLE C-19. ANALYSIS OF VARIANCE OF DISSOLVED OXYGEN LEVELS RECORDED AT EXPOSURE PANEL STATIONS IN BARNEGAT BAY FROM JULY, 1975 THROUGH NOVEMBER, 1982

Stations are grouped into Regions: Region 2 (near OCGS): Stas. 5, 6, 7, 8; Region 2 (south): Stas. 2, 3, 4, 4A; Region 3 (east): Stas. 1, 17; Region 4 (near north): Stas. 9, 10, 10A, 10B, 11; Region 5 (north): Stas. 12, 13, 14, 15, 16.

Months are grouped by season: Winter = Jan, Feb, Mar; Spring = Apr, May, June; Summer = July, Aug, Sep; Autumn = Oct, Nov, Dec.

Bioyear = July Year A through June Year B.

| Source of Variation | Sum of Squares | DF | Mean Square | F | Significance of F | Source of Variation | Sum of Squares | DF | Mean Square | F | Significance of F |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MAIN EFFECTS | 5285.075 | 12 | 440.423 | 196.437 | 0.000 | MAIN EFFECTS | 5993.340 | 35 | 171.238 | 78.472 | 0.000 |
| Region | 78.929 | 4 | 19.732 | 8.801 | 0.000 | Station | 116.078 | 19 | 6.109 | 2.800 | 0.000 |
| Season | 4768.739 | 3 | 1589.580 | 708.983 | 0.000 | Month | 5435.165 | 11 | 494.106 | 226.429 | 0.000 |
| Bioyear | 655.572 | 5 | 131.114 | 58.480 | 0.000 | Bioyear | 626.244 | 5 | 125.249 | 57.397 | 0.000 |
| 2-WAY INTERACTIONS | 716.379 | 47 | 15.242 | 6.798 | 0.000 | | | | | 9.113 | .001 |
| Region/Season | 57.832 | 12 | 4.819 | 2.150 | 0.012 | | | | | 2.881 | .001 |
| Region/Bioyear | 35.374 | 20 | 1.769 | 0.789 | 0.729 | | | | | 1.058 | .30 |
| Season/Bioyear | 610.079 | 15 | 40.672 | 18.140 | 0.000 | | | | | 24.318 | |
| 3-WAY INTERACTIONS | 100.390 | 58 | 1.731 | 0.772 | 0.894 | | | | | 1.035 | .30 |
| Region/Season/Bioyear | 100.390 | 58 | 1.731 | 0.772 | 0.894 | | | | | | |
| EXPLAINED | 6101.844 | 117 | 52.153 | 23.261 | 0.000 | EXPLAINED | 6810.109 | 140 | | | |
| RESIDUAL | 2636.657 | 1176 | 2.242 | | | RESIDUAL | 1928.392 | 1153 | 1.673 | | |
| TOTAL | 8738.501 | 1293 | 6.758 | | | | | | | | |

This pattern is nearly the exact opposite of that seen for temperature, indicating that higher temperatures are associated with decreased dissolved oxygen levels. This was confirmed by the correlation coefficient calculated for the relationship between these two parameters (r = -.8236).

Finally, multiple comparisons involving dissolved oxygen levels averaged by bioyear produced the following pattern:

82/83 <u>80/81 81/82</u> <u>75/76 76/77 77/78 79/80 78/79</u>

There is some indication here that oxygen levels throughout the Bay have decreased in the past few years, although the position of the current bioyear (82/83) may well be an artifact due to the incomplete data set.

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GPU Nuclear

GPU Nuclear
P.O. Box 388
Forked River, New Jersey 08731
609-693-6000
Writer's Direct Dial Number:

May 25, 1983

Regional Administrator
Region I
U. S. Nuclear Regulatory Commission
631 Park Avenue
King of Prussia, PA 19406

Dear Sir:

Subject: Oyster Creek Nuclear Generating Station
Docket No. 50-219
Annual Woodborer Study Report

GPU Nuclear Corporation herewith submits in accordance with Section 3.1 of the Oyster Creek Environmental Technical Specifications, the Annual Woodborer Study Report by R. E. Hillman, C. I. Belmore, and R. A. McGrath. This report covers the period December 1, 1981 to November 30, 1982.

If you have any questions concerning this report, please do not hesitate to contact Mr. Douglas Moore of our Licensing and Regulatory Affairs Department at (609) 971-4630.

Very truly yours,

Peter B. Fiedler
Vice President and Director
Oyster Creek

PBF:jal
Enclosure

cc: Director (17 copies)
Office of Nuclear Reactor Regulations
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555
c/o Distribution Services Branch, DDC, ADM

N. J. Bureau of Radiation Protection
Attention: Chief
Division of Environmental Quality
United Sierra Building
380 Scotch Road
West Trenton, NJ 08625

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