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Ecological Studies of Wood-Boring Bivalves in the Vicinity of the Oyster Creek Nuclear Generating Station

Progress Report
June - August 1982

Prepared by K. E. Hoagland

Department of Malacology
Academy of Natural Sciences of Philadelphia

Prepared for
U.S. Nuclear Regulatory
Commission

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Prepared by
K. E. Hoagland

Department of Malacology
Academy of Natural Sciences of Philadelphia
19th and the Parkway
Philadelphia, PA 19103

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Office of Nuclear Regulatory Research
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PREVIOUS REPORTS

Twelve reports have been prepared under Contract AT(49-24)-0347 (=NRC-04-76-[illegible]) during three years of funding from the U.S. Nuclear Regulatory Commission, 1976-1979, under the title:

Analysis of populations of boring and fouling organisms in the vicinity of the Oyster Creek Nuclear Generating Station with discussion of relevant physical parameters.

Those reports with NTIS numbers are:

NUREG/CR-0223	Dec. 1, 1977-Feb. 28, 1978
NUREG/CR-0380	Mar. 1, 1978-May 31, 1978
NUREG/CR-0634	Sept. 1, 1977-Aug. 31, 1978
NUREG/CR-0812	Sept. 1, 1978-Nov. 30, 1978
NUREG/CR-0896	Dec. 1, 1978-Feb. 28, 1979
NUREG/CR-1015	Mar. 1, 1979-May 31, 1979
NUREG/CR-1209	June 1, 1979-Aug. 31, 1979

Five reports have been published in this current series:

Ecological studies of wood-boring bivalves in the vicinity of the Oyster Creek Nuclear Generating Station.

NUREG/CR-1517	Sept. 1, 1979-Feb. 28, 1980, 65 pp.
NUREG/CR-1795	March 1-May 31, 1980, 31 pp.
NUREG/CR-1855	June 1-Aug. 31, 1980, 48 pp.
NUREG/CR-1939	Vol. 1 Sept. 1, 1980-Nov. 30, 1980, 36 pp.
	Vol. 2 Dec. 1, 1980-Feb. 28, 1981, 41 pp.
	Vol. 3 March 1, 1981-May 31, 1981, 38 pp.
	Vol. 4 June 1-Aug. 31, 1981, 44 pp.
NUREG/CR-2727	Vol. 1 Sept. 1-Nov. 30, 1981, 40 pp.
	Vol. 2 December, 1981-February, 1982, 28 pp.
	Vol. 3 March - May, 1982, 34 pp.

ABSTRACT

The species composition, distribution, and population dynamics of wood-boring bivalves are being studied in the vicinity of the Oyster Creek Nuclear Generating Station, Barnegat Bay, New Jersey. Untreated wood test panels are used to collect organisms at 12 stations. Physiological tolerances of 3 species are also under investigation in the laboratory. Competition among the species is being analyzed. Adult populations of *Teredo bartschi* existed in both Oyster Creek and Forked River in the summer of 1982, but the species was rare. There was no large settlement of this or any other teredinid species in Barnegat Bay. *Teredo navalis* was the most common species in the monthly panels. The fouling community reached its maximum yearly diversity in June-July. There was a thermal effluent causing a ΔT of 3-4° C during most of the summer, and salinity in Oyster Creek and Forked River was similar to that of Barnegat Bay. The lack of a shipworm outbreak in 1982 may be related to the low ΔT in summer, plus the lack of a thermal effluent in the preceding winter-spring period.

SUMMARY OF FINDINGS

The purpose of this investigation is to understand the population dynamics and competitive interactions of shipworms in the vicinity of the Oyster Creek Nuclear Generating Station (ONCGS) and at control stations outside the influence of the station. The relative importance of the introduced species Teredo bartschi in causing damage, and physiological tolerances of all species, are being assessed. On a monthly basis, wood panels are added and removed for analysis of population dynamics and to obtain live animals for the lab studies. We also record temperature, salinity, and we estimate siltation levels at each station.

1. The generating station was operating during most of the summer, but the ΔT was only 3-4° C.

2. The temperature and salinity in Barnegat Bay, including Oyster Creek, were nearly ideal for teredinid growth and reproduction in June, July, and August.

3. There was some recirculation of the heated effluent into Forked River in August.

4. Settlement of teredinid larvae was absent in June, sparse in July, and heavy only in Forked River in August. The most common species settling was Teredo navalis, although adults of T. bartschi were present at 4 stations and theoretically could have supplied larvae.

5. Very few adult specimens of T. navalis were found with larvae in the gills. Plankton tows likewise revealed few larvae.

6. T. bartschi was present at two stations (11 and 12) in Oyster Creek and two (4 and 5) in Forked River.

7. Empty boreholes were common in panels from Forked River, indicating early mortality of teredinid larvae.

8. Many of the fastest-growing teredinid specimens were from Oyster Creek.

9. A high percentage of Bankia gouldi survived the winter, but few T. navalis and T. bartschi survived.

10. In general, teredinid attack was light at all inner Barnegat Bay stations in 1982.

11. Comparing 1982 with previous years when the generating station was not operating in winter-spring, I predict that an outbreak of T. bartschi could occur in September-October.

12. Pediveligers of T. bartschi prefer temperatures above 20° C but below 34° C. Pediveligers of T. navalis are active between 18° C and 31° C and between 14-27°/₀₀.

13. The fouling community was more diverse in June than in August. The greatest richness of taxa occurred in Forked River.

14. Bowerbankia gracilis dominated at most stations. Oyster Creek was characterized by Polysiphonia species, yellow sponge, and numerous young amenones and Molgula manhattenis. Forked River was characterized by the orange sponge Microciona prolifera, various green algae including the introduced Codium fragile, and Sertularia argentea.

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ACKNOWLEDGMENTS

We thank the many residents of Oyster Creek who have cooperated in our field work. Lauralynn Crocket, John Flynn, and Beth Ann Tanzosh provided technicial assistance. Eugenia Böhlke of the Academy of Natural Sciences of Philadelphia served as X-ray technologist. J.C.P. & L. Co. provided data on the operation of the Generating Station. R. Smith typed the manuscript.

ECOLOGICAL STUDIES OF WOOD-BORING BIVALVES

IN THE VICINITY OF THE OYSTER CREEK

NUCLEAR GENERATING STATION

June - August, 1982

INTRODUCTION

Previous studies have shown a direct causal relationship between the effluent of the Oyster Creek Nuclear Generating Station and the proliferation of shipworms (Teredinidae) in Oyster Creek and adjacent portions of Barnegat Bay, New Jersey (Turner, 1974; Hoagland et al., 1977; Hoagland et al., 1978; Hoagland and Crocket, 1979; Hoagland and Turner, 1980; Hoagland et al., 1980). The effluent adds heat to the receiving waters, which extends the breeding season of teredinids, increases their growth rates, and reduces their winter mortality rates. It has allowed the establishment of a tropical-subtropical shipworm, Teredo bartschi, in Oyster Creek and Forked River. The design of the generating station's cooling system, taking salt water from Barnegat Bay up Forked River, through the plant, and out into Oyster Creek, has increased the salinity of these two creeks. Shipworms now can reside in these creeks, which previously were unsuitable in salinity level and constancy for the establishment of stable, actively breeding shipworm populations.

The populations of Teredo bartschi compared with the native species in Oyster Creek and Forked River are the focus of current studies. This report summarizes an ongoing collection of data on physical parameters of Barnegat Bay, as well as species composition, distribution, growth, mortality, and reproduction of teredinids. We assess the degree of shipworm damage occurring at each station. We also report on physiological studies comparing the native and introduced shipworms with regard to temperature and salinity tolerances.

METHODS

Stations

Over the first three years of our study, 20 stations were established in Barnegat Bay to monitor boring and fouling organisms. In September, 1979, the number was reduced to 12. The stations are shown in Hoagland and Turner, 1980, and are listed in the appendix. The station numbers are not contiguous because some have been discontinued.

Station 1 is a northern control station on Barnegat Bay outside the influence of the heated effluent. Some shipworms, primarily Bankia gouldi, are traditionally found there. Station 3 is a control station in a tidal creek outside the influence of the effluent. Shipworms are rarely found there. Stations 4 and 5 are in Forked River, influenced by the plant's water intake system. There is some recirculation of heated water that affects these stations, but the main influence is that the salinity is essentially that of the bay.

Station 8 is on the bay between Oyster Creek and Forked River. Stations 10-12 are in Oyster Creek, influenced directly by heat, increased (and constant) salinity, and other components of the effluent (heavy metals, silt, increased flow rate, etc.). Since J.C.P. & L. calculates average values of heavy metal input per month, exact data necessary to characterize the effluent completely are not available.

Stations 14 is at or near the southern limit of the thermal plume, on Barnegat Bay in the mouth of Waretown Creek. During the January 1982, our racks and thermometer at station 14 were destroyed by bulkheaders working in the area. A new station 14 has been established on the opposite side of Waretown Creek in Skipper's Cove. Station 18 on Long Beach Island is being used only as a reliable source of Teredo navalis for laboratory experiments. Stations 6 and 15 inshore on Barnegat Bay are being used as sources of Bankia gouldi for laboratory work.

Field work

Once each month, the water temperature and salinity are measured at each station. Air temperature and time of day are also recorded. The amount of silt settling on wood panels submerged for one month is estimated as trace, light, moderate, or heavy. At stations 1, 5, 11, and 14, records of temperature are kept by means of constant recording instruments that are serviced once a month.

In June and August, the major macroscopic fouling organisms on panels and racks at each station were recorded. They were listed in order of abundance, the species covering the most space being first.

White pine panels, approximately 3/4" x 4" x 8", are used to obtain shipworms for study. There are three panel series: 1) Each month, a panel that has been in the water for 1 month is removed and replaced. In this way data on monthly settlement and early growth of borers are obtained. 2) Each month, a panel that has been in the water for 12 months is removed. 3) Each May, a series of 12 panels is deployed. These panels are removed one a month. They provide information on the cumulative growth and maturation of individual borers as well as development of the boring and fouling communities. The cumulative monthly amount of wood destruction can be evaluated. These three panel series are called M, Y, and C, respectively. The C series is replicated at all stations in 1982. As field work will end in November, 1982, no new yearly panels are being submerged.

Panels are presoaked for 2 weeks, then set on aluminum frame racks against bulkheading or off finger docks. They rest about 6" above the water-sediment interface.

Laboratory Work

Panels are examined for pediveliger shipworm larvae and boring isopods, scraped, and X-rayed to locate the shipworms and provide a permanent record of damage. It is possible to count and often to idenfity shipworms from the X-rays in uncrowded panels, but X-rays do not provide quantitative data in most cases. Therefore, using the X-rays as guides, the panels are dissected. All the shipworms are removed, identified, examined for larvae in the gills, and measured (length only). They are preserved in 75% buffered alcohol. Identifications are first made by technicians, but all *Teredo* spp. are checked by Dr. Hoagland.

During dissection of the wood panels, we estimate the percentage of empty tubes, which indicates mortality. If pallets are still present in the empty tubes, we can record the species of the dead shipworm.

Shipworms from the replicate 12-month panels are not preserved but are kept alive and allowed to spawn in tanks containing filtered sea water (22% salinity) and new pine panels. In this way, we have established pure laboratory populations of *Teredo bartschi*. Individuals of *B. gouldi* and *T. navalis* from the field are being maintained in the laboratory. These stocks are used for temperature and salinity tolerance experiments. Larvae of *Teredo navalis* are being cultured in the laboratory and used for physiological experiments. Larvae are being fed cultures of *Monochrysis lutheri* and *Isochrysis galbana*. Both algae and larvae are maintained in an incubator at 22°C. The procedures for culturing shipworm larvae are those of Culliney, Boyle and Turner (1975) and Turner and Johnson (1971).

Physiological Ecology

Larvae of *Teredo navalis* and *T. bartschi* acclimated to 25-27° C were subjected to rising and falling temperatures at a controlled salinity of 22°/oo. The larvae of *T. navalis* had been reared to the pediveliger stage, while those of *T. bartschi* were already at the pediveliger stage when released from the parents. The larvae were observed for behavioral changes as discussed in our previous quarterly reports. Controls were maintained at 25-27° C in the laboratory. Sample size was 10 larvae per experiment.

Pediveligers of *Teredo navalis* were subjected to both rising and falling salinities at a temperature of 25-26° C. Sample size was 12 larvae per experiment. The initial salinity was 23°/oo. Behavioral categories were recorded as in our previous reports.

Plankton

Plankton samples were taken in Oyster Creek and at station 8 between Oyster Creek and Forked River on September 8, 1982. Organisms identified in the samples are listed in this report.

Fouling

A rank-order list of fouling organisms was made for panels and racks at each station at the time monthly sampling was done in June and August. These list are included in this report.

RESULTS AND DISCUSSION

Physical Factors

A small but significant thermal impact was observable in Oyster Creek during the summer months, 1982 (Tables 1, 2). On the day of sampling, the ΔT was 3° in June, 4° in July, and 4° C in August (Table 1). There was no thermal impact in Forked River in June or July, but a slight temperature elevation was observed in August. In all three months the temperature at station 3, Stout's Creek, was above ambient, probably due to decomposition of organic material in the Cedar swamp directly above the station. The seasonal change in temperature from June to August averaged 7°.

The mean monthly summer temperature data (Table 2) shows a mean ΔT of about 3° C. The recirculation of the heated effluent into Forked River was evident by a 1° C elevation in Forked River between August 9 and September 8. The highest recorded temperature was 31.0° C at station 11 (Oyster Creek) in August. That temperature could cause distress to native boring and fouling organisms if it was maintained over a long period of time, but it occurred for only a few hours. The monthly temperature range was greatest in Oyster Creek, but the daily temperature fluctuation was greater elsewhere.

Table 3 gives the salinity profiles for the summer, 1982. The salinity was high enough for settlement of teredinids at all stations, although the optimal salinity was not reached at control station 3. The species of teredinids found in Barnegat Bay, *Bankia gouldi*, *Teredo navalis*, and *T. bartschi*, all thrive at salinities of 20-26°/₀₀, which is the range found in Barnegat Bay in the summer of 1982. The salinities in Oyster Creek (stations 10-12) were 1-2°/₀₀ lower than those in Forked River (stations 4, 5).

The temperature and precipitation in a portion of the general watershed areas for Barnegat Bay is reviewed in Table 4. Especially in early summer, the weather was cooler and wetter than normal. There was no long-term drought that could raise salinity and thus affect teredinid populations in upper estuaries.

The summer level of operation of the Oyster Creek nuclear generating station is summarized in Table 5. The plant was operating for most of the period of this report, as verified by the ΔT's of 3-4° C reported here. Yet the ΔT's are lower than those of some previous summers. Dilution flow was high relative to operation levels of the plant.

Table 1

Temperature Profiles in °C, June - August, 1982

Station	June 9, 1982	July 7, 1982	August 9, 1982	Differential among months
1	20.0[b]	25.5[b]	26.5	6.5
3	24.0[a]	29.0	29.5	5.5
4	20.0[b]	25.5[b]	27.0	7.0
5	20.0[b]	25.5	28.0	8.0
8	20.0[b]	28.0	29.0	9.0
10	23.0	29.0	30.0	7.0
11	23.0	29.5[a]	30.5[a]	7.5
12	23.0	29.5[a]	30.5[a]	7.5
14	21.5	25.5[b]	26.0[b]	4.5
Differential among stations	4.0	4.0	4.5	

[a]highest value each month

[b]lowest value each month

Accuracy to 0.5°C

Table 2

Continuous Temperature Recorder Data (°C) for July 7, 1982 - Sept. 8, 1982

I. Temperature at 1:00 P.M. E.S.T.

Date monthly chart was removed	July 7, 1982				August 9, 1982				Sept. 8, 1982			
	1	5	11	14[a]	1[a]	5	11	14	1	5	11	14
Mean daily temp. at 1PM	22.0	23.3	26.1			27.4	30.6	27.6	23.7	24.0	25.7	23.8
Standard Deviation	2.2	2.1	1.7			1.2	1.4	1.2	1.2	1.9	2.2	1.6
Highest value of temp. at 1 PM	24.6	25.9	28.4			29.5	33.2	30.0	26.4	28.0	30.7	26.6
Lowest value of temp. at 1 PM	16.6	18.5	17.0			25.6	28.1	25.8	21.2	20.2	22.0	19.9
Monthly Range of temp. at 1 PM	8.0	7.4	11.4			3.9	5.1	4.2	5.2	7.8	8.7	6.7

II. Maximum daily temperature

	July 7, 1982				August 9, 1982				Sept. 8, 1982			
	1	5	11	14	1	5	11	14	1	5	11	14
Mean value of Max. Daily Temp.	22.6	24.0	2.7			27.7	31.3	28.0	24.2	24.4	26.2	24.2
Standard Deviation	1.9	2.1	1.6			1.2	1.4	1.2	1.3	1.6	2.2	1.8
Highest value of Max. Daily Temp.	24.6	26.7	28.4			30.0	34.5	30.2	26.4	28.0	31.0	27.2
Lowest value of Max. Daily Temp.	17.8	19.0	17.9			25.8	29.2	26.3	21.2	21.5	22.2	19.9
Monthly Range of Max. Daily Temp.	6.8	7.7	10.5			4.2	5.3	3.9	5.2	6.5	8.8	7.3

Table 2 cont.

III. Minimum Daily Temperature

	July 7, 1982				August 9, 1982				Sept. 8, 1982			
	1	5	11	14[a]	1[a]	5	11	14	1	5	11	14
Mean value of Min. Daily Temp.	21.2	22.1	24.5			26.2	29.7	26.2	23.0	22.4	24.3	21.7
Standard Deviation	2.1	2.0	1.7			1.2	1.5	1.2	1.2	1.8	2.2	1.8
Highest value of Min. Daily Temp.	23.6	25.0	26.9			29.0	32.8	28.3	25.3	26.8	29.5	25.5
Lowest value of Min. Daily Temp.	16.5	17.7	15.5			24.1	26.8	24.1	20.6	19.5	20.0	18.8
Monthly Range of Min. Daily Temp.	7.1	7.3	11.4			4.9	6.0	4.2	4.7	7.3	9.5	6.7

IV. Daily Temperature Range

	July 7, 1982				August 9, 1982				Sept. 8, 1982			
	1	5	11	14	1	5	11	14	1	5	11	14
Mean ΔT Daily	1.4	1.9	2.1			1.5	1.6	1.8	1.2	2.0	2.0	2.6
Standard Deviation	0.6	0.9	0.8			0.6	0.7	0.5	0.7	0.6	0.8	1.1
Largest Daily ΔT for one month	3.1	3.8	5.0			3.4	3.5	2.9	2.8	4.0	3.8	5.2
Smallest Daily ΔT for one month	0.5	0.6	1.0			0.3	0.7	0.9	0.0	1.0	0.8	0.8

[a]Data missing.

Table 3

Salinity Profiles in °/₀₀, June - August, 1982

Station	June 9	July 7	August 9	Differential among months
1	21	19	20	2
3	18[b]	14[b]	16[b]	4
4	25	23.5[a]	25[a]	1.5
5	24.5	23.5[a]	25[a]	1.5
8	26[a]	23.5[a]	26	2.5
10	23	23	23	0
11	24	23	22.5	1.5
12	24	23	23	1
14	25	23.5[a]	23.5	1.5
Differential among stations	8	9.5	9	

[a]highest value each month

[b]lowest value each month

Accuracy to 0.5°/₀₀

Table 4

Average Temperature and Precipitation in New Jersey, Deviation from Normal. June - August, 1982

	Temperature(°F)	Precipitation (inches)
June	-3.6	+5.1
July	-0.1	-0.8
August*		

*Data not received in time to include in this report.

Table 5

Oyster Creek Nuclear Generating Station Outages, Circulation and Dilution Flow in gal. x 10^6 for June - August, 1982

	Total Water Flow (gal. x 10^6)	Outage Dates
June	36,100	June 4-5
July	43,700	
August	36,000	August 15-28

Shipworm Populations

There were no teredinids in the June or July monthly panels. The monthly panels removed in August are described in Tables 6-7. Many of the newly-settled individuals were too small to identify positively, although most of these were probably Teredo navalis, looking ahead to the findings from cumulative panels removed from the same stations in August. Most of the July-early August settlement occurred in Forked River. Surprisingly, there were no newly-settled Teredo bartschi in Oyster Creek or elsewhere. All but 2 identified specimens were T. navalis. Some empty boreholes were found at all stations having shipworms. Some of these may represent early mortality, but others may represent lost animals due to the scraping of the panels to remove fouling prior to x-raying of the wood. The small size of all teredinids taken from the August monthly panels (Table 7) indicates that settlement occurred close to the August 9 removal date.

The June cumulative panels are essentially monthly panels, since the 1982 cumulative series was deployed on May 9, 1982. They contained no shipworms. However, unlike the July monthly panels, the July 7 cumulative panels contained a few individuals (Table 8). This result indicates that there were some teredinid larvae available for settlement in late June or early July, but that they preferred wood soaked longer than one month to wood in the water only a few weeks. It should be noted that all wood was presoaked for 2 weeks in filtered seawater in the laboratory before being deployed.

Only one specimen of Teredo bartschi settled on the cumulative panels, that being in Forked River. All but 5 of the identified specimens on the panels were T. navalis. The heaviest attack took place in Forked River, although a few specimens settled in Oyster Creek and at Holly Park (station 1). Replicate panels showed some differences; for example, there were 4 shipworms in one panel and one in the other from Holly Park in July. With such low total settlement, no more than 12 individuals per panel, fluctuations of this order of magnitude from panel to panel are within the range of sampling error. Likewise, variations from station to station cannot be attributed to more than sampling error. There is one exception: station 3 had no shipworms in any of the cumulative panels, and can be said to differ from all other stations.

Table 9 adds empty tubes and boreholes to the number of living teredinids in cumulative panels, to estimate the total attack of larvae on each panel. As in the monthly panels, some of the boreholes may be an artifact of our scraping the panels to eliminate fouling. However, empty tubes revealed that some mortality had already occurred by August at stations 4 and 5. Empty boreholes occurred most commonly in panels from Oyster Creek and Forked River. When dead animals and boreholes are

Table 6

Numbers of Shipworms in Monthly Panels
Removed August 9, 1982

Station	B.g.	T.n.	T. sp.	Teredinid	Borehole	Total Alive	Total Alive + Boreholes
1	1	0	0	0	3	1	4
3	0	0	0	0	0	0	0
4	0	0	20	10	2	30	32
5	1	7	0	1	11	9	20
8	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0
11	0	0	0	0	1	0	1
12	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0
Totals	2	7	20	11	17	40	57

Table 7

Length Ranges of Shipworms Removed
from Monthly Panels August 9, 1982 (mm)

Station	B. gouldi	T. navalis	T. sp.
1	2		
4			1-8
5	4	2-6	3

Table 8

Numbers of Living Shipworms in Cumulative Panels
Submerged May 9, 1982

Date Removed:	July 7, 1982			August 9, 1982			
Station	T.n.	T.b.	Total	B.g.	T.n.	Teredinid sp.	Total
1	4	0	4	1	3	0	4
3	0	0	0	0	0	0	0
4	3	0	3	0	4	3	7
5	2	0	2	2	5	5	12
8	2	0	2	0	3	0	3
10	1	0	1	0	0	0	0
11	0	0	0	0	2	0	2
12	0	0	0	0	1	0	1
14	0	0	0	0	0	0	0
Total	12	0	12	3	18	8	29
1	0	0	0	1	0	1	2
3	0	0	0	0	0	0	0
4	2	1	3	0	3	0	3
5	0	0	0	1	0	3	4
8	2	0	2	0	2	0	2
10	0	0	0	0	0	0	0
11	1	0	1	0	1	0	1
12	0	0	0	0	1	0	1
14	0	0	0	0	1	0	1
Totals	5	1	6	2	8	4	14

Table 9

Numbers of Living Shipworms plus Empty Tubes and Boreholes, Cumulative Panels

Date Removed:	July 7, 1982				August 9, 1982				
Station	T.n.	T.b.	Boreholes	Total	B.g.	T.n.	T.sp.	Boreholes	Total
1	4	0	0	4	1	3	0	0	4
3	0	0	0	0	0	0	0	0	0
4	3	0	5	8	0	7	3	0	10
5	2	0	3	5	2	6	5	0	13
8	2	0	1	3	0	3	0	0	3
10	1	0	0	1	0	0	0	0	0
11	0	0	0	0	0	2	0	0	2
12	0	0	3	3	0	1	0	2	3
14	0	0	0	0	0	0	0	0	1
Totals	12	0	12	24	3	22	8	2	35
1	0	0	0	0	1	0	1	0	2
3	0	0	0	0	0	0	0	0	0
4	2	1	3	6	0	3	0	4	7
5	0	0	0	0	1	0	3	4	8
8	2	0	5	7	0	2	0	2	4
10	0	0	0	0	0	0	0	0	0
11	1	0	4	5	0	1	0	4	5
12	0	0	0	0	0	1	0	3	4
14	0	0	0	0	0	1	0	0	1
Totals	5	1	12	18	2	8	4	17	31

included, the pattern of relative abundance and distribution of teredinids in Barnegat Bay is not changed from that when only living specimens are included. Table 10 gives the percentage survival at each station. There is no pattern in the data that can be related to the operation of the Oyster Creek generating station. Sample size is too small for detailed statistical analysis.

The growth of two teredinid specimens in the July cumulative panels exceeded that of all others by 8mm (Table 11). Both of these specimens were taken from Oyster Creek. The largest specimen of T. navalis taken from the August cumulative panels was also from Oyster Creek. The largest Bankia gouldi was from Holly Park (Station 1); this species did not occur in the Oyster Creek panels.

The numbers of living teredinids taken from yearly panels submerged for 2 months (Table 12) were similar to the numbers taken from the cumulative panels (Table 8). The major difference is that many of the Bankia gouldi and Teredo bartschi were adults that survived the winter. Virtually all of the June, 1982, specimens were such survivors. Teredo bartschi survived in low numbers in Oyster Creek and at station 5 in Forked River. The reversal in abundance of Bankia gouldi and T. navalis that occurred in August was the result of July-August settlement of T. navalis. As shown by the cumulative and monthly panels, that settlement occurred most heavily in Forked River.

Table 13 shows the total teredinid attack in 1981-82, including animals that died in the interval. The overall attack was light, compared with past years. The numbers of Teredo bartschi per panel were on the order of 10-50, with only one panel harboring over 150. That panel, the replicate panel from Station 11, contained 122 animals less than 5 mm long and 33 longer individuals. The smaller ones could be 1982 spat, although no spatfall of that magnitude was recorded on either the July monthly or cumulative panel. Patchy settlement late in 1981 with little growth, plus a small settlement in 1982, could account for the anomaly.

Table 14 gives the percentage survivorship for shipworms in the yearly panels. Mortality was highest for Teredo bartschi, compared with the other species. Survivorship in Oyster Creek was less than 20% in all panels.

Length ranges of the specimens taken from yearly panels are in Table 15. Many of the specimens were dead when collected. The largest specimens of Teredo bartschi were in Oyster Creek rather than Forked River. The largest specimens of T. navalis were in Oyster Creek in June and July;

Table 10

Percentage of Specimens that were Alive when Collected, Cumulative Panels

Date Removed:	July 7, 1982			Aug. 9, 1982		
Station	Number Living Specimens	Total no. Tubes Observed	% Alive	Number Living Specimens	Total No. Tubes Observed	% Alive
1	4	4	100	4	4	100
3	0	0	-	0	0	-
4	3	8	38	7	10	70
5	2	5	40	12	13	92
8	2	3	66	3	3	100
10	1	1	100	0	0	-
11	0	0	-	2	2	100
12	0	3	0	1	3	33
14	0	0	-	0	0	-
Totals	12	24	50	29	35	83
1	0	0	-	2	2	100
3	0	0	-	0	0	-
4	3	6	50	3	7	43
5	0	0	-	4	8	50
8	2	7	29	2	4	50
10	0	0	-	0	0	-
11	1	5	20	1	5	20
12	0	0	-	1	4	25
14	0	0	-	1	1	100
Totals	6	18	33	14	31	45

Table 11

Length Ranges of Shipworms, in mm,
Cumulative Panels Submerged May 9, 1982

Date Removed:	July 7, 1982		August 9, 1982		
Station	*T.n.*		*B.g.*	*T.n.*	*T. sp.*
1	8-10		6	48-110	
3					
4	3-8			30-76	2-5
5	3-5		4-8	4-56	1-4
8	7-8			4-85	
10	30*				
11				60-95	
12				135*	
14					
Replicates	*T.n.*	*T.b.*			
1			44*		1
3					
4	2	5*		6-85	
5			3		1-3
8	7-18			62-64	
10					
11	26*			82	
12				4	
14				37	

*Largest specimen each month, each species

Table 12

Numbers of Living Shipworms in Yearly Panels
Submerged in 1981

Date Removed:	June 9, 1982				July 7, 1982				Aug. 9, 1982				
Station	Bg.	T.n.	T.b.	Total	B.g.	T.n.	T.b.	Total	B.g.	T.n.	T.b.	T.sp	Total
1	9	0	0	9	4	0	0	4	1	1	0	0	2
3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	1	0	1	0	2	0	0	2
5	2	0	0	2	1	6	0	7	1	3	1	1	6
8	5	0	0	5	4	1	0	5	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	2	2	0	0	1	1	0	0	0	0	0
12	0	0	2	2	0	0	0	0	0	0	0	0	0
Totals	16	0	4	20	9	8	1	18	2	6	1	1	10
1 Rep.	15	0	0	15	7	0	0	7	8	1	0	0	9
11 Rep.	1	0	3	3	1	1	0	0	1	1	35	0	37

Table 13

Numbers of Living Shipworms plus Empty Tubes and Boreholes,
Yearly Panels

Date Removed:	June 9,1982				July 7, 1982					Aug. 9, 1982				
Station	B.g.	T.n.	T.b.	Tot-al	B.g.	T.n.	T.b.	Tere-dinid	Tot-al	B.g.	T.n.	T.b.	Tere-dinid	Tot-al
1	10	0	0	10	5	0	0	0	5	1	1	0	0	2
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	1	0	1*	2	0	2	0	1*	3
5	3	0	0	3	1	6	0	0	7	2	3	1	1*	7
8	5	2	0	7	4	1	0	0	5	0	3	0	0	3
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	25	25	0	0	11	0	11	0	0	18	0	18
12	0	0	10	10	0	0	51	0	51	0	0	52	0	52
Totals	18	2	35	55	10	8	62	1	81	3	9	71	2	85
1 Rep.	17	0	0	17	9	0	0	1	10	8	2	0	0	10
11 Rep.	1	1	38	40	1	1	155	0	157	1	1	69	0	71

*boreholes

Table 14

Percentage of Specimens that were Alive when Collected, Yearly Panels

Date Removed:	June 9, 1982			July 7, 1982			Aug. 9, 1982		
Station	Number Living Specimens	Total No. Tubes Observed	% Alive	Number Living Specimens	Total No. Tubes Observed	% Alive	Number Living Specimens	Total No. Tubes Observed	% Alive
1	9	10	90	4	5	80	2	2	100
3	0	0	-	0	0	-	0	0	-
4	0	0	-	1	2	50	2	3	66
5	2	3	67	7	7	100	6	7	86
8	5	7	71	5	5	100	0	3	0
10	0	0	-	0	0	-	0	0	-
11	2	25	8	1	11	9	0	18	0
12	2	10	20	0	51	0	0	52	0
Totals	20	55	36	18	81	22	10	85	12
1 Rep.	15	17	88	7	10	70	9	10	90
11 Rep.	3	40	7	0	157	0	37	69	54

Table 15

Length Ranges of Shipworms, in mm,
Yearly Panels

Date Removed:	June 9, 1982			July 7, 1982			Aug. 9, 1982		
Station	B.g.	T.n.	T.b.	B.g.	T.n.	T.b.	B.g.	T.n.	T.b.
1	50[a]-183	-	-	134-280*	-	-	210	78	-
3	-	-	-	-	-	-	-	-	-
4	-	-	-	-	4	-	-	5-18	-
5	110-220	-	-	169	83-181	-	200[a]-495*	2-5	9
8	119-192	25[a]-36[a]	-	200-261	12	-	-	30[a]-146[a]*	-
10	-	-	-	-	-	-	-	-	-
11	-	-	4-38[a]	-	-	6-49	-	-	2[a]-41[a]
12	-	-	2-46[a]	-	-	5-47	-	-	2[a]-47[a]
1 Rep.	41[a]-220	-	-	78-240	-	-	85-235	90	-
11 Rep.	292*	73*	6[a]-77[a]*	172	21*	2[a]-76[a]*	165	38	2-70[a]*

*Largest specimen each month, each species
[a]dead

none of that species was found in Oyster Creek in August. The largest Bankia gouldi occurred at a different station each month.

The percentage of living Teredo navalis found with larvae in the gills, for all stations and months, is given in Table 16. The percentages are lower than usual for August. Parasitization was observed in T. navalis, which might cause reduced fecundity in that species. No T. bartschi were found with larvae, and no specimens of any species carried larvae in June or July.

Physiological Ecology

On August 25, 1982, 100% of the 10 experimental Teredo bartschi larvae became inactive when the temperature was lowered to 20° C. Fifty percent of the animals were inactive at 21.5° C, but controls at 26° also showed 50% inactivity at times. Hence 100% inactivity was used to positively indicate thermal stress. The experiment was repeated on August 26, using a new batch of 10 larvae. This time, 100% inactivity occurred by the time 20.5° C was recorded, and 50% inactivity occurred at 21° C. The values are higher than expected on the basis of previous experiments with adults, which are active above about 13-15° C. All specimens of Teredo navalis became inactive at 18-19° C, again higher than expected. Adults are active above 4° C.

A new group of larvae was used to study the effects of rising temperature. Fifty percent inactivity of Teredo bartschi was reached at 32° C, while 100% inactivity occurred at 34° C. By comparison, adults show thermal stress at 35° C. Pediveligers of T. navalis were totally inactive at 31° C; adults also become inactive at 30-31° C.

Pediveliger larvae of Teredo navalis were all closed on the bottom when a salinity of 31‰ was reached. More than 50% of the 12 test larvae were actively swimming at salinities from 7 to 27 ‰.

Plankton

The plankton samples taken on September 8, 1982, were not rich (Table 17). The most abundant organisms were diatoms, protozoans, and invertebrate eggs of several kinds. No teredinid larvae were positively identified, although two bivalve larvae of uncertain identity were found. The scarcity of teredinid larvae in the plankton in front of the collecting panels corresponds to the low density of recently-settled teredinids in the panels themselves.

Fouling

Tables 18-20 list the most abundant macroscopic fouling organisms on racks and panels for the months of June and August, 1982. Abundance is recorded as coverage of surface area on the racks and panels. Diversity

Table 16

Percentage of Living Teredo navalis Carrying Larvae in the Gills

Sta.	Month Removed	Months Submerged	Max. Length of ship-worms with Larvae(mm)	Min. Length of ship-worms with Larvae(mm)	Max. length of ship-worms without Larvae (mm)	Min. length of ship-worms without Larvae (mm)	% of adult shipworms with Larvae	Panel Composition
1C	August	3	-	-	110	48	0	3 adults, 3 total living
4C	August	3	-	-	30	76	0	5 adults, 7 total living
4E*	August	3	85	46	6	6	100	
5C	August	3	-	-	56	4	0	2 adults, 5 total living
8C	August	3	-	-	85	4	0	2 adults, 3 total living
11C	August	3	95	95	60	60	50	2 adults, 2 total living
12C	August	3	135	135	-	-	100	1 adults, 1 total living

*1-14E August: No larvae in any teredinids except those listed above, station 4E.

Table 16 cont.

Percentage of Living Teredo navalis Carrying Larvae in the Gills

Sta.	Month Removed	Months Submerged	Max. Length of ship-worms with Larvae(mm)	Min. Length of ship-worms with Larvae(mm)	Max. length of ship-worms without Larvae (mm)	Min. length of ship-worms without Larvae (mm)	% of adult shipworms with Larvae	Panel Composition
1Y	August	12	78	78	-	-	100	1 adult, 1 total living
4Y	August	12	-	-	5	5	0	2 total living
5Y	August	12	-	-	5	5	0	3 total living

The total number of adults found with larvae in the gills during the summer of 1982 was 5, all T. navalis.

Table 17

Contents of Plankton Samples Taken September 8, 1982

	Station		
	8	11	12
Bivalve larvae, straight-hinge	1	0	1
Gastropod larvae	4	1	0
Tunicate larvae	2	0	0
Trochophore larvae	4	7	1
Nauplius larvae	6	2	1
Diatoms	thousands	hundreds	hundreds
Protozoans	hundreds	12	6
Invertebrate eggs	hundreds	hundreds	hundreds
Harpacticoid copepods	12	12	2
Nematodes	2	0	0
Amphipods	1	0	0
Hydroid Medusa	0	1	0
Foraminifera	0	1	0

Table 18. Most Abundant Macroscopic Fouling Organisms on Racks and Panels[a], June, 1982.

Station

1	3	4	5
Balanus eburneus	*Bowerbankia gracilis*	*Bowerbankia gracilis*	*Hydroides dianthus*
Electra sp.[b]	*Barentsia* sp.	*Enteromopha intestinalis*	*Polysiphonia harveyi*
Botryllus schlosseri	*Balanus eburneus*	*Ulva lactuca*	Blue-green algae
Barentsia sp.	*Corophium* spp.	*Codium fragile*	*Enteromorpha intestinalis*
Bowerbankia gracilis	Blue-green algae	*Microciona prolifera*	*Botryllus schlosseri*
Chondria sp.	*Electra* sp.[b]	*Mytilus edulis*	*Molgula manhattensis*
Blue-green algae	*Balanus improvisus*	*Hydroides dianthus*	*Mitrella lunata*
Corophium sp.	*Nereis succinea*	*Lepidonotus squamatus*	*Anachis avera*
Diadumene leucolena		*Electra* sp.[b]	*Ilyanassa obsoleta* (eggs)
Haliplanella luciae		*Balanus eburneus*	*Corophium* spp.
Dasya pedicellata		*Corophium* spp.	*Ulva lactuca*
Doridella obscura		*Polydora ligni*	*Mytilus edulis*
Crepidula convexa		*Amanthia* sp.	*Codium fragile*
Hydroides dianthus		*Sertularia argentea*	*Microciona prolifera*
Haliclona loosanoffi		*Botryllus schlosseri*	*Electra* sp.[b]
Mytilus edulis		*Antithamnion* sp.	*Sertularia argentea*
Edotea triloba		*Gammarus mucronatus*	*Schizotricha tenella*
Sabella microphthalma		*Anachis avera*	*Campanulareid hydroid*
Nereis succinea		*Molgula manhattensis*	
Polydora ligni		*Chondria* sp.	
Caprillidae		*Champia parvula*	
Aeolid eggs		*Idotea baltica*	
		Polysiphonia harveyi	
		Doridella obscura	
		Spirorbus sp.	
		Sabellaria vulgaris	
		Stiliger fuscatus	

[a]In order of greatest to least coverage of panels and racks. [b]May be Membranipora.

Table 18, continued

Station

8	10	11	12
Polysiphonia harveyi	*Bowerbankia gracilis*	*Polysiphonia* sp.	*Electra* sp.[b]
Corophium spp.	*Haliclona loosanoffi*	*Bowerbankia gracilis*	*Balanus eburneus*
Ulva lactuca	*Hydroides dianthus*	*Balanus eburneus*	*Haliclona loosanoffi*
Amanthia sp.	*Polysiphonia* sp.	*Barentsia* sp.	Blue-green algae
Sertularia argentea	*Molgula manhattensis*	*Molgula manhattensis*	*Polysiphonia* sp.
Hydroides dianthus	*Corophium* spp.	Blue-green algae	*Bowerbankia gracilis*
Mytilus edulis	Amphipod spp.	*Enteromorpha intestinalis*	*Barentsia* sp.
Electra sp[b]	*Balanus eburneus*	*Haliplanella luciae*	*Enteromorpha intestinalis*
Molgula manhattensis	Blue-green algae	*Electra* sp[b]	*Corophium* spp.
Botryllus schlosseri	*Enteromorpha intestinalis*	Corophium spp.	Amphipod spp.
Codium fragile	*Haliplanella luciae*	Amphipod spp.	*Polydora ligni*
Blue-green algae	*Neopanope* sp.	*Balanus improvisus*	*Molgula manhattensis*
Daysa pedicellata	*Modiolus demissus*	*Aeolidia papillosa*	*Idotea baltica*
Ceramium sp.	*Gracilaria foliifera*	*Doridella obscura*	*Hydroides dianthus*
Enteromorpha intestinalis	*Stiliger fuscatus*	*Nereis succinea*	*Stiliger fuscatus*
Urosalpynx cinerea	*Electra* sp[b]		*Doridella obscura*
Microciona prolifera			
Doridella obscura			
Stiliger fuscatus eggs			

Table 19. Most Abundant Macroscopic Fouling Organisms on June, 1982 Monthly Panels

Station

1	3	4	5
Corophium spp	*Corphium* spp.	*Polysiphonia* sp.	*Polysiphonia* sp.
Botryllus schlosseri	*Balanus* sp.	*Enteromorpha intestinalis*	*Enteromorpha intestinalis*
Balanus sp.		*Botryllus schlosseri*	*Botryllus schlosseri*
Polysiphonia sp.		*Electra* sp.	Blue-green algae
		Bowerbankia gracilis	*Mitrella lunata*
		Doridella obscura	*Anachis avera*
		Balanus eburneus	*Corophium* spp.
		Spirorbus sp.	
		Amphipoda spp.	
		Corophium spp.	
		Idotea baltica	
		Gammarus mucronatus	

Station

8	10	11	12
Botryllus schlosseri	*Molgula manhattensis*	*Molgula manhattensis*	*Molgula manhattensis*
Corophium spp	*Polysiphonia* sp.	*Corophium* spp.	*Corophium* spp.
Stiliger fuscatus (eggs)	Blue-green algae	*Enteromorpha intestinalis*	*Balanus eburneus*
Polysiphonia harveyi	*Electra* sp[b]	Polysiphonia sp.	*Polysiphonia* sp.
Dasya pedicellata	Stiliger fuscatus	Barentsia sp.	*Enteromorpha intestinalis*
Enteromorpha prolifera	*Corophium* spp.	*Bowerbankia gracilis*	*Stiliger fuscatus*
Molgula manhattensis	*Enteromorpha intestinalis*	*Amphipoda* spp.	*Polydora ligni*
Enteromorpha intestinalis		*Aeolida papillosa*	

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Botryllus schlosseri
Blue-green algae

Table 20. Most Abundant Macroscopic Fouling Organisms on Racks and Panels,[a] August, 1982

Station 1	Station 3	Station 4	Station 5
Champia parvula	*Balanus eburneus*	*Codium fragile*	*sertularia argentea*
Haliclona loosanoffi	*Bowerbankia gracilis*	*Haliclona loosanoffi*	*Schizotricha tenella*
Polysiphonia sp.	*Barentsia* sp.	*Champia parvula*	*Champia parvula*
Balanus eburneus	White fungus	*Bowerbankia gracilis*	*Enteromorpha intestinalis*
Diadumene leucolena		*Sertularia argentea*	*Hydroides dianthus*
Corophium sp.		*Schizotricha tenella*	*Microciona prolifera*
Botryllus schlosseri		*Balanus* sp.	*Anachis avera*
Electra crustulenta		*Diadumene leucolena*	*Haliclona loosanoffi*
Doridella obscura		*Microciona prolifera*	*Polysiphonia* sp.
Nereis succinea		*Mytilus edulis*	*Dasya pedicellata*
Crepidula convexa		*Hydroides dianthus*	*Balanus eburneus*
Sabella microphthalma		*Crepidula convexa*	*Amphipoda* spp.
Molgula manhattensis		*Ulva lactuca*	*Nereis succinea*
		Anachis avera	*Sabella microphthalma*
		Urosalpinx cinerea	*Mitrella lunata*
		Corophium spp.	*Crepidula convexa*
		Amphipoda spp.	
		Nereis succinea	
		Sabella microphthalma	
		Polysiphonia sp.	
		Botryllus schlosseri	
		Electra sp[b]	
		Gracilaria foliifera	

[a]In order of greatest to least coverage of panels and racks.

Table 20, continued

Station

8	10	11	12
Champia parvula	*Haliclona loosanoffi*	*Haliclona loosanoffi*	*Haliclona loosanoffi*
Polysiphonia harveyi	*Bowerbankia gracilis*	*Polysiphonia harveyi*	*Bowerbankia gracilis*
Haliclona loosanoffi	*Barentsia* sp.	*Bowerbankia gracilis*	*Barentsia* sp.
Microciona prolifera	*Sabella microphthalma*	*Barentsia* sp.	*Polysiphonia harveyi*
Schizotricha tenella	*Diadumene leucolena*	*Balanus eburneus*	*Balanus eburneus*
Codium fragile	*Balanus eburneus*	Amphipoda spp.	*Nereis succinea*
Molgula manhattensis	*Balanus improvisus*	*Diadumene leucolena*	*Sabella microphthalma*
Enteromorpha intestinalis	*Hydroides dianthus*	*Haliplanella luciae*	
Hydroides dianthus	Amphipoda spp.	*Sabella microphthalma*	
Botryllus schlosseri	*Nereis succinea*	*Hydroides dianthus*	
Sabella microphthalma	*Crepidula convexa*	Gobies	
Balanus improvisus			
Amphipoda spp			
Modiolus demissus			
Ulva lactuca[b]			
Electra sp.			
Diadumene leucolena			
Nereis succinea			
Ceramium sp.			
Dasya pedicellata			

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Molgula manhattensis
Bowerbankia gracilis
Balanus eburneus
Hydroides dianthus
Amphipoda spp.
Polysiphonia harveyi
Gracilaria foliifera
Nereis succinea
Sabella microphthalma
Dasya pedicellata
Brania clavata
Caprellid amphipods

and species richness were lowest at the control low-salinity station #3, followed by the stations in Oyster Creek. Richness was greatest in Forked River. There were fewer species present in August than in June, due to summer mortality and slough-offs. Some of the mortality is probably due to overgrowth by superior competitors for space, but some could be due to high water temperatures in late July and early August.

Both Oyster Creek and Forked River were characterized by growth of sponges, but Microciona prolifera dominated in Forked River while Haliclona sp., probably H. loosanoffi, dominated in Oyster Creek. The introduced green alga Codium fragile, which has occurred sporadically in Barnegat Bay since our studies began in 1971, was found in Forked River. Bowerbankia gracilis, often mixed with Barentsia sp., covered the racks and panels at most stations.

Tables 18-20 show that numerous grazers and predators existed in the community. Several of these such as Aeolidia papillosa, Stiliger fuscatus, Doridella obscura, and the caprellid amphipods, are food specialists, with a potential impact on fouling species composition. This aspect of the fouling community will be analyzed in the final report.

Table 19 lists only those species found on the June monthly panels submerged from May 5 to June 9, 1982. During that period, the new panels were colonized by mobile organisms such as Corophium spp., snails, and polychaetes, but also by algae, barnacles, bryozoa and tunicates. Hydroids were not among the colonists. Oyster Creek was characterized by Molgula manhattensis in large numbers, whereas Botryllus schlosseri dominated the attached fouling on the bay, and Polysiphonia spp. dominated within Forked River.

A comparison of tables 18 and 20 shows that the fouling community is dynamic and unstable over short periods. The most common species change dramatically over a 2-month period, although certain species such as Balanus eburneus remain on the panels month after month. Despite the heavy set of Molgula manhattensis in Oyster Creek in May and June, by August it was a minor element of the fouling community there, while the yellow-sponge Haliclona had taken the number one spot. Molgula manhattensis was common at other stations in August. Oyster Creek may have been too warm for it in August.

CONCLUSIONS

The prolonged shutdown of the Oyster Creek nuclear generating station appears to have prevented a spring and summer outbreak of Teredo bartschi in Oyster Creek. Density of planktonic larvae, spat, and mature individuals of all species was low throughout the inner shore of Barnegat Bay in summer, 1982, although enough large Bankia gouldi were present at Holly Park to cause noticeable damage to wooden structures. The population of Teredo navalis in Oyster Creek and especially Forked River was on the rise in July and August due to a new spatfall, but numerous empty boreholes evidenced high mortality at settlement. Fecundity of adults of both T. bartschi and T. navalis was low in the summer months.

Even though there was no outbreak in the summer of 1982, the potential exists for a late outbreak of Teredo bartschi in September or October. Apparently, some T. bartschi are able to survive prolonged cold winter temperatures in Forked River and Oyster Creek even without a thermal effluent being present.

The pediveligers of both Teredo bartschi and T. navalis require higher temperatures for activity than do the adults. Laboratory conditions may give misleading quantitative results, but repeat trials with both species increase the likelihood that the general result is correct.

Several common fouling organisms are found in Forked River but not Oyster Creek, indicating that 100% circulation of larvae does not occur between the two creeks. Fouling diversity and richness decline slightly in August, due to either competitive exclusion or mortality from high temperature or both. Diversity is far lower at the control station with low salinity. The most common species at each station changes from month to month as species settle and disappear.

REFERENCES

Culliney, J. L., P. J. Boyle and R. D. Turner. 1975. New approaches and Techniques for Studying Bivalve Larvae. In Culture of Marine Invertebrate Animals, Smith, W.L. and Chanley, M.H., eds., Plenum Publishing Corporation, New York, pp. 257-271.

Hoagland, K. E. and L. Crocket. 1979. Analysis of populations of boring and fouling organisms in the vicinity of the Oyster Creek Nuclear Generating Station. Annual Progress Report. Sept. 1, 1977-Aug. 31, 1978. NUREG/CR-0634. 113 pp.*

Hoagland, K. E. and R. D. Turner. 1980. Range extensions of teredinids (shipworms) and polychaetes in the vicinity of a temperate-zone nuclear generating station. Marine Biology 58:55-64.

Hoagland, K. E., L. Crocket and M. Rochester. 1978. Analysis of populations of boring and fouling organisms in the vicinity of the Oyster Creek Nuclear Generating Station with discussion of relevant physical factors over the period: Dec. 1, 1977-Feb. 28. 1978. NUREG/CR-0223. 44 pp.*

Hoagland, K. E., L. Crocket and R. D. Turner. 1980. Ecological studies of wood-boring bivalves in the vicinity of the Oyster Creek Nuclear Generating Station, Sept. 1, 1979-Feb. 28, 1980. NUREG/CR-1517. 65 pp.*

Hoagland, K.E., R. D. Turner and M. Rochester. 1977. Analysis of boring and fouling organisms in the vicinity of the Oyster Creek Nuclear Generating Station with discussion of relevant physical parameters over the period: April 30-November 30, 1976. Report to the U.S. Nuclear Regulatory Commission. Jan. 1, 1977. 61 pp.

Turner, R. D. 1974. In the path of a warm, saline effluent. American Malacol. Union Bull. for 1973. 39:36-41.

Turner, R. D. and A. C. Johnson. 1971. Biology of Marine Wood-Boring Molluscs. In: Marine Borers, Fungi and Fouling Organisms of Wood, Chapter 13. Jones, E. B. G., and Eltringham, S. K. (eds.), Organization for Economic Cooperation and Development, Paris, pp. 259-301.

*Available for purchase from the NRC/GPO Sales Program, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, and the National Technical Information Service, Springfield, VA 22161.

APPENDIX: STATION LOCALITIES

STATION NUMBER	NAME	DESCRIPTION	COORDINATES
1	Holly Park	Dick's Landing Island Drive Bayville, N.J. Bay control	Lat. 39° 54' N Lon. 74° 8' W
3	Stout's Creek	End of Raleigh Drive Gustav Walters' residence Estuarine control	39° 50.7' N 74° 9.8' W
4	Mouth of Forked River	South Shore Developed property Possible temperature increase, increased oceanic influence due to reverse flow	39° 49.6' N 74° 9.8' W
5	Leilani Drive	At branch point of Forked River	39° 49.6' N 74° 10.5' W
6	Elk's Club	South Branch Forked River Increase in salinity due to plant intake canal	39° 49.4' N 74° 10.9' W
8	Bayside Beach Club	On bay between Oyster Creek and Forked River across from 1815 Beach Blvd., Forked River, N.J. Temperature increase since plant operation.	39° 49.0' N 74° 9.7' W
10	Kochman's Residence	End of Compass Rd. on #1 Lagoon, Oyster Creek Waretown, N.J. Temperature, salinity siltation increase	39° 48.5' N 74° 10.6' W
11	Crisman's Residence	Dock Ave. on Oyster Creek, Waretown, N.J. Temperature, salinity, siltation increase	39° 48.5' N 74° 11.0' W
12	Gilmore's Residence	20 Dock Ave. on Oyster Creek Waretown, N.J. Temperature, salinity, siltation increase	39° 48.5' N 74° 11.3' W

STATION NUMBER	NAME	DESCRIPTION	COORDINATES
14	Cottrell's Clam Factory	End of North Harbor Rd. Waretown, N.J. (Mouth of Waretown Creek). Within but near limits of reported thermal plume*	39° 47.7' N 74° 10.9' W
15	Carl's Boats	Washington & Liberty Sts. Waretown, N.J. (on the bay)	39° 47' N 74° 11' W
18	Barnegat Light	Marina adjacent to Coast Guard Station	39° 45.8' N 74° 6.5' W

*In May, Sta. 14 was moved to 19 Jolly Roger Way, Waretown, NJ, across Waretown Creek from the old site.

DISTRIBUTION LIST

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North Harbor Road
Waretown, New Jersey 08758

Mr. Wilson T. Crisman
901 Hudson Street
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Mr. and Mrs. Thomas Gilmore
20 Dock Ave., Box 205 E, R.R.1.
Waretown, New Jersey 08758

Mr. Walter Holzman
1915 Beach Blvd.
Forked River Beach, New Jersey 08731

Mr. Charles Kochman
Compass Road
Waretown, New Jersey 08758

Mr. Ed Sheridan
1108 Leilani Drive
Forked River, New Jersey 08731

Mr. Gustav Walters
100 Manhattan Avenue, Apt. 706
Union City, New Jersey 07087

Mr. Edward Wheiler
16 River View Drive, P.O. Box 642
Forked River, New Jersey 08731

Mr. John Turner
19 Jolly Roger Way
Waretown, New Jersey 08758

Part B

Battelle Columbus Laboratories
Clapp Laboratories
Duxbury, Massachusetts 02332

Mr. Michael Roche
Supervisor of Environmental Science
Jersey Central Power and Light Co.
Madison Ave. at Punchbowl Road
Morristown, New Jersey 07960

Dr. Glenn Paulson
Asst. Commissioner for Science
Dept. of Environmental Protection
State of New Jersey
P.O. Box 1390
Trenton, New Jersey 08625

Mr. Alan R. Hoffman
Lynch, Brewer, Hoffman & Sands
Ten Post Office Square
Suite 329
Boston, Massachusetts 02109

Mr. John Makai
Nacote Creek Research Station
Star Route
Absecon, New Jersey 08201

Mr. Steve Lubow
NJDEP-Division of Water Resources
P.O. Box CN-029
Trenton, New Jersey 08625

Dr. Harry L. Allen
US EPA Region II
26 Federal Plaza
Room 832
New York, New York 10007

Dr. John Strand
Ecosystems Department
Battelle Northwest Lab
Richland, Washington 99352

Dr. D. Heyward Hamilton, Jr.
EV-34, GTN
U.S. Dept. of Energy
Washington, D.C. 20545

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Department of Malacology
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16. ABSTRACT (200 words or less)

The species composition, distribution, and population dynamics of wood-boring bivalves are being studied in the vicinity of the Oyster Creek Nuclear Generating Station, Barnegat Bay, New Jersey. Untreated wood test panels are used to collect organisms at 12 stations. Physiological tolerances of 3 species are also under investigation in the laboratory. Competition among the species is being analyzed. Adult populations of *Teredo bartschi* existed in both Oyster Creek and Forked River in the summer of 1982, but the species was rare. There was no large settlement of this or any other teredinid species in Barnegat Bay. *Teredo navalis* was the most common species in the monthly panels. The fouling community reached its maximum yearly diversity in June-July. There was a thermal effluent causing a ΔT of 3-4° C during most of the summer, and salinity in Oyster Creek and Forked River was similar to that of Barnegat Bay. The lack of a shipworm outbreak in 1982 may be related to the low ΔT in summer, plus the lack of a thermal effluent in the preceding winter-spring period.

17. KEY WORDS AND DOCUMENT ANALYSIS

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DECEMBER 1982