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

Progress Report
March - May 1981

Prepared by K. E. Hoagland, L. Crocket

Wetlands Institute
Lehigh University

Prepared for
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Prepared by
K. E. Hoagland, L. Crocket

Wetlands Institute
Lehigh University
Stone Harbor, NJ 08247

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PREVIOUS REPORTS

Twelve reports have been prepared under Contract AT(49-24)-0347 (=NRC-04-76-347) 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.

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. Relative destructiveness and competition among the species are being analyzed. The native species *Teredo navalis* and *Bankia gouldi* coexist with the introduced *T. bartschi* in Oyster Creek and at the mouth of Forked River. The population *Teredo bartschi* is reduced when the power plant does not operate for prolonged periods. It survives well at temperatures above 16° C (but not above 30° C) and at salinities of 22 ‰ in the laboratory. It prefers to settle at the mudline, while the other species of teredinids did not show this preference.

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 (OCNGS) 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. Physiological experiments are performed to evaluate temperature and salinity tolerances of the native and introduced species.

Our major findings are:

1. The ΔT of the thermal effluent in Oyster Creek during the spring months of 1981 was +4° C or less. There was no evidence of recirculation of the effluent into Forked River, and most of the excess heat dissipated before reaching Waretown, New Jersey. The plant was not operating from April 19-May 28, 1981.

2. The temperatures were high enough to support gonadal development by April in Oyster Creek and late April or early May at the other stations.

3. The salinity was high enough for survival of shipworms and their larvae at all stations. In fact, the salinity in Barnegat Bay was close to the optimum for Teredo bartschi, about 22-24°/oo.

4. There was no settlement of young on any panel during March-May, 1981.

5. Teredo bartschi was limited to Oyster Creek and the Bayside Beach Club between Oyster Creek and Forked River. These were also the areas with the heaviest shipworm attack overall. They are the most influenced by the Oyster Creek Nuclear Generating Station.

6. Although Teredo bartschi was the dominant species, most specimens from the 1980-81 year class were dead by May, 1981.

7. The largest specimens of all three species were found in Oyster Creek, indicating that the warmer waters of the thermal effluent were favorable for growth.

8. Settlement of Teredo navalis and Bankia gouldi was not at random with respect to the yearly and cumulative racks, but was clumped.

9. Mortality of Teredo bartschi was over 90%; mortality of Teredo navalis was about 50%; mortality of Bankia gouldi was less than 10%.

10. Specimens of Teredo bartschi settled in a cluster near the mudline on the leeside of stakes, while specimens of Bankia gouldi and Teredo navalis settled at random with respect to currents and were not concentrated at the mudline.

11. Teredo bartschi adults did not filter water at temperatures lower than 15° C when maintained at a salinity of 22 °/oo.

12. The preferred temperature and salinity for reproduction in Teredo bartschi were 20° C and 22 °/oo. Reproduction did not occur at 10° C and was delayed or did not occur at 6 °/oo.

13. Growth of Teredo bartschi was greatest at 30° C and both 14 and 22 °/oo; growth was poor at 10° C regardless of salinity.

14. Mortality of Teredo bartschi was high at both 10 and 30° C but was very low at 20° C, especially at salinities of 6 and 14 °/oo when compared with 22 °/oo.

15. It was concluded that 20° C and 22 °/oo were the optimal conditions for survival growth, and reproduction of Teredo bartschi of those conditions tested.

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ECOLOGICAL STUDIES OF WOOD-BORING BIVALVES IN THE VICINITY OF THE OYSTER CREEK NUCLEAR GENERATING STATION

March - May, 1981

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). 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 its spread into 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 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 our ongoing collection of data on some 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, 5, and 6 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 6 is sampled on a reduced schedule, only 4 times a year.

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 JCP & L calculates average values of heavy metal input per month, exact data necessary to characterize the effluent completely are not available.

Stations 14 and 15 are at or near the southern limit of the thermal plume, on Barnegat Bay. Station 15, like Station 6, is being sampled on a reduced schedule. Station 18 on Long Beach Island is being used only as a reliable source of Teredo navalis for laboratory experiments.

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 and salinity are kept by means of constant recording instruments that are serviced once a month.

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 and replaced. It provides data on timing of reproduction, species and age structure of established borer communities, and other population data.

3) Each May, most recently on May 7, 1981, a series of 12 panels is deployed. These panels are removed one per 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 Y and C series are replicated at some stations, as indicated in the data tables to follow. Replication is not possible at all stations because of limited space where the water is deep enough to submerge a series of shipworm panels.

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.

A series of wood stakes 90 cm in length and 3x7 cm in thickness were submerged on May 3, 1980, in order to test the hypothesis that shipworm larvae, regardless of species, prefer to settle near the mudline. Three identical lengths of white pine were submerged by driving them into the mud; a portion of the wood remained above the water line. The stakes were fastened to bulkheading at stations 1, 4, 8, 10, 11, and 14.

In September, 1980, one of the three stakes was removed at each station except at station 1 where the stakes apparently had been removed. Because the amount of destruction was obviously low, two of the stakes were kept in the water so that they might accumulate a heavier attack of shipworm larvae. The stakes were marked to indicate the positions of the mud and waterline, and were then X-rayed. The exteriors of the stakes were examined for boreholes that may not have appeared in the X-rays. Then, the position of each borehole and the direction of growth of the individual was recorded.

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 identify 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 one of the senior investigators.

Wood fragments from the dissected panels are saved. Calcareous tubes and other debris left by the shipworms are removed with HCℓ. The wood is washed in fresh water, then dried to constant weight, allowed to cool to room temperature, and weighed. The panels are also weighed before going into the water. The weight difference is a measure of wood destruction due to boring organisms.

During dissection of the wood panels, we estimate the percentage of empty tubes, which indicate 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 immediately 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. Breeding colonies of Teredo navalis are now being established. Individuals of B. gouldi from the field are being maintained in the laboratory. Algal cultures (Isochrysis-Monochrysis) have been established to use as supplemental food for Teredo navalis adults and to feed veligers. Lab stocks of the second generation are used in the physiological experiments.

Two experiments were performed during this quarter to elucidate the physiological tolerances of Teredo bartschi. First, on March 11, 1981, a panel containing 22 adult specimens of T. bartschi was taken from the laboratory (22 ^{o}/oo salinity and 22^{o} C) and placed at ambient temperature (11^{o} C) in an outdoor water table. The water temperature and the number of siphons visible were recorded daily. A constant recording thermometer was used to obtain a record of the daily temperature changes until April 2, 1981, when the experiment was terminated. The panel was dissected to determine the number of surviving shipworms. The stock used for this experiment was bred in the laboratory from a few adults taken from station 12 in Oyster Creek and hence was inbred.

The second experiment was designed to test the independent and joint effects of various temperatures and salinities on the survival and growth of newly metamorphosed Teredo bartschi. Pediveligers were exposed to 18 identical panels of clear white pine cut from the same board. After the pediveligers began to bore, they were counted and the panels were isolated from one another in filtered and aerated sea water. Attempts were made to obtain densities of about 30 pediveligers per panel so that crowding would not be a factor in growth of the animals. Two panels each were established at all combinations of 10, 20, and 30^{o} C and 6, 14, and 22 ^{o}/oo salinity.

The water was changed weekly and filtered. The filter paper was dried and the dry weight of the frass and fecal material determined. The experiment began on February 18, 1981, and was terminated on May 20, 1981. Each time the water was changed, it was examined for pediveliger larvae. At the conclusion of the experiment, the panels were X-rayed. The number of specimens per panel and their lengths were recorded.

RESULTS AND DISCUSSION

Physical Data

The temperature profiles (Table 1) show that the thermal effluent was present in Oyster Creek during March and April but was absent on the date of sampling in May. The ΔT was about $+4^{o}$ C both on March 9 and April 6. There was no evidence of recirculation of the effluent into Forked River on the March and April sampling dates. Nor was the effluent noticable at Waretown Creek south of the generating station (Station 14). On March 9 and May 7, station 3 in Stout's Creek was warmer than the other control stations by 2.5^{o} C.

Table 2 presents the temperature data in greater detail, showing average ΔT's of less than 4^{o} C. The most important observation is that the temperature remained above 9.7^{o} C at station 11 in Oyster Creek from April 6 onward. Gonad development would be expected in the teredinids at about this temperature. There was high enough temperature in May at all stations for gonad development to occur. There was an anomalously low minimum daily temperature at station 5 in April (3.0^{o} C).

The salinities at the test stations were fairly constant from month to month except at stations 8 and 14 on Barnegat Bay (Tables 3 and 4). The salinities were high enough to support teredinids (over 10 $^{o}/oo$) at all stations during the spring months. In fact, the average salinities of 20-26 $^{o}/_{oo}$ in Table 4 cover the optimum salinity range for *Teredo bartschi* as determined in the laboratory (see earlier volumes of this report and pp. 25-29 of this volume).

The spring salinities were higher than usual due to low precipitation in winter, hence lower spring runoff. However, Table 5 shows that the drought was eased during March-May. Table 6 shows the overall precipitation figures for 1980; a pronounced drought is evident.

The Oyster Creek nuclear generating station was not operating March 12-16, March 28-31, and April 19-May 28, 1981. The total water flow through the station for the 3 months was 38,344 gal. x 10^6 in March, 31,180 gal. x 10^6 in April, and only 23,487 gal. x 10^6 in May (M. Kennish, personal communication).

Shipworm Populations

There were no larvae settling on the monthly panels during the period of this report. These results are consistent with other years of this study. The cumulative panels containing the 1980 year-class are reported in Table 7. *Bankia gouldi* was the most abundant species. The proportions of the species were similar in March and April, but in May no specimens

TABLE 1

Temperature Profiles in ^{o}C, March to May, 1981

Date Removed:	March 9, 1981	April 6, 1981	May 7, 1981	Differential within stations Among Months
Station				
1	6.0	13.0[b]	16.5	10.5
3	8.5	13.5	19.0[a]	10.5
4	5.8[b]	11.5	16.0	10.2
5	6.2	13.5	16.0	9.8
8	6.5	13.0[b]	16.0	9.5
10	9.0	17.5[a]	15.0[b]	8.5
11	9.5	16.5	15.3	7.0
12	10.0[a]	16.5	16.0	6.5
14	6.0	13.0[b]	15.0[b]	9.0
Differential among stations	4.2	6.0	4.0	

[a] highest value each month

[b] lowest value each month

Table 2

Continuous Temperature Recorder Data (^{o}C) for March 9 to June 8, 1981

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

	March 9-April 6				April 6-May 7				May 7-June 8			
	1[a]	5	11[a]	14	1[a]	5	11	14	1	5	11	14[b]
Mean Daily Temp. at 1PM		8.1		6.9		13.7	15.1	12.5	19.1	19.3	20.4	
Standard Deviation		4.0		3.4		1.6	1.8	1.7	2.7	2.8	4.3	
Highest value of Temp. at 1 PM		17.6		13.3		16.5	18.3	16.7	24.2	24.6	27.5	
Lowest value of Temp. at 1 PM		3.3		2.7		11.3	11.5	10.0	15.6	15.4	14.8	
Monthly Temp. Range at 1 PM		14.3		10.6		5.2	6.8	6.7	8.6	9.2	12.7	

II. Maximum Daily Temperature

	March 9-April 6		April 6-May 7			May 7-June 8			
	5	14	5	11	14	1	5	11	14
Mean value of Max. Daily Temp.	8.9	7.6	14.6	15.4	13.6	19.9	19.8	21.0	19.6
Standard Deviation	4.4	3.6	1.5	1.8	1.6	2.6	2.7	4.2	2.9
Highest value of Max. Daily Temp.	17.7	14.2	17.4	18.3	16.9	24.3	24.7	28.0	24.2
Lowest value of Max. Daily Temp.	4.3	3.3	11.9	11.6	11.0	16.5	15.6	15.7	15.2
Monthly Range of Max. Daily Temp.	13.4	10.9	5.5	6.7	5.9	7.8	9.1	12.3	9.0

Table 2, continued

III. Minimum Daily Temperature

	March 9-April 6		April 6-May 7			May 7-June 8			
	5	14	5	11	14	1	5	11	14
Mean value of Min. Daily Temp.	6.2	5.9	11.8	12.9	11.1	18.3	17.6	18.7	17.4
Standard Deviation	4.4	3.2	2.3	1.8	1.5	2.6	2.9	4.4	2.9
Highest value of Min. Daily Temp.	15.7	12.2	14.8	15.9	14.7	22.5	22.5	25.7	21.7
Lowest value of Min. Daily Temp.	-0.5	2.2	3.0	9.7	8.8	14.5	13.4	13.6	12.9
Monthly Range of Min. Daily Temp.	16.2	10.0	11.8	6.2	5.9	8.0	9.1	12.1	8.8

IV. Daily Temperature Range

	March 9-April 6		April 6-May 7			May 7-June 8			
	5	14	5	11	14	1	5	11	14
Mean Daily ΔT	2.7	1.7	2.9	2.5	2.3	1.6	2.3	2.4	2.2
Standard Deviation	1.6	0.8	2.0	0.9	0.7	0.6	0.8	1.0	1.0
Largest Daily ΔT for One Month	7.7	3.9	12.2	4.4	3.9	2.9	3.8	5.2	4.2
Smallest Daily ΔT for One Month	1.0	0.8	0.8	1.0	0.4	0.6	0.6	0.5	0.9

a not in operation

b unable to determine 1 PM due to technical difficulties

Table 3

Salinity Profiles in $^{o}/_{oo}$, March to May, 1981

Station	March 9	April 6	May 7	Differential among months
1	20[b]	24	21	4
3	20[b]	20[b]	18[b]	2
4	24	25[a]	27	3
5	24	23	26	3
8	23	22	28[a]	6
10	23	22	21	2
11	23	22	21	2
12	23	21	21	2
14	25[a]	22	28[a]	6
Differential among stations within months	5	5	10	

[a] highest value

[b] lowest value

Table 4

Continuous Recording Salinometer Readings
at 12:00 Noon EST
in parts per thousand [a]

Dates	Statistic[b]	Sta. 1	Sta. 5	Sta. 11	Sta. 14
Feb 6 - March 9, 1981	N	27	12	0	30
	$\bar{x}$	21.4	22.6	-	26.3
	S_x	1.4	0.8	-	1.0
March 9 - April 6, 1981	N	27	9	0	29
	$\bar{x}$	21.2	21.0	-	24.5
	S_x	1.4	1.7	-	1.3
April 6 - May 7, 1981	N	24	8	7	20
	$\bar{x}$	20.9	22.4	24.4	24.6
	S_x	1.7	0.7	1.1	1.3

a data represent readings taken at 12:00 Noon EST

b N, number of days recorded indicates extent of missing data
$\bar{x}$ = mean, S_x = standard deviation

Table 5

Temperature and precipitation in New Jersey

Average deviation from normal   Spring, 1981[a]

	Temp. (° F)	Precipitation (")
March	-1.5	+2.4
April	+2.0	+0.5
May	0.0	+0.8

[a] data calculated from N.O.A.A.

Table 6

Overall departure from normal of temperature and precipitation, New Jersey, 1980. [a]

Average temperature, departure from normal (° F):	Northern:	-1.0
	Southern:	-0.3
	Coastal:	-0.9
Total precipitation, departure from normal (inches):	Northern:	-6.13
	Southern:	-4.89
	Coastal:	-4.93

[a] data calculated from N.O.A.A.

Table 7

Numbers of Living Shipworms in Cumulative Panels Submerged May 3, 1980

	Date Removed: March 9, 1981				April 6, 1981				May 7, 1981		
Station	B.g.	T.n.	T.b.	Total	B.g.	T.n.	T.b.	Total	B.g.	T.n.	Total
1	0	1	0	1	1	1	0	2	1	1	2
3	0	0	0	0	0	0	0	0	0	0	0
4	1	0	0	1	6	0	0	6	1	0	1
5	0	0	0	0	1	1	0	2	3	0	3
8	12	1	0	13	8	0	0	8	10	0	10
10	1	1	0	2	0	0	0	0	1	0	1
11	3	1	1	5	4	1	0	5	0	0	0
12	1	0	5	6	1	1	4	6	2	0	2
14	1	1	0	2	0	0	0	0	2	2	4
	19	5	6	30	21	4	4	29	20	3	23
4 Rep	2	1	0	3	5	0	0	5	1	0	1
8 Rep	7	0	1	8	5	0	9	14	8	3	11
11 Rep	1	0	0	1	5	0	0	5	2	0	2

Rep = replicate panel
B.g. = *Bankia gouldi*
T.n. = *Teredo navalis*
T.b. = *Teredo bartschi*

of Teredo bartschi were found. The absolute number of B. gouldi and T. navalis was the same for each month. The two replicate panels at stations 4, 8, and 11 were similar, except that one panel had 9 T. bartschi and the other had none, reflecting the patchy settlement of T. bartschi. The patchy settlement is due to the brooded larval development of T. bartschi, contrasted with the planktonic development of the other species.

All of the specimens of Teredo bartschi were found either in Oyster Creek, primarily at station 12, or at the Bayside Beach Club (station 8). Each time T. bartschi has undergone a bottleneck, a residual population has existed at station 12. A drainage pipe does enter Oyster Creek just above station 12; it may be a source of warm water during winter outages of the generating station. Inspection of Oyster Creek by SCUBA in May revealed little untreated wood in the vicinity of station 12 that harbors living shipworms. Most of the old wood is crumbling and contains only empty tubes.

The greatest number of living shipworms in cumulative panels occurred at station 8, followed by stations 12, 11, and 4. The total number of live shipworms can only be characterized as few, even in Oyster Creek and at the Bayside Beach Club.

Table 8 gives a more realistic view of shipworm destruction in the 1980-1981 season. Now it can be seen that the cumulative panels at station 12 in Oyster Creek were heavily damaged, but that most individuals were dead by March, 1981. Likewise, the attack at Bayside Beach Club (#8) was heavy. Teredo bartschi was the dominant species in both areas where the heavy attack occurred. Control areas (stations 1 and 3) had light attack, as did Forked River.

Table 9 pinpoints the localities where mortality was heavy sometime between fall, 1980 and spring, 1981. Overall, the greatest mortality occurred at station 12 in Oyster Creek.

The size ranges of the specimens are in Table 10. Bankia gouldi was largest at station 11 in Oyster Creek. Teredo navalis was largest at station 10 in Oyster Creek. T. bartschi reached its largest size, 110 mm, at station 12 in Oyster Creek. The sizes did not increase from March to May, except for Teredo bartschi. Rather than being due to growth, the lack of T. bartschi below 15 mm in length in May perhaps can be blamed on mortality of small specimens. No small specimens were found of either Bankia gouldi or T. navalis during the spring. Thus no settlement of larvae took place on the cumulative panels.

The yearly panels are described in Tables 11-14. The results are similar to those of the cumulative panels, because the cumulative panels were deployed for almost a full year and were susceptible to shipworm attack during the same settlement period, June-November, 1980, as the yearly panels. The total number of living shipworms in all panels per month

Table 8

Numbers of Living Shipworms Plus Empty Tubes, Cumulative Panels

Date Removed:	March 9, 1981					April 6, 1981				May 7, 1981				
Station	B.g.	T.n.	T.b.	T.sp.	Total	B.g.	T.n.	T.b.	Total	B.g.	T.n.	T.b.	Tere-dinid	Total
1	0	1	0	0	1	1	1	0	2	2	1	0	0	3
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1	2	0	0	3	7	3	0	10	1	2	0	1	4
5	0	1	0	1	2	1	2	0	3	3	0	0	0	3
8	13	1	0	0	14	8	0	0	8	10	0	0	0	10
10	1	1	0	0	2	0	0	0	0	1	0	0	1	2
11	3	2	1	0	6	4	1	0	5	0	0	0	0	0
12	1	0	73	0	74	1	1	51	53	2	0	4	0	6
14	1	2	0	0	3	0	1	0	1	2	3	0	0	5
Totals	20	10	74	1	105	22	9	51	82	21	6	4	2	33
4 Rep	2	4	0	0	6	5	1	0	6	1	2	0	0	3
8 Rep	8	0	14	0	22	5	3	~100	~108	9	9	4	13	35
11 Rep	1	0	0	0	1	5	0	0	5	3	0	0	0	3

Table 9

Percentage of Specimens that were Alive when Collected, Cumulative Panels

Month Collected:	March 9, 1981			April 6, 1981			May 7, 1981		
Station	No. Living Specimens	Total No. Tubes Observed	% Alive	No. Living Specimens	Total No. Tubes Observed	% Alive	No. Living Specimens	Total No. Tubes Observed	% Alive
1	1	1	100	2	2	100	2	3	67
3	0	0	-	0	0	-	0	0	-
4	1	3	33	6	10	60	1	3	33
5	0	2	0	2	3	67	3	3	100
8	13	14	93	8	8	100	10	10	100
10	2	2	100	0	0	-	1	2	50
11	5	6	83	5	5	100	0	0	-
12	6	74	8	6	82	7	2	≥6	≤33
14	2	3	66	0	1	0	4	5	80
Total	30	105	29	29	82	36	23	≥33	≤70
4 Rep	3	6	50	5	6	83	1	3	33
8 Rep	8	22	36	14	108	13	11	35	31
11 Rep	1	1	100	5	5	100	2	3	67

Table 10

Length Ranges of Shipworms, in mm, Cumulative Panels

Date Removed:	March 9, 1981			April 6, 1981			May 7, 1981		
Station	B.g.	T.n.	T.b.	B.g.	T.n.	T.b.	B.g.	T.n.	T.b.
1		100		160	210		27-40	170	
3									
4	200	165-265		130-302	89-219*		205	275-290*	
5		80		230	165-180		146-181		
8	117-210	70		170-260			96-191		
10	250	360*					183		
11	245-270	170-315	1.5	137-336*	172				
12	315		1-110*	205	195	1-85*	155-240		16-75
14	158	175-200			150		140-195	160-155	
4 Rep	150-215	130-250		137-220	155		210	200-220	
8 Rep	90-275		1-60	135-165	135-180	5-75	120-165	150	18-90*
11 Rep	335*			210-285			270-310*		

Table 11

Numbers of Living Shipworms in Yearly Panels

Date Removed:	March 9, 1981				April 6, 1981				May 7, 1981			
Station	B.g.	T.n.	T.b.	Total	B.g.	T.n.	T.b.	Total	B.g.	T.n.	T.sp.	Total
1	0	1	0	1	3	0	0	3	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	6	0	0	6	1	0	0	1
5	1	1	0	2	1	1	0	2	0	2	0	2
8	3	0	4	7	2	0	0	2	5	4	3	12
10	2	0	0	2	0	3	0	3	0	1	0	1
11	1	0	0	1	5	4	1	10	3	0	0	3
12	1	0	7	8	0	0	10	10	0	0	0	0
14	0	6	0	6	0	6	0	6	1	7	0	8
Totals	8	8	11	27	17	14	11	42	10	14	3	27
1 Rep	1	0	0	1	0	0	0	0	1	0	0	1
3 Rep	1	0	0	1	0	0	0	0	–	–	–	a
11 Rep	1	0	0	1	2	0	0	2	1	0	0	1
14 Rep	2	0	0	2	1	5	0	6	0	4	0	4

a = Series discontinued
Rep = Replicate panel

Table 12

Numbers of Living Shipworms Plus Empty Tubes, Yearly Panels

Date Removed:	March 9, 1981					April 6, 1981						May 7, 1981				
Station	*B.g.*	*T.n.*	*T.b.*	Tere-dinid	Total	*B.g.*	*T.n.*	*T.b.*	*T.sp.*	Tere-dinid	Total	*B.g.*	*T.n.*	*T.b.*	*T.sp.*	Total
1	0	1	0	0	1	3	0	0	0	0	3	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	3	7	0	0	10	6	5	0	1	0	12	1	3	0	0	4
5	1	1	0	0	2	1	2	0	0	1	4	0	2	0	0	2
8	3	0	4	0	7	2	2	0	0	0	4	5	4	0	3	12
10	2	0	0	0	2	0	3	0	0	0	3	0	1	0	0	1
11	1	3	0	0	4	5	4	1	0	0	10	3	0	0	0	3
12	1	0	59	0	60	0	0	>68	0	0	>68	0	0	20	0	20
14	0	11	0	1	12	0	13	0	0	0	13	1	12	0	0	13
	11	23	63	1	98	17	29	>69	1	1	>117	10	22	20	3	55
1 Rep	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1
3 Rep	1	0	0	0	1	0	0	0	0	0	0	-	-	-	-	a
11 Rep	1	0	0	0	1	2	0	0	0	0	2	1	0	0	0	1
14 Rep	2	1	0	0	3	1	6	0	0	0	7	0	7	0	0	7

a series discontinued

Table 13

Percentage of Specimens that were Alive when Collected, Yearly Panels

Month Collected:	March 9, 1981			April 6, 1981			May 7, 1981		
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	1	1	100	3	3	100	0	0	-
3	0	0	-	0	0	-	0	0	-
4	0	10	0	6	12	50	1	4	25
5	2	2	100	2	4	50	2	2	100
8	7	7	100	2	4	50	12	12	100
10	2	2	100	3	3	100	1	1	100
11	1	4	25	10	10	100	3	3	100
12	8	60	13	10	>68	< 15	0	20	0
14	6	12	50	6	13	46	8	13	62
Total	27	98	28	42	> 117	< 36	27	55	50
1 Rep	1	1	100	0	0	-	1	1	100
3 Rep	1	1	100	0	0	-	-	-	a
11 Rep	1	1	100	2	2	100	1	1	100
14 Rep	2	3	67	6	7	86	4	7	57

a series discontinued

Table 14

Length Ranges of Shipworms, in mm, Yearly Panels

Date Removed:	March 9, 1981			April 6, 1981			May 7, 1981		
Station	B.g.	T.n.	T.b.	B.g	T.n.	T.b.	B.g.	T.n.	T.b.
1		300		110-210					
3									
4	180-262	175-292		120-235	190-230		280	35-210	
5	125	125		95	165-230			240-244*	
8	175-235		3-10	130-260	190-280		80-330	135	2-13
10	255-353*				14-280			32	
11	310	275-340*		155-260	40-300*	6	132-350*		
12	177		[illegible]-65*			1-75*			1-70*
14		85-155			90-270		125	2-190	
1 Rep	95						155		
3 Rep	147								
11 Rep	185			290-330*			320		
14 Rep	160-167	115		165	12-140			8-141	

was not more than 30, and station 8 at Bayside Beach Club contained the most living specimens. The Stout's Creek control station had one shipworm total in 5 yearly panels recovered. Teredo bartschi was found only at stations 8, 11, and 12.

Counting the empty tubes and dead shipworms (Table 12), it is clear that a heavy outbreak of Teredo bartschi had occurred at station 12 in Oyster Creek, but that over 80% were dead by March (Table 13). There were no live specimens in May; the cumulative panels yielded the same result. The number of dead T. bartschi is probably underestimated in panels from station 12, because there were numerous very small specimens of less than 5 mm. The shipworm attack was light at all other stations and was very light at stations 1, 3, and 10. Comparing Table 12 with Table 8 for the cumulative panels, only one difference is notable: there were proportionately more Bankia gouldi than Teredo navalis in the cumulative panels, and the reverse was true in the yearly panels. This difference is of considerable magnitude; the ratio is 2:1 in both cases. One hypothesis to explain the difference is that T. navalis might prefer to settle on wood that has soaked for a longer time. However, this argument cannot explain the May 7, 1981 data, since both the cumulative and yearly panels were submerged at the same time and are therefore replicates. The difference is due to a large number of T. navalis in the yearly panel at station 14 and a large number of B. gouldi in the cumulative panel at station 8. The best explanation is patchy settlement of the two species at those two stations. The cumulative and yearly panels were kept on separate racks. Mortality of Bankia gouldi was very low, less than 10%. However, 50% of Teredo navalis specimens and nearly all T. bartschi died before they were collected.

The largest specimens of all three species were found in Oyster Creek (Table 14). These results are similar to those obtained from the cumulative panels (Table 10). The lengths of specimens in these panels represent their abilities to grow nearly unlimited by crowding, since most panels contained fewer than 10 individuals.

Table 15 presents the amount of wood lost to woodborers. Except for a few Limnoria sp. at station 14, all of the damage was due to shipworms. In 8 years of careful searching, no attack of Limnoria has been found in Oyster Creek, although a few of the isopods were once found crawling on the exterior of the wooden panels at station 10 near the mouth of Oyster Creek.

Despite the greater number of specimens at station 12, the greatest damage was at station 8 where all three species were present in abundance, followed by stations 4 and 11. Statistical analyses of the amount of damage per station will be presented in our final report.

Table 15

Percentage Weight Loss by Cumulative and Yearly Panels

A. Cumulative Panels Submerged May 3, 1980 and removed:

Station	March 9, 1981	April 6, 1981	May 7, 1981
1	5.5	10.9	8.4
3	0.0	0.0	0.0
4	15.2	30.6 [a]	9.3
5	8.6	15.0	7.9
8	43.0 [a]	18.1	38.1 [a]
10	13.0	0.0	7.4
11	20.2	27.9	0.0
12	15.2	14.3	14.4
14	14.0	10.2	13.8
4 Rep	15.9	30.8 [a]	7.7
8 Rep	34.9	32.4 [a]	37.3 [a]
11 Rep	12.4	b	18.6

B. Yearly Panels

Station		April 6, 1981	May 7, 1981
1		14.2	0.0
3		0.0	0.0
4		37.3 [a]	15.6
5		12.0	6.1
8		16.3	23.7 [a]
10		14.4	3.2
11		35.9	20.1
12		9.8	9.0
14		22.4	11.0
1 Rep		0.0	8.4
11 Rep		17.6	13.0
14 Rep		10.5	10.6

[a] greatest damage

b missing data

Few specimens contained larvae in the gills during March-May, 1981. The living specimen of Teredo bartschi collected in the March cumulative panel at station 8 contained living larvae. In April and May, empty tubes of T. bartschi in cumulative panels at station 8 contained dead larvae. A March cumulative panel at station 14 contained one specimen of T. navalis with very early larvae in the gills. In May, one of the yearly panels at station 14 contained one of five specimens of T. navalis brooding larvae. There was no sign of earlier brooding in Oyster Creek.

The outage of the Oyster Creek station during the last half of the period of this report is important for the interpretation of the shipworm data. Occurring in late spring, the outage did not prevent the waters in Oyster Creek from reaching the minimum temperature for gonad development. However, the lack of a heated effluent from mid-April to the end of May did probably prevent specimens of Teredo bartschi from releasing pediveligers and generally retarded development of shipworm larvae in Oyster Creek.

Patterns of Shipworm Settlement

Wooden stakes extending from below the mudline to above the water line were deployed in May, 1980. Those deployed at stations 4, 8, 10, 11, and 14 were retrieved on Sept. 5, 1980, after 4 months of exposure. At station 4, there was only one shipworm, a specimen of Bankia gouldi. The stake at station 8 contained the heaviest infestation, 10 B. gouldi, 6 Teredo navalis, 8 T. bartschi, and 7 unidentified teredinids. At station 10, there were 2 B. gouldi; at station 11, 1 B. gouldi, 1 T. navalis and 1 T. bartschi. The stake at station 14 contained 2 B. gouldi and 2 T. navalis. Unfortunately the stakes at station 1 were lost, probably removed by the marina owners.

Table 16 shows the lengths, position, and direction of growth of the shipworms in the stakes. There is a distinct preference for downward growth once the shipworm enters the wood, regardless of the species. The position of the borehole of Teredo bartschi was most often on the protected side away from the currents; the same was true for the small, unidentified specimens. Both settled close to the mudline, usually within 8 cm of the mud. Bankia gouldi and Teredo navalis settled in the current about as often as on the leeside of the stakes. They also were found scattered along the length of the stakes rather than concentrated at the mudline. Thus while Teredo bartschi did cluster near the mudline, the other species did not, under these conditions of sparse settlement.

Shipworm Physiological Ecology

The response of Teredo bartschi to low temperature was more extreme than that expected on the basis of the field data. When the water temperature reached 17° C (March 13, 1981), the siphons of all 22 individuals were withdrawn. All siphons remained withdrawn until March 26, when the temperature reached 15° C, and 6 siphon pairs were visible. The temperature

Table 16

Lengths and Positions of Teredinidae in Stakes Submerged in Barnegat Bay

Station	Position of Entry Hole	Distance of Entry Hole above Mud Line	Direction of Growth	Length (cm)	Species
4	leeside	19 cm	down	19.0	B. gouldi
10	in currents	40	down	32.0	B. gouldi
	leeside	23	down	1.3	B. gouldi
11	in currents	45	up	34.5	B. gouldi
	in currents	48	down	0.4	T. bartschi
	leeside	10	down	6.0	T. navalis
14	leeside	65	up	17.5	B. gouldi
	in currents	58	down	16.5	B. gouldi
	leeside	20	up	7.2	T. navalis
	leeside	14	down	5.0	T. navalis
8	in currents	88	down	13.5	B. gouldi
	in currents	76	down	24.0	B. gouldi
	leeside	8	up	15.5	B. gouldi
	leeside	31	down	19.5	B. gouldi
	leeside	34	down	24.0	B. gouldi
	in currents	28	down	24.5	B. gouldi
	in currents	30	down	28.0	B. gouldi
	in currents	11	down, then up	27.0	B. gouldi
	in currents	38	down	32.0	B. gouldi
	leeside	55	down	24.0	B. gouldi
	in currents	10	down	8.0	T. navalis
	leeside	15	down	12.0	T. navalis
	leeside	20	down	12.0	T. navalis
	in currents	28	up	11.0	T. navalis
	leeside	35	down	11.0	T. navalis
	in currents	7	down	14.5	T. navalis
	leeside	4	down	0.8	T. bartschi
	leeside	4	up	0.5	T. bartschi
	leeside	4	up	0.3	T. bartschi
	leeside	4	down	0.6	T. bartschi
	leeside	4	down	0.2	T. bartschi
	leeside	4	down	0.2	T. bartschi
	in currents	7	up	0.5	T. bartschi
	in currents	6	down	0.7	T. bartschi
	leeside	3	down	0.1	T. sp.
	leeside	4	down	.015	T. sp.
	leeside	3	down	.015	T. sp.
	leeside	4	--	(hole)	T. sp.
	in currents	4	down	~0.1	T. sp.
	in currents	5	down	~0.1	T. sp.
	leeside	35	--	(hole)	T. sp.

had dipped to 13° C when observations were made again on March 30, and all of the siphons were withdrawn. Observations on March 31 revealed 11 siphon pairs and a water temperature of 15° C. On April 2, 12 siphon pairs were observed and the water temperature was 20° C. Table 17 presents a record of the water temperature during the course of the experiment. Of the initial 22 specimens, only 12 survived the experiment.

From these data, the lowest temperature at which normal filtering activities can take place at a salinity of 22°/₀₀ is about 14-15° C. Two weeks of winter temperature of 2.5 - 13° C appear to have caused mortality to about 50% of the Teredo bartschi culture, although other causes of mortality cannot be ruled out. Control panels kept in the laboratory showed about 5-10% mortality over the same time period.

A major experiment was conducted from February 18 to May 20 to determine the relationship of temperature and salinity to survival and growth of Teredo bartschi. The amounts of frass produced per shipworm per week under each combination of temperature and salinity are recorded in Table 18, while the lengths of specimens, mortality, and reproduction are reported in Table 19.

The earliest maturation and reproduction took place at 20° C and 22 °/₀₀ rather than at the highest temperature. Reproduction was delayed at 6 °/₀₀, and no reproduction at all occurred at 10° C. Growth was very poor at 10° C. The greatest growth occurred at 30° C and the two higher salinities, but it was affected strongly by the number of specimens per piece of wood even though crowding did not appear to inhibit growth directly. Growth at 20° C and 22 °/₀₀ was comparable to that at 30° C and 14 °/₀₀. Mortality was much less at 20° C than at either the higher or the lower temperature, regardless of salinity. However, lower salinity did appear to cause an increase in mortality at both 30° and 10° C.

It can be concluded that, of the conditions tested, the optimal for Teredo bartschi is 20° C and 22 °/₀₀. Unfortunately, these conditions are met in Oyster Creek during a significant proportion of the year.

Examination of the amount of frass and faecal material produced per unit time per individual shipworm (Table 18) shows an increase in frass production with age of the shipworms at 30° and both 14 and 22 °/₀₀. However, there was no such trend at 10° C nor at any temperature at 6 °/₀₀. There was a correlation of frass production with age in one of the two experiments run at 20° C, 22 °/₀₀. The trend also existed at 20° C, 14 °/₀₀, but was not significant.

Even a cursory glance at the pairs of data points for each temperature-salinity combination reveals that the number of individuals per panel is crucial to the rate of frass production. The data points cannot be

Table 17

Range of Water Temperatures During Experiment Testing the Low Temperature Response of *Teredo bartschi*

	Max. Temp. (° C)	Min. Temp. (° C)
March 14	12.2	9.6
15	13.3	7.4
16	11.6	9.0
17	9.1	5.0
18	6.1	5.7
19	11.7	3.6
20	10.7	4.4
21	12.9	5.3
22	13.1	5.1
23	10.6	7.3
24	15.0	4.8
25	14.4	6.8
26	15.1	5.7
27	15.7	9.4
28	17.1	8.9
29	19.0	9.7
30	13.7	12.7
31	20.4	13.3
April 1	16.4	13.8
2	19.4	13.2

Table 18

Frass Production by Specimens of <u>Teredo bartschi</u> under Various Temperatures and Salinities

Experimental Conditions		Dry Weight of Frass per Shipworm per Day after X Days (gr. x 10^{-4})													Average/ 90 days (x10^{-4}g.)
		7	13	20	26	35	41	49	55	63	68	76	82	90 days	
30°	22 °/oo	4.16	5.21	6.25	7.99	9.72	8.68	6.25	9.38	9.64	12.92	12.76	17.71	16.37	9.58
		2.29	2.44	3.62	3.78	4.00	4.00	3.85	4.43	3.17	5.60	3.67	5.11	5.17	3.93
	14 °/oo	1.38	4.84	6.45	6.99	7.89	6.99	8.06	10.22	8.06	13.55	12.10	13.98	13.71	8.75
		2.48	2.00	2.67	3.33	4.00	3.11	0.68	3.56	3.17	5.60	3.67	4.22	4.00	3.21
	6 °/oo	4.31	2.83	3.50	3.46	3.56	2.83	4.25	3.46	4.25	6.04	4.95	4.40	3.30	3.92
		0.94	0.55	1.64	1.37	1.09	1.09	1.02	0.27	0.41	0.66	0.41	0.55	0.21	0.78
20°	22 °/oo	3.57	5.56	5.95	6.94	10.19	9.72	11.46	13.89	10.42	13.33	13.54	22.22	25.96	11.67
		0.70	0.91	1.39	1.83	2.37	1.63	1.52	1.93	1.52	2.07	2.21	4.57	3.58	1.78
	14 °/oo	0.97	1.14	1.30	1.89	3.79	2.27	2.27	2.27	2.27	3.18	3.41	3.79	4.26	2.58
		0.41	0.79	1.22	1.43	2.12	1.43	1.91	2.06	1.67	2.48	2.26	1.75	2.38	1.70
	6 °/oo	1.15	0.54	0.69	1.08	1.08	1.08	1.22	1.08	0.81	1.94	2.02	2.15	2.07	1.29
		1.35	0.94	1.62	1.57	1.89	1.57	2.12	2.20	1.89	2.64	2.36	2.20	3.30	1.99
10°	22 °/oo	-[a]	0.00[a]	-	0.13	-	0.22	-	-	-	-	-	-	0.14	0.13
		-	0.45	-	0.45	-	0.39	-	-	-	-	-	-	0.12	0.26
	14 °/oo	-	0.00	-	0.07	-	0.01	-	-	-	-	-	-	0.04	0.03
		-	0.38	-	0.31	-	0.03	-	-	-	-	-	-	0.00	0.11
	6 °/oo	-	0.11	-	0.02	-	0.01	-	-	-	-	-	-	0.00	0.02
		-	0.09	-	0.15	-	0.02	-	-	-	-	-	-	0.00	0.04

[a] too little frass to measure.

Table 19

Survivorship, Reproduction, and Lengths of *Teredo bartschi* Temperature-Salinity Experiment

Experimental Conditions		Mean Length	± S.D.	N	Mortality	Reproduction [a]
30°	22 °/₀₀	37.45	15.36	48	7 (15%)	Apr. 27
		24.20	10.24	75	6 (8%)	Apr. 27 [b]
	14 °/₀₀	37.23	10.10	31	13 (42%)	Apr. 27
		23.96	8.61	75	19 (25%)	Apr. 27
	6 °/₀₀	26.00	9.94	53	8 (15%)	May 11
		9.85	4.41	61[c]	42 (69%)	-
20°	22 °/₀₀	37.25	15.18	12	1 (8%)	Apr. 8
		14.76	5.63	164	0	Apr. 14
	14 °/₀₀	11.09	5.96	44	0	May 11
		14.98	5.64	105	0	May 5
	6 °/₀₀	13.55	7.15	31	0	-
		17.07	8.18	53	0	May 11 [d]
10°	22 °/₀₀	4.90	3.06	60	15[e] (20%)	-
		4.24	2.14	17	3 (18%)	-
	14 °/₀₀	4.84	2.74	57	44[f] (53%)	-
		2.67	0.58	20	17 (85%)	-
	6 °/₀₀	3.22	2.37	50	16 (32%)	-
		4.16	3.34	25	10 (40%)	-

a Date when pediveligers were first observed.
b New set of pediveligers established in the wood.
c 73 specimens 1 mm long; not included in N. Died early.
d New set of 1 pediveliger.
e Including 14 holes that were not included in N.
f Including 26 holes that were not included in N.

considered replicates. The greater the number of shipworms per panel, the less is the frass produced per animal. Only at 10° C, at which temperature little growth occurred, did this relationship break down. The highest rate of frass production occurred in one of the 20° C/22 °/₀₀ experimental panels. This was also the panel containing the lowest number of individuals (only 12), which factor is probably more important than the environmental conditions in determining frass production.

In general, Table 18 shows that the higher temperatures and salinities yield higher production of frass and faecal material. For example, at any given temperature, higher salinity yields higher frass production. Frass production is directly related to the amount of wood-boring, while faecal production is related to the amounts of wood-boring and filter-feeding.

CONCLUSION

The data in this report provide further evidence that the area of Oyster Creek is enhanced as a habitat for shipworms, particularly *Teredo bartschi*. It is clear that prolonged shutdowns of the Oyster Creek Nuclear Generating Station retard the reproduction and growth of the *T. bartschi* population. It appears that the three species of teredinids now occupying Oyster Creek and the mouth of Forked River have different physiological tolerances and patterns of settlement that allow all three to coexist, although one may dominate a particular piece of wood. The optimal conditions for *T. bartschi*, of those tested, appear to be about 20° C and about 22-24 °/₀₀ salinity; 30° C allows faster growth but promotes higher mortality.

Our field data continue to be in agreement with those of the Clapp Laboratories/Battelle Labs.

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* Available for purchase from the NRC/GPO Sales Program, U. S. Nuclear Regulatory Commission, Washington, D.C. 20555, and/or 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 74° 8' W
3	Stout's Creek	End of Raleigh Drive Gustav Walters' residence Estuarine control	39° 50.7' N 74° 9' 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 Streets 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

DISTRIBUTION LIST

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Part A

Mr. Richard Baumgardt
Dick's Landing
Holly Park
Bayville, New Jersey 08721

Mr. William Campbell
P.O. Box 668
108 Long John Silver Way
Waretown, New Jersey 08758

Mr. Stan Cottrell
North Harbor Road
Waretown, New Jersey 08758

Mr. Wilson T. Crisman
901 Hudson Street
Hoboken, New Jersey 07030

Mr. and Mrs. Thomas Gilmore
20 Dock Ave., Box 205 E, R.R.I.
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

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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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. Relative destructiveness and competition among the species are being analyzed. The native species *Teredo navalis* and *Bankia gouldi* coexist with the introduced *T. bartschi* in Oyster Creek and at the mouth of Forked River. The population *Teredo bartschi* is reduced when the power plant does not operate for prolonged periods. It survives well at temperatures above 16° C (but not above 30° C) and at salinities of 22 ‰ in the laboratory. It prefers to settle at the mudline, while the other species of teredinids did not show this preference.

17. KEY WORDS AND DOCUMENT ANALYSIS

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Oyster Creek
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Bankia gould

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