NUREG/CR-2727
Vol. 1

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Progress Report
September - November 1981

Prepared by K. E. Hoagland, L. Crocket

Wetlands Institute
Lehigh University

Prepared for
U.S. Nuclear Regulatory Commission

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NUREG/CR-2727
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Manuscript Completed: May 1982
Date Published: June 1982

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Prepared for
Division of Health, Siting and Waste Management
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
NRC FIN B5744

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

Six 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-August, 1981,	44 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. In the fall of 1981, *Teredo bartschi* remained in Oyster Creek despite continuous prolonged outages of the Oyster Creek Nuclear Generating Station. It did not spread to Forked River or Waretown as it had done in other years when the effluent was present. The peak in larval production and settlement of *T. bartschi* occurred between September and October. Settlement of shipworms occurred on no monthly panels except those in Oyster Creek during the period of this report. Laboratory experiments revealed that *T. bartschi* becomes inactive at 5° C (24‰) and *T. navalis* shows signs of osmotic stress below 10‰ at 18° C. The shipworms in Barnegat Bay do not show a preference for settling at the mudline when the substrate is not limited.

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.

1. The generating station was not operating during a significant portion of the period of this report, and had not been operating during the 2 weeks preceding this period.

2. When present, the thermal effluent in Oyster Creek caused a ΔT of about +4° C.

3. The salinity in Oyster Creek and Forked River was similar to that of nearby portions of Barnegat Bay.

4. *Teredo bartschi* was common at stations 11 and 12 in Oyster Creek. One individual was found at station 10 in Oyster Creek.

5. *Teredo navalis* and *T. bartschi* suffered more mortality than *Bankia gouldi*.

6. Larvae of *Teredo bartschi* settled late September and early October, 1981, in Oyster Creek only. Veligers of *T. navalis* and *T. bartschi* were found in the water in the first week of October. More specimens settled on the October than the September panels. No shipworms settled at stations outside Oyster Creek during Sept.-Nov., 1981.

7. Ctenophores are present at the same time and place as shipworm larvae in in Oyster Creek.

8. Larvae of *Teredo bartschi* are inactive at 5° C but are not killed outright. They may be effectively dead, as they seem not to recover when returned to 17° C.

9. Adults of *T. navalis* are behaviorally affected by salinities of 7-10 °/oo at ~18° C.

10. Analysis of position of entry and direction of boring has shown that *Teredo navalis*, *T. bartschi*, and *Bankia gouldi* do not settle preferentially at the mudline.

11. *Teredo bartschi* can survive in Oyster Creek even in the absence of a thermal plume. This introduced species numerically dominates the 2 native species. There was no outbreak of shipworms outside of Oyster Creek despite low rainfall over the past 2 years.

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ACKNOWLEDGMENTS

We thank the many residents of Oyster Creek who have cooperated in our field work. James Selman, Sheila Turner, and Dominic Dragotta provided technical 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.

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

September 1-November 30, 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; 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 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, 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, 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.

In May, 1980, three 5 x 10 cm wooden stakes were installed each at stations 1, 4, 8, 10, 11, and 14. Those at stations 1 and 8 were lost. One from each remaining station was removed in September, 1980, and reported upon in an earlier report. One from each station was removed in September, 1981 and is reported upon here. The stakes were X-rayed and the position of entry, direction of growth, and length of each specimen recorded. The species were identified from the images of the pallets in the X-rays.

Plankton tows were taken near the test racks at stations 8, 10, 11, and 12 on October 6, 1981. The concentrated plankton samples were examined while still alive for bivalve larvae and other organisms.

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 $HC\ell$. 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 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. Attempts are underway to establish breeding colonies of *Teredo navalis*.

Shipworm Physiological Ecology

The behavior of the pediveliger larvae of *Teredo bartschi* was recorded at low temperature (5° C) and at a control temperature of 17-20° C. Twelve individuals were placed in each of 2 shallow dishes containing $24^{\circ}/_{\circ\circ}$ seawater and observed over a 5-day period. A piece of white pine wood was available in each dish. The behaviors recorded were swimming, burrowing, crawling, closed on the bottom, and gaping on the bottom.

Adults of *Teredo navalis* were obtained in pure culture in wood from Station 18. For 3 panels, the salinity was gradually reduced, $3^{\circ}/_{\circ\circ}$ per day, from $22^{\circ}/_{\circ\circ}$ to $7^{\circ}/_{\circ\circ}$ while the temperature was maintained at 17-18° C. Another 3 panels (controls) remained at $22^{\circ}/_{\circ\circ}$. The number of pairs of siphons per panel was counted daily as a measure of the activity of the individuals. The number of individuals per panel varied from 30 to 50. Observations continued for 24 days, after which the salinity was returned to $22^{\circ}/_{\circ\circ}$ and observations were made for 2 additional days. The water was changed every morning in both the control and experimental aquaria. Observations were made in the late afternoon.

RESULTS AND DISCUSSION

Physical Factors

The temperatures recorded at the time of sampling for shipworms are reported in Table 1. There was no heated effluent present in Oyster Creek on September 3rd or October 6th. On November 4th, the Oyster Creek Nuclear Generating Station had just resumed operation after a brief shutdown, and there was evidence of a thermal effluent in Oyster Creek. The ΔT was about 4° C. The general range of temperatures in Barnegat Bay in fall, 1981, was much cooler in the month of September, yet warmer in November, compared with 1980. The temperature profiles in 1979 and 1981 were more similar, except September was slightly cooler in 1981.

The continuous temperature recorder data (Table 2) showed very similar temperatures for the 4 stations in September. There was some thermal discharge in October, as seen by the mean daily maximum temperature of 14.5° in Oyster Creek, 13.2° in Forked River, and 12.8° at the two control stations north and south of the power plant. The value at Forked River indicates recirculation of the effluent. In November, the temperature recorder and panels at station 14 were totally destroyed by a bulkheading crew. A comparison of stations 1 and 11 does reveal an average ΔT of about 4° C in Oyster Creek.

We have discontinued use of constant recording salinometers at stations 1, 4, 11, and 14 due to continual repair problems that could not be resolved by Beckman Corporation. Salinity profiles taken at the regular sampling times are reported in Table 3. Salinity increased from September to November at all stations. The change in salinity was greatest at Stout's Creek (station 3). Oyster Creek had salinity readings within 1-2‰ of inner shores of Barnegat Bay (e.g., stations 8 and 14).

Table 4 provides the data on the operation levels of the power plant. Outages were extensive, including all of September and half of October (combined with the last half of August). Water flow was maintained at a level of about 50% during September when there was no heated effluent. From the data in Table 4, it can be seen that slight augmentation of shipworm growth and breeding could be expected in October and November.

Table 5 presents general weather data for New Jersey. The low precipitation in November could explain the higher salinity found then, especially at the creek station 3. However, the timing is not perfect, since the salinity values were recorded in the first week of November. No overall trends of drought have been observed in the period of this report, although precipitation is below average.

Table 1

Temperature Profiles in ^{o}C, September-November 1981

Station	Sept. 3	Oct. 6	Nov. 4	Differential among months
1	22.5[b]	16.5	14.0	8.5
3	23.5	19.0[a]	15.0	8.5
4	23.0	16.0[b]	14.0	9.0
5	22.5[b]	17.0	15.0	7.5
8	23.0	16.5	*	-
10	24.0[a]	16.5	17.5	-
11	23.0	17.0	17.0[a]	6.0
12	23.0	18.0	*	-
14	23.5	16.0[b]	13.0[b]	10.5
Differential among stations	1.5	3.0	4.0	

[a] highest value each month

[b] lowest value each month

* no data

Table 2

Continuous Temperature Recorder Data (^{o} C) for Sept. 3 to Dec. 3, 1981

I. Temperature at 1:00 PM (EST)

	Sept. 3-Oct. 6				Oct. 6-Nov. 4				Nov. 4-Dec. 3			
	1	5	11	14	1	5	11	14	1	5*	11	14*
Mean Daily Temp. at 1PM	19.1	19.3	19.1	18.9	12.2	12.8	13.8	12.1	7.1		12.0	
Standard deviation	2.9	2.8	2.7	3.0	0.9	1.0	2.1	1.1	2.4		2.3	
Highest value of Temp. at 1 PM	23.2	23.3	23.5	23.2	14.4	14.6	17.9	15.5	13.0		17.5	
Lowest value of Temp. at 1 PM	13.5	14.4	13.7	13.0	10.6	11.0	10.7	10.7	2.8		8.1	
Monthly Temp. Range at 1 PM	9.7	8.9	9.8	10.2	3.8	3.6	7.2	4.8	10.2		9.4	

II. Maximum Daily Temperature

	Sept. 3-Oct. 6				Oct. 6-Nov. 4				Nov. 4-Dec. 3			
	1	5	11	14	1	5	11	14	1	5*	11	14*
Mean value of Max. Daily Temp.	19.8	19.7	19.4	19.6	12.8	13.2	14.5	12.8	7.6		12.5	
Standard Deviation	2.9	2.8	2.7	3.0	0.9	1.0	2.1	1.0	2.5		2.2	
Highest value of Max. Daily Temp.	23.4	23.5	23.5	24.3	15.2	15.1	18.1	15.0	13.1		17.5	
Lowest value of Max. Daily Temp.	13.8	14.5	13.8	13.6	10.8	11.2	11.3	11.3	3.7		8.4	
Monthly Range of Max. Daily Temp.	9.6	9.0	9.7	10.7	4.4	3.9	7.8	3.7	9.4		9.1	

Table 2, continued

III. Minimum Daily Temperature

	Sept. 3-Oct. 6				Oct. 6-Nov. 4				Nov. 4-Dec. 3			
	1	5	11	14	1	5	11	14	1	5*	11	14*
Mean value of Minimum Daily Temp.	18.3	17.9	17.5	18.3	11.6	11.5	12.5	11.6	6.7		11.0	
Standard Deviation	3.1	3.1	3.1	3.0	0.8	1.1	2.2	0.8	2.3		2.2	
Highest value of Minimum Daily Temp.	23.0	22.5	22.3	22.8	13.3	13.7	16.8	13.4	11.5		15.5	
Lowest value of Min. Daily Temp.	12.8	12.4	11.6	12.5	10.6	8.8	10.2	10.4	2.8		7.0	
Monthly Range of Min. Daily Temp.	10.2	10.1	10.7	10.3	2.7	4.9	6.6	3.0	8.7		8.5	

IV. Daily Temperature Range

	Sept. 3-Oct. 6				Oct. 6-Nov. 4				Nov. 4 - Dec. 3			
	1	5	11	14	1	5	11	14	1	5*	11	14*
Mean Daily ΔT	1.4	1.8	1.7	1.5	1.2	1.7	2.0	1.1	0.9		1.5	
Standard Deviation	0.7	0.9	0.8	0.7	0.5	0.9	0.9	0.4	0.4		0.9	
Largest Daily ΔT for one month	3.2	4.6	4.2	3.3	2.1	4.7	4.1	2.2	1.7		4.0	
Smallest Daily ΔT for one month	0.4	0.4	0.4	0.5	0.2	0.5	0.8	0.3	0.1		0.4	

* Sta. 5 paper failed to record completely.

Sta. 14 recorder destroyed by workmen.

Table 3

Salinity Profiles in $^{o}/_{oo}$, September-November 1981

Station	Sept. 3	Oct. 6	Nov. 4	Differential among months
1	22	24	25[b]	3
3	16[b]	19[b]	25[b]	9
4	26[a]	27[a]	29	3
5	26[a]	27[a]	29	3
8	26[a]	27[a]	28	2
10	24	27[a]	30[a]	6
11	24	26	28	4
12	24	26	28	4
14	25	27[a]	29	3
Differential among stations	10	8	5	

[a] highest value each month

[b] lowest value each month

Table 4

Oyster Creek Nuclear Generating Station Outages,
Circulation and Dilution Flow in gal. x 10^6
for Sept.-Nov., 1981

	Total Water Flow (gal. x 10^6)	Outage Dates
Sept.	19,657	1-30
Oct.	33,820	1-19; 31
Nov.	42,270	1

Table 5

Average Temperature and Precipitation in
New Jersey, Deviation from Normal. Sept.-Nov., 1981

	Temperature (^{o} F)	Precipitation (inches)
Sept.	-1.0	0
Oct.	-4.7	+0.68
Nov.	-1.0	-2.26

Shipworm Populations

Table 6 shows that juvenile shipworms settled at only 2 stations during September and October, 1981. Both stations were in Oyster Creek. All of the identifiable juveniles were *Teredo bartschi*, and those too small to be identified beyond *Teredo* sp. were most likely also *T. bartschi*. Specimens settling in September and removed in October showed less growth than specimens settling in August and removed in September. Two of the 27 individuals at station 12 were dead when collected on October 6; all other specimens were collected alive. It is interesting that the number of settling young was greater in the October panels than in those collected in September. Release and settlement of the pediveligers of *T. bartschi* seems to occur in waves. There was no settlement on monthly panels deployed on October 6 and retrieved on November 4, 1981.

In previous years, there was much heavier attack of monthly panels removed in fall months. In September of 1978, shipworms of 3 species were found in monthly panels at stations from Holly Park to Waretown Creek, and settlement of *Teredo bartschi* in Oyster Creek included 133 specimens at the 3 stations. However, only 5 specimens settled in the following month. In September of 1979, settlement was recorded at most stations, and all 3 species were represented. Thousands of *T. bartschi* occurred on panels at the 3 stations in Oyster Creek. Only *T. bartschi* were found in October (a total of 184 specimens, all in Oyster Creek). In 1980, only 1 shipworm was retrieved from the September monthly panels, but hundreds of *T. bartschi* were found at station 12 in Oyster Creek the following month, and 35 *T. bartschi* were found at station 12 in the November monthly panel. The reduced settlement of shipworms in the fall of 1981 might be related to the frequent and prolonged outages of the Oyster Creek generating station in the period August-October, 1981 (Table 4).

The cumulative panels deployed in May and removed in the fall (Table 7) revealed *Teredo bartschi* only at stations 11 and 12 in Oyster Creek. The attack was moderate (less than 100 per panel) at station 11, but heavy (over 500 per panel) at station 12. This pattern has existed for two seasons. It suggests that larvae need not travel far before boring into wood, and that station 12 is more suitable than station 11 for proliferation of *T. bartschi*. *T. bartschi* was last found in Forked River in July, 1981. It was very abundant at all 3 Oyster Creek stations in the fall of 1978 and 1979.

The percentage of the living specimens in all Barnegat Bay stations that were *Teredo bartschi* increased from 65% in September to 82% in October and 94% in November. This was due to reproduction of *T. bartschi* at station 12. *Bankia gouldi* was slightly more abundant than *T. navalis*, due to greater abundance at station 1, Holly Park. Replicate panel pairs at stations 1, 4, 8, and 11 were similar in species composition and abundance. As in past years, there was no shipworm attack at the control creek station 3. Shipworm attack was low at all stations outside of Oyster Creek except for station 1.

Table 6

Numbers of Shipworms in Monthly Panels

	September 3, 1981				October 6, 1981			
Station	*T.bartschi*	*Teredo* sp.	Total	% Alive	*T.bartschi*	*Teredo* sp.	Total	% Alive
11	1 (3)*	1 (2)	2	100		10 (0.5-1)	10	100
12	1 (3)	3 (0.5-1)	4	100		27 (0.5-1)	27	93

* Numbers in parentheses are lengths, in mm.

Table 7

Numbers of Living Shipworms in Cumulative Panels Submerged May 7, 1981

Date Removed:	September 3					October 6				November 4			
Station	B.g.	T.n.	T.b.	T.sp.*	Total	B.g.	T.n.	T.b.	Total	B.g.	T.n.	T.b.	Total
1	10	3	0	0	13	24	3	0	27	13	6	0	19
3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	3	0	0	3	1	3	0	4	2	0	0	2
5	0	3	0	0	3	0	2	0	2	2	0	0	2
8	1	3	0	0	4	3	2	0	5	2	3	0	5
10	0	0	0	0	0	0	0	0	0	0	0	0	0
11	2	2	31	3	38	1	2	59	62	1	1	15	17
12	0	1	83	28	112	0	1	132	133	1	0	516	517
14	1	2	0	0	3	0	1	0	1	0	2	0	2
Total	14	17	114	31	176	29	14	191	234	21	12	531	564
Replicates													
1	10	2	0	0	12					7	1	0	8
4	0	4	0	0	4		#			1	3	0	4
8	1	3	0	0	4					2	2	0	4
11	0	0	7	0	7					0	0	13	13

* Based on November's data, nearly all are T. bartschi, but a few may be T. navalis.

Panels used for laboratory experiments.

Tables 8 and 9 reveal the extent of mortality over the May-November 1981 period. There tended to be high mortality in Forked River, followed by Oyster Creek. Control stations 1 and 14 were nearly free of mortality. The differential mortality by area is in part due to species composition. Teredo navalis in Forked River and T. bartschi in Oyster Creek suffered the greatest mortality.

Growth over the May-November, 1981, period is shown in Table 10. The largest specimens were not associated with any particular station. Such an association was not expected, because of the absence of the thermal effluent over much of the period. Because the density of the shipworms per panel was low, growth was rapid. Comparing Table 10 with Table 14 of our last report, a monthly size increase of the largest individuals of all 3 species was noticable through October 6. Specimens of Teredo bartschi were no larger in November than in October. The 1981 year class of all species was large enough to be sexually mature in August. Comparing the sizes of specimens removed from cumulative panels in 1981 with previous years, we find that growth was lower for Bankia gouldi in 1981 than in 1978-1980, but about the same for the other two species.

The results from the yearly panels submerged in the fall of 1980 are reported in Tables 11-14. The replicate panel pairs at station 11 show the effects of patchy settlement accumulated over an entire year (e.g., 45 specimens in one panel, only 8 in another removed in October). However, the replicate panel pairs at station 1 and at station 14 are similar (e.g., 18 Bankia gouldi in one panel, 14 B. gouldi and one T. navalis in another at station 1, November). The difference is due to the species involved: T. bartschi, with its release of pediveligers, is more prone to patchy distribution.

The pattern of settlement on the yearly panels is similar to that of the cumulative panels. Teredo bartschi was restricted to Oyster Creek and was abundant only at station 12. Bankia gouldi was moderately abundant at station 1. There was only one shipworm found at station 3. Overall, 93% of the specimens found alive in Barnegat Bay were T. bartschi. Comparing Tables 8 and 12, there was greater settlement but higher mortality in the September and October yearly panels than the cumulative panels of the same months. Some of the settlement occurred in September and October, 1980, but many of these individuals died over the winter of 1980-81. The lower number of shipworms in the November, 1981 yearly panel indicates little settlement in November, 1980. The greatest settlement of the period appears to have occurred in October, 1980. This agrees with our findings of that year (Hoagland and Crocket, 1981, report #1939).

Mortality was great in the Teredo species, but virtually absent in Bankia gouldi (Table 12). Of all the panels, mortality was greatest in that from station 12 in September (Table 13). The percent mortality figures are somewhat misleading unless one considers the total number of specimens involved.

Table 8

Numbers of Living Shipworms Plus Empty Tubes, Cumulative Panels

Date Removed:	September 3						October 6				November 4				
Station	*B.g.*	*T.n.*	*T.b.*	*T.sp.*	tere-dinid	Total	*B.g.*	*T.n.*	*T.b.*	Total	*B.g.*	*T.n.*	*T.b.*	tere-dinid	Total
1	10	3	0	0	0	13	24	3	0	27	14	6	0	2	22
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	7	0	0	0	7	1	4	0	5	2	2	0	0	4
5	0	4	0	0	0	4	0	5	0	5	2	1	0	0	3
8	1	8	0	0	1	10	3	3	0	6	2	10	0	0	12
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	2	2	31	9	0	44	1	2	72	75	1	3	34	1	39
12	0	1	84	52	0	137	0	1	133	134	1	1	541	0	543
14	1	2	0	0	0	3	0	1	0	1	0	2	0	0	2
Total	14	27	115	61	1	218	29	19	205	253	22	25	575	3	625
Replicates															
1	10	2	0	0	1	13					7	2	0	0	9
4	0	5	0	0	0	5					1	4	0	0	5
8	1	5	0	0	0	6					2	2	0	0	4
11	0	0	8	0	0	8					0	0	14	0	14

Table 9

Percentage of Specimens that were Alive when Collected, Cumulative Panels

Month Collected:	September 3			October 6			November 4		
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	13	13	100	27	27	100	19	22	86
3	0	0	-	0	0	-	0	0	-
4	3	7	43	4	5	80	2	4	50
5	3	4	75	2	5	40	2	3	67
8	4	10	40	5	6	83	5	12	42
10	0	0	-	0	0	-	0	0	-
11	38	44	86	62	75	83	17	39	44
12	112	137	82	133	134	99	517	543	95
14	3	3	100	1	1	100	2	2	100
Total	176	218	81	234	253	92	564	625	90
1	12	13	92				8	9	89
4	4	5	80				4	5	80
8	4	6	66				4	4	100
11	7	8	88				13	14	93

Table 10

Length Ranges of Shipworms, in mm, Cumulative Panels

Date Removed:	September 3			October 6			November 4		
Station	B.g.	T.n.	T.b.	B.g.	T.n.	T.b.	B.g.	T.n.	T.b.
1	13-143	43-96		52-209*	124-132		8-185	106-165	
3									
4		74-151*		178	79-152		153-158	92-97	
5		48-102			62-193*		148-239*	82	
8	90	42-90		8-127	67-89		182-228	45-154	
10									
11	56-164*	64-120	1-33	28	90-117	2-131*	32	112-208	1-102*
12		18	1-35		87	.5-69	35	124	.5-84
14	119	14-78			79			13-50	
Replicates									
1	6-60	17-90					25-106	147-162	
4		64-127					215	78-210*	
8	74	53-76					155-175	60-85	
11			2.5-55*						3-54

* Largest specimen of each species, each month.

Table 11

Numbers of Living Shipworms in Yearly Panels

Date Removed:	September 3, 1981				October 6, 1981				November 4, 1981			
Station	*B.g.*	*T.n.*	*T.b.*	Total	*B.g.*	*T.n.*	*T.b.*	Total	*B.g.*	*T.n.*	*T.b.*	Total
1	12	0	0	12	15	0	0	15	18	0	0	18
3	0	0	0	0	0	0	0	0	1	0	0	1
4	0	0	0	0	0	1	0	1	1	1	0	2
5	2	1	0	3	1	1	0	2	1	4	0	5
8	7	1	0	8	3	2	0	5	5	0	0	5
10	0	0	1	1	0	0	1	1	0	0	1	1
11	0	1	2	3	0	0	8	8	0	0	2	2
12	0	0	48	48	0	0	673	673	0	0	363	363
14	0	1	0	1	1	1	0	2	0	3	0	3
Total	21	4	51	76	21	5	682	707	26	8	366	400
Replicates												
1	11	0	0	11	18	1	0	19	14	1	0	15
11	0	0	9	9	1	0	45	46	1	0	33	34
14	0	2	0	2	0	1	0	1	0	5	0	5

Table 12

Numbers of Living Shipworms Plus Empty Tubes, Yearly Panels

Date Removed:	September 3, 1981				October 6, 1981					November 4, 1981					
Station	B.g.	T.n.	T.b.	Total	B.g.	T.n.	T.b.	tere-dinid	Total	B.g.	T.n.	T.b.	T.sp.	tere-dinid	Total
1	12	0	0	12	15	1	0	0	16	18	0	0	0	3	21
3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
4	0	0	0	0	0	1	0	0	1	1	1	0	0	0	2
5	2	3	0	5	1	3	0	1	5	1	4	0	0	0	5
8	7	11	0	18	3	5	0	1	9	5	4	0	1	0	10
10	0	0	1	1	0	0	1	0	1	0	0	1	0	0	1
11	0	1	3	4	0	1	9	0	10	0	1	2	0	0	3
12	0	0	330	330	0	0	787	0	787	0	0	406	0	0	406
14	0	3	0	3	1	1	0	0	2	0	4	0	0	0	4
Total	21	18	334	373	21	12	797	2	831	26	14	409	1	3	453
Replicates															
1	11	0	0	11	18	1	0	0	19	14	1	0	0	0	15
11	0	4	9	13	1	3	45	0	49	1	1	39	0	0	41
14	0	5	0	5	1	2	0	0	3	0	6	0	0	0	6

Table 13

Percentage of Specimens that were Alive when Collected, Yearly Panels

Date Removed	September 3, 1981			October 6, 1981			November 4, 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	12	12	100	15	16	94	18	21	86
3	0	0	-	0	0	-	1	1	100
4	0	0	-	1	1	100	2	2	100
5	3	5	60	2	5	40	5	5	100
8	8	18	44	5	9	56	5	10	50
10	1	1	100	1	1	100	1	1	100
11	3	4	75	8	10	80	2	3	67
12	48	330	15	673	787	86	363	406	89
14	1	3	33	2	2	100	3	4	75
Total	76	373	20	707	831	85	400	453	88
Replicates									
1	11	11	100	19	19	100	15	15	100
11	8	13	62	46	49	94	34	41	83
14	2	5	40	1	3	33	5	6	83

The lengths of the shipworms from the yearly panels are in Table 14. As for the cumulative series, there was no strong tendency for the largest specimens to be in Oyster Creek. Specimens of the Teredo species were larger in September than in October and November, because both T. bartschi and T. navalis settled in September of 1980. Bankia gouldi does not settle that late in the year. The length ranges of specimens collected in the yearly and cumulative series in October and November are similar because most of the surviving specimens in both settled over the 1981 season.

Table 15 gives the percentages of wood lost from the various test panels. Despite the greater number of shipworms in the cumulative panels at station 12, wood destruction was no greater than in other cumulative panels. The small size of Teredo bartschi is responsible for this result. The percentage wood weight lost increased between October and November only at stations 8, 12, and 14. Because of the equality of the age of most specimens in the yearly and cumulative panels, the wood weight data from the two series are comparable.

The percentage of the Teredo navalis carrying larvae in the gills is given in Table 16. In September, 78% of the individuals were brooding young. In October, the percentage was 73%; in November, it fell to 38%. There were no young juveniles of T. navalis reported; all specimens were large enough to be sexually mature as females.

On the contrary, the fall panels contained numerous immature specimens of Teredo bartschi. The smallest mature specimen measured 7 mm in length. The percentage of adults brooding young for September, October, and November was 62%, 87%, and 63%, respectively. The peak of production of pediveligers occurs in October.

Shipworm larvae were found in plankton samples from stations 8, 11, and 12. The straight-hinge larvae were probably Teredo navalis. They could also have been Bankia gouldi, but most B. gouldi settles before October. The greatest density of larvae occurred at station 11 in Oyster Creek; station 8 had only 2 larvae.

Other organisms found in the plankton samples are listed in Table 17. Very little was found alive in the 3 replicate tows at station 10 in a lagoon near the mouth of Oyster Creek. At the other stations, barnacle nauplii were common. Ctenophores and gastropod veligers were also common at the Oyster Creek stations. There were many more species represented in the samples from Oyster Creek than those from Forked River.

The position of entry and direction of growth of shipworms entering 5x10 cm stakes is shown in Table 18. There is no pattern of entry at the mudline for any species, nor is there a preference for entering on the lee side or the side of the stake facing the currents. However, most specimens grow downward, regardless of the species. Most T. bartschi were clustered at 50-60 cm above the mudline. In 1980, the data were comparable except that T. bartschi were clustered about 8 cm above the mudline.

Table 14

Length Ranges of Shipworms, in mm, Yearly Panels

Date Removed:	September 3, 1981			October 6, 1981			November 4, 1981		
Station	B.g.	T.n.	T.b.	B.g.	T.n.	T.b.	B.g.	T.n.	T.b.
1	34-94			13-211	60		18-202		
3							46		
4					181		57	28	
5	63-68	80-270*		156	105-111		138	20-200*	
8	43-194*	61-155		137-171	47-122		85-210	25-73	
10			11			43			33
11		233	6-28		137	1-52		127	36-46
12			.5-130*			.5-64*			.5-57*
14		27-69		18	6			68-114	
Replicates									
1	64			62-214*	139		67-162	137	
11		48-270*	4-34	204	130-185*	.5-59	211*	120	1-40
14		61-110		156	84-91			19-199	

* Largest specimen, each species, each month

Table 15

Percentage of Wood Weight Lost by Panels

A. May 7, 1981 Cumulative Series

Date Removed:	September 3	October 6	November 4
Station			
1	8.21	36.54	25.52
3	0.00	0.00	0.00
4	0.00	14.27	10.66
5	6.73	11.13	9.63
8	6.86	8.16	12.67
10	0.00	0.00	0.00
11	8.55	14.57	12.33
12	8.67	13.00	19.21
14	8.54	7.30	8.64
Replicates			
1	9.44	-	10.37
4	9.57	-	12.78
8	8.26	-	9.48
11	8.04	-	8.46

B. Yearly Series

1	12.28	26.18	22.63
3	0.00	0.00	7.67
4	0.00	6.83	7.60
5	13.93	12.55	8.30
8	15.32	15.82	12.27
10	9.75	8.81	8.53
11	11.11	6.50	9.27
12	13.54	31.5	*
14	12.06	13.41	10.66
Replicates			
1	9.15	35.04	20.22
11	12.35	10.80	10.04
14	12.33	9.80	12.65

*No data

Table 16

Percentage of Living Teredo Carrying Larvae in the Gills

T. navalis Sta.	Month	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	Sample Size
4	Sept.	4	151	118	89	89	67	3
4	Sept.	4	127	64	-	-	100	4
5	Sept.	4	92	92	102	48	33	3
8	Sept.	4	90	55	-	-	100	3
8	Sept.	4	72	68	57	57	67	3
11	Sept.	4	120	120	64	64	50	2
12	Sept.	4	18	18	-	-	100	1
14	Sept.	4	78	78	-	-	100	1
5	Sept.	12	80	80	-	-	100	1
8	Sept.	12	76	76	-	-	100	1
11	Sept.	12	233	233	-	-	100	1
4	Oct.	5	129	105	152	152	67	3
5	Oct.	5	173	108	-	-	100	2
8	Oct.	5	89	89	67	67	50	2
11	Oct.	5	117	117	90	90	50	2
12	Oct.	5	87	87	-	-	100	1
14	Oct.	5	79	79	-	-	100	1
4	Oct.	12	181	181	-	-	100	1
8	Oct.	12	122	122	95	95	50	2
14	Oct.	12	91	91	-	-	100	1
4	Nov.	6	146	146	210	210	50	2
8	Nov.	6	154	154	127	117	33	3
14	Nov.	12	92	92	114	85	33	3
14	Nov.	12	64	64	99	55	20	5

Table 16, continued

Percentage of Living Teredo Carrying Larvae in the Gills

Sta.	Month	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	Sample Size
T. bartschi								
11	Sept.	4	55	55	28	2.5	33	3
11	Sept.	4	33	10	51	2	86	22
12	Sept.	4	35	7	12	2	45	31
10	Sept.	12	11	11	-	-	100	1
11	Sept.	12	28	28	11	11	50	2
11	Sept.	12	34	13	-	-	100	7
12	Sept.	12	20	7	130	7	50	18
11	Oct.	5	74	11	131	7	76	59
12	Oct.	5	69	7	10	0.5	99	74
10	Oct.	12	43	43	-	-	100	1
11	Oct.	12	48	29	3	1	100	4
11	Oct.	12	59	13	2	0.5	100	8
12	Oct.	12	64	7	38	0.5	86	341
11	Nov.	6	71	44	64	3	40	10
11	Nov.	6	43	28	54	4	73	11
12	Nov.	6	61	15	72	0.5	47	162
10	Nov.	12	33	33	-	-	100	1
11	Nov.	12	46	36	-	-	100	2
11	Nov.	12	32	21	4	1	100	2
12	Nov.	12	57	12	50	0.5	81	141

Table 17

Contents of Plankton Samples Collected Oct. 6, 1981

	Station 8	10	11	12
Teredo navalis larvae	present	-	common	common
Barnacle nauplii	common	-	common	common
Polychaete trochophore	present	-	present	present
Late-juvenile polychaete	present	rare	common	present
Nematodes	present	-	present	present
Polydora ligni	present	-	-	-
Bryozoan larvae	present	-	present	-
Calanoid copepods	present	-	present	present
Harpacticoid copepods	present	-	present	present
Paleomonetes sp.	rare	-	-	-
Protozoans	present	-	present	present
Foraminifera	-	-	present	present
Fish eggs	-	-	-	present
Chaetognath eggs & larvae	-	-	present	present
Lorica	-	-	-	present
Ctenophore	-	-	common	common
Gastropod veligers	-	-	common	common
Ostracode	-	-	present	-
Plant seeds	common	-	-	-
Marine mite	-	-	present	-

Table 18

Length, Position of Entry, and Direction of Growth in Stakes at Several Stations.

Station	Position of Entry hole	Distance of Entry Hole above Mud Line	Direction of Growth	Length (cm)	Species
4	in currents	21 cm	down	36.5	B. gouldi
	edge, currents	68	down	14.5	B. gouldi
	in currents	59	down	16.0	T. navalis
10	edge, currents	5	down	11.5	B. gouldi
	in currents	17	down	52.0	B. gouldi
	leeside	20	down	38.0	B. gouldi
	in currents	19	down	40.0	B. gouldi
	in currents	3	down	1.3	B. gouldi
	leeside	17	up	43.0	B. gouldi
	in currents	56	down	3.0	B. gouldi
	leeside	76	down	28.5	B. gouldi
	edge, currents	72	diagonal, down	32.0	T. navalis
	in currents	12	down	0.6	T. bartschi
11	leeside	70	down	33.0	B. gouldi
	leeside	13	up	25.0	T. navalis
	leeside	61	up	37.0	T. navalis
	leeside	8	down	1.5	T. bartschi
	leeside	15	down	0.8	T. bartschi
	leeside	35	up	1.6	T. bartschi
	leeside	44	down	5.5	T. bartschi
	in currents	16	down	1.4	T. bartschi
	in currents	37	down	7.5	T. bartschi
	in currents	42	down	2.0	T. bartschi
	in currents	48	down	5.9	T. bartschi
	in currents	48	down	1.2	T. bartschi
	in currents	49	up	1.3	T. bartschi
	in currents	50	up	1.2	T. bartschi
	in currents	51	down	0.8	T. bartschi
	in currents	51	up	1.2	T. bartschi
	in currents	51	up	1.5	T. bartschi
	in currents	52	down	0.8	T. bartschi
	in currents	53	down	1.2	T. bartschi
	in currents	53	down	1.2	T. bartschi
	in currents	53	down	0.8	T. bartschi
	in currents	55	up	1.2	T. bartschi
	in currents	55	down	1.4	T. bartschi
	in currents	58	down	1.5	T. bartschi
	edge, currents	60	down	2.3	T. bartschi
	edge, currents	22	up	3.2	T. bartschi
	edge, currents	51	down	1.1	T. bartschi
	edge, currents	54	up	1.4	T. bartschi
	edge, currents	56	up	1.5	T. bartschi

Table 18, continued

Station	Position of Entry hole	Distance of Entry Hole above Mud Line	Direction of Growth	Length (cm)	Species
11	edge, lee	62	up	1.0	_T. bartschi_
	edge, lee	48	up	1.0	_T. bartschi_
	edge, lee	48	up	2.1	_T. bartschi_
	edge, lee	49	up	8.0	_T. bartschi_
	edge, lee	52	down	2.0	_T. bartschi_
	edge, lee	52	up	1.6	_T. bartschi_
	edge, lee	53	down	1.6	_T. bartschi_
	edge, lee	54	diagonal	1.2	_T. bartschi_
	edge, lee	54	down	2.3	_T. bartschi_
	edge, lee	55	down	2.1	_T. bartschi_
	edge, lee	55	down	1.4	_T. bartschi_
	edge, lee	56	down	2.2	_T. bartschi_
	edge, lee	55	up	0.8	_T. bartschi_
	edge, lee	57	down	2.3	_T. bartschi_
	edge, lee	60	down	6.3	_T. bartschi_
	edge, lee	60	down	0.5	_T. bartschi_
	edge, lee	62	down	0.8	_T. bartschi_
	edge, lee	64	down	0.6	_T. bartschi_
	edge, lee	65	down	0.3	_T. bartschi_
	edge, lee	68	down	0.4	_T. bartschi_
	edge, lee	69	down	4.4	_T. bartschi_
	edge, lee	57	down	0.3	_T. bartschi_
	in currents	54	-	borehole	-
	in currents	80	-	borehole	-
	in currents	80	-	borehole	-
	in currents	75	-	borehole	-
	in currents	61	-	borehole	-
	in currents	60	-	borehole	-
	in currents	60	-	borehole	-
	in currents	40	-	borehole	-
	in currents	57	-	borehole	-
	in currents	57	-	borehole	-
	in currents	54	-	borehole	-
	in currents	54	-	borehole	-
	in currents	57	-	borehole	-
	in currents	52	-	borehole	-
	in currents	52	-	borehole	-
	in currents	60	-	borehole	-
	in currents	61	-	borehole	-
	in currents	61	-	borehole	-
	in currents	62	-	borehole	-
	in currents	66	-	borehole	-
	in currents	53	-	borehole	-
	in currents	48	-	borehole	-
	in currents	48	-	borehole	-
	in currents	47	-	borehole	-

Table 18, continued

Station	Position of Entry hole	Distance of Entry Hole above Mud Line	Direction of Growth	Length (cm)	Species
14	edge, currents	0.3	down	5.8	B. gouldi
	in currents	2	down	5.5	T. navalis
	leeside	21	down	8.1	T. navalis
	in currents	31	down	9.1	T. navalis

SUMMARY

	Settlement		Growth		Within 10 cm of mudline	
	in currents	leeside	up	down	yes	no
B. gouldi	8	4	1	11	3	9
T. navalis	4	3	2	5	1	6
T. bartschi	24 living 29 dead	26	15	35	0	74

Shipworm Physiological Ecology

The pediveligers of Teredo bartschi were inactive at 5° C (Table 19). They remained alive after 5 days at that temperature. However, when returned to room temperature (17° C), they did not succeed in penetrating the wood. Control specimens from the same female were more active at the control temperature range of 17-20° C, and 5 of the 12 eventually penetrated the wood. The salinity for all experiments was 24 ‰.

The effect of reduced salinity on adults of Teredo navalis is shown in Table 20. Activity of the control individuals was quite variable among panels. Panel A averaged over 90% active individuals with little day-to-day variance. Panel B was usually above 85% active, but on one day, only 25% of the individuals were seen. Panel C showed the lowest and most variable activity (often under 50%). There was no trend from day to day.

The experimental panels showed activity levels comparable to those for control panel C. No ill effects of reduction of salinity were observed until the salinity reached 10 ‰. Then, recovery time after the water was changed extended over 4 hours. The salinity was left at 10 ‰ for 3 days, and activity increased in all 3 panels each day. Then. the salinity was reduced to 7 ‰, and again there was a prolonged recovery period, with activity increasing over a 3 day period. The siphons were never extended fully at 7 ‰. Therefore, to avoid losing the specimens, the salinity was returned to 22 ‰. Activity levels of the experimental panels were again comparable to those of the controls. These results are very similar to those given in an earlier report (#1517) for Teredo bartschi.

Table 19

Behavior of <u>Teredo</u> <u>bartschi</u> larvae at Low Temperature

Behavior	Day: 0 Temp: 17°	0 17°	1 5°	1 17°	2 5°	2 17°	3 5°	3 18°	4 5°	4 19°	5 5°	5 20°
Swimming	5	5	0	4	0	2	0	3	0	4	0	1
Burrowing	2	3	0	1	0	1	0	1	0	2	0	1
Crawling	2	1	0	1	0	1	0	3	0	1	0	5
Closed on bottom	3	3	11	4	3	7	5	5	1	3	4	1
Gaping on bottom*	0	0	1	2	9	1	7	0	11	2	8	4

* Not dead. Capable of responding to touch.

Table 20

Behavior of Adult <u>Teredo</u> <u>navalis</u> Exposed to Reduced Salinity
% of Animals with Siphons Extended

Day	Salinity	Reduced Salinity °/₀₀ A	B	C	Controls (22 °/₀₀) A	B	C
1	22	71	100	66	91	90	55
3	19	75	94	61	96	100	55
4	16	79	90	55	93	25	14
5	13	83	90	61	91	85	28
6	10	17	6	5	93	85	66
7	10	71	62	41	93	95	38
9	10	100	82	59	-	-	-
16	7	13*	24*	39*	91	90	34
17	7	46*	74*	55*	-	-	-
19	7	33*	80*	68*	98	85	100
26	22	58	80	100	100	95	90

* Siphons partially extended.

GENERAL DISCUSSION AND CONCLUSION

The data collected in the fall of 1981 fit the pattern established in previous years. Teredo bartschi accounts for most of the shipworms in Oyster Creek. It survives periods when the thermal effluent is absent, but does not spread to nearby localities as it does when there is an effluent. The native species were few in number throughout Barnegat Bay in 1981; they were apparently not influenced by the low rainfall in New Jersey during the past 2 years.

Field data on settlement of larvae indicate that no species clusters at the mudline, although settlement of Teredo bartschi is patchy. The seasonal peaks of settlement of larvae of the three species do not coincide. The major peak for Bankia gouldi is mid-summer, while those for Teredo bartschi and T. navalis are in late September or early October. T. bartschi has multiple peaks of settlement.

Physiological studies conducted thus far show that shipworms of all species have similar low salinity tolerances, and that below 10 °/₀₀, symptoms of osmotic stress occur. This result is important in that the operation of the Oyster Creek Nuclear Generating Station has eliminated periods of low salinity in the affected portions of Oyster Creek and Forked River (particularly the south branch). Therefore it has increased the potential for shipworm outbreaks in these areas.

Fortunately for those concerned about shipworm damage, frequent and prolonged plant outages have reduced woodborer attack in Oyster Creek and Forked River. The persistence of Teredo bartschi in Oyster Creek since 1974 and its population characteristics allowing rapid population growth indicate that the only final solution will be the cessation of operation of the plant. However, the infestation can be reduced by removing infected wood.

We have found higher mortality in the Teredo species than in Bankia gouldi. The role of heavy metals, disease, and parasites in mortality of woodborers and fouling organisms requires further study.

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

* 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, NJ Bay control	Lat. 39° 54' Lon. 74° 8'	N W
3	Stout's Creek	End of Raleigh Drive Gustav Walters' residence	39° 50.7' 74° 9'	N W
4	Mouth of Forked River	South Shore Developed property Possible temperature increase increased oceanic influence due to reverse flow	39° 49.6' 74° 9.8'	N W
5	Leilani Drive	At branch point of Forked River	39° 49.6' 74° 10.5'	N W
6	Elk's Club	South Branch Forked River Increase in salinity due to plant intake canal	39° 49.4' 74° 10.9'	N W
8	Bayside Beach Club	On bay between Oyster Creek and Forked River across from 1815 Beach Blvd., Forked River, NJ Temperature increase since plant operation.	39° 49.0' 74° 9.7'	N W
10	Kochman's Residence	End of Compass Rd. on #1 Lagoon, Oyster Creek Waretown, NJ Temperature, salinity siltation increase	39° 48.5' 74° 10.6'	N W
11	Crisman's Residence	Dock Ave. on Oyster Creek Waretown, NJ Temperature, salinity, siltation increase	39° 48.5' 74° 11.0'	N W

STATION NUMBER	NAME	DESCRIPTION	COORDINATES
12	Gilmore's Residence	20 Dock Ave. on Oyster Creek Waretown, NJ. Temperature, salinity, siltation increase	39° 48.5' N 74° 11.3' W
14	Cottrell's Clam Factory	End of North Harbor Rd. Waretown, NJ (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, NJ (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

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NRC FORM 335 (7-77)

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

1. REPORT NUMBER *(Assigned by DDC)*
NUREG/CR-2727, Vol. 1

4. TITLE AND SUBTITLE *(Add Volume No., if appropriate)*
Ecological Studies of Wood-Boring Bivalves in the Vicinity of the Oyster Creek Nuclear Generating Station
Progress Report
September - November 1981

2. *(Leave blank)*

3. RECIPIENT'S ACCESSION NO.

7. AUTHOR(S)
K. E. Hoagland and L. Crocket

5. DATE REPORT COMPLETED
MONTH May | YEAR 1982

9. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS *(Include Zip Code)*
Lehigh University
Wetland Institute
Stone Harbor, NJ 08247

DATE REPORT ISSUED
MONTH June | YEAR 1982

6. *(Leave blank)*

8. *(Leave blank)*

12. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS *(Include Zip Code)*
U.S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
Division of Health, Siting, and Waste Management
Washington, D. C. 20555

10. PROJECT/TASK/WORK UNIT NO.

11. CONTRACT NO.
B5744

13. TYPE OF REPORT
Quarterly Progress Report

PERIOD COVERED *(Inclusive dates)*
September 1, 1981 - November 30, 1981

15. SUPPLEMENTARY NOTES

14. *(Leave blank)*

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. In the fall of 1981, *Teredo bartschi* remained in Oyster Creek despite continuous prolonged outages of the Oyster Creek Nuclear Generating Station. It did not spread to Forked River or Waretown as it had done in other years when the effluent was present. The peak in larval production and settlement of *T. bartschi* occurred between September and October. Settlement of shipworms occurred on no monthly panels except those in Oyster Creek during the period of this report. Laboratory experiments revealed that *T. bartschi* becomes inactive at 5° C (24°/₀₀) and *T. navalis* shows signs of osmotic stress below 10°/₀₀ at 18° C. The shipworms in Barnegat Bay do not show a preference for settling at the mudline when the substrate is not limited.

17. KEY WORDS AND DOCUMENT ANALYSIS

17a. DESCRIPTORS

Thermal Effluents
Shipworms
Oyster Creek
Teredo bartschi
Teredo navalis
Bankia gould

17b. IDENTIFIERS/OPEN-ENDED TERMS

18. AVAILABILITY STATEMENT
Unlimited

19. SECURITY CLASS *(This report)*
UNCLASSIFIED

21. NO. OF PAGES

20. SECURITY CLASS *(This page)*
UNCLASSIFIED

22. PRICE
S

NRC FORM 335 (7-77)

NUREG/CR-2727, Vol. 1

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

JUNE 1982

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, DC 20555-0001

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