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Progess Report
March - May 1980

Prepared by K. E. Hoagland, L. Crocket

Wetlands Institute
Lehigh University

Prepared for
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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, at the mouth of Forked River and on the coast of the bay between the two creeks. Heavy mortality occurred in all species during winter and spring when the generating station was not operating. Very few *T. bartschi* were found alive in the spring panels; they were more affected than native species by the plant shutdown. Temperature and salinity tolerance tests begun during April and May, 1980, were not completed by the end of May because the adult shipworms proved to be very resistant to drastic changes in these physical parameters.

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.

Our major findings are:

1. The OCNGS was not operating during the entire period of this report, and had been off since January 5, 1980. This caused a dramatic drop in shipworm infestation.

2. Water temperatures were often above ambient at Stout's Creek. Temperatures were slightly higher in the southern part of the study area during March and April.

3. No shipworm larvae settled on monthly panels removed in March-May, 1980.

4. Teredo bartschi was found alive only in Oyster Creek and at Bayside Beach Club. Winter-spring mortality was high for all species, but was highest for T. bartschi.

5. Larvae were found in the gills of T. navalis only in May, 1980.

6. The greatest number of living shipworms occurred at Holly Park, Waretown, and Bayside Beach Club near the mouth of Forked River. But because of past destruction, the greatest amount of wood loss occurred in Oyster Creek.

7. The largest living specimens in the cumulative panels consistently occurred at Station 4 in Forked River. Stations 1 and 14 had the largest living specimens taken from the yearly panels, but most individuals in the panels from Oyster Creek and Forked River were dead.

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ACKNOWLEDGMENTS

We thank the many residents of Oyster Creek who have cooperated in our field work. James Selman, Jane Halbeisen, and Kenneth Pidcock provided technical assistance. Eugenia Böhlke of the Academy of Natural Sciences of Philadelphia served as X-ray technologist. Virginia Ohori of J.C.P. & L. provided data on the operation of the Generating Station.

PREVIOUS REPORTS

Twelve reports have been prepared under Contract AT(49-24)-0347 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

One report has been published in this current series:

Ecological studies of wood-boring bivalves in the vicinity of the Oyster Creek Nuclear Generating Station, Sept. 1, 1979-Feb. 28, 1980. NTIS # NUREG/CR-1517. 65 pp.

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

March 1 - May 31, 1980

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 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 also assess the degree of shipworm damage occurring at each station.

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.

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*.

Experiments to determine temperature and salinity tolerances of the three teredinid species are underway. Three were reported in our last report (Hoagland et al, 1980). None were completed within March-May, 1980, so none are reported here. Long-term experiments were necessary because the shipworms tolerated drastic short-term changes in temperature and salinity.

RESULTS AND DISCUSSION

Physical Data

The Oyster Creek Nuclear Generating Station was not operating during March-May, 1980, as shown by the temperature data in Tables 1 and 2. As in past years, Station 3 at Stout's Creek was often a few degrees warmer than the other stations. The daily temperature range was often slightly greater at bay stations than in the tidal creeks. The continuous temperature recorder data for March suggested a low-level heat addition for at least part of the month. However, the comparative data for Station 14 south of Oyster Creek are missing. Looking at the data for April, there may have been naturally warmer waters in the southern part of our test area (Stations 11 and 14) during March and April.

Tables 3 and 4 present monthly salinity profiles at the 9 stations to the nearest part per thousand. The fluctuation from month to month was very large at the two northernmost stations. The salinity at Stout's Creek in March was unusually high, while the among-station variation for March was low, indicating an intrusion of bay waters into the tidal creeks. The data for May show why shipworms are rarely found at Stout's Creek: the salinity there fell to only 4 $^{\circ}/_{\circ\circ}$, while remaining above 13 $^{\circ}/_{\circ\circ}$ at all other stations. The Oyster Creek station was pumping water at a reduced rate during this period (Table 5).

The amount of silt deposited on panels removed in March and April was estimated independently by two technicians on a scale of trace-light-moderate-heavy. All monthly panels contained trace amounts. The cumulative panels removed in April varied in degree of silt. Silt was recorded at "trace" levels at bay control Stations 1 and 14 as well as at the bay Station 8 between Oyster Creek and Forked River. Silt was ht at the control creek (Stout's Creek, Station 3). Moderate silt .s recorded at Station 11 in Oyster Creek, but all other stations in Oyster Creek and Forked River had heavy siltation.

Table 1

Temperature Profiles in ° C
March 7 - May 3, 1980[a]

Station	March 7	April 7	May 3	Differential among months, within stations
1	2.5[b]	12.8	16.0	13.5
3	6.0[c]	13.5	19.2[c]	13.2
4	4.0	14.2[c]	15.0	11.0
5	4.5	13.0	15.0	10.5
8	3.5	13.0	17.0	13.5
10	2.5[b]	12.5	14.0	11.5
11	4.0	13.0	14.0	10.0
12	4.2	11.5[b]	14.5	10.3
14	4.0	12.5	13.5[b]	9.5
Differential among stations within months	3.5	1.3	5.7	

[a] The nuclear generating station was not operating

[b] Lowest monthly value

[c] Highest monthly value

Table 2

Continuous Temperature Recorder Data (°C) for March 7 - June 6, 1980

Stations 1, 5, 11, 14

I. Temperature at 1:00 P.M. EST

	March 7-April 7				April 7-May 3				May 3-June 6			
	1	5	11	14[a]	1	5	11	14	1	5	11[a]	14
Mean Daily Temp. at 1PM	6.1	5.8	7.5		12.6	13.0	13.8	13.5	18.2	18.6		18.2
Standard deviation	2.4	2.1	2.2		1.5	1.5	1.6	1.4	2.6	1.9		2.5
Highest value of Temp. at 1 PM	11.3	10.3	12.1		15.4	15.4	16.4	16.0	23.8	22.8		22.9
Lowest value of Temp. at 1 PM	1.4	1.1	3.5		10.2	10.4	8.8	10.3	12.8	15.6		13.0
Monthly Temp. Range	9.9	9.2	8.6		5.2	5.0	7.6	5.7	11.0	7.2		9.9

II. Maximum Daily Temperature

	March 7-April 7				April 7-May 3				May 3-June 6			
	1	5	11	14[a]	1	5	11	14	1	5	11[a]	14
Mean value of Max. Daily Temp.	6.8	7.1	8.3		13.4	13.7	15.2	14.8	18.9	19.7		19.3
Standard deviation	2.5	2.1	1.8		1.6	1.6	1.5	1.7	2.6	2.7		2.5
Highest value of Max. Daily Temp.	12.1	11.9	12.2		15.9	15.9	17.7	18.2	24.4	25.3		23.4
Lowest value of Max. Daily Temp.	2.4	2.5	4.4		10.6	10.6	12.3	12.1	13.8	15.8		14.0
Monthly Range of Max. Daily Temp.	9.7	9.4	7.8		5.3	5.3	5.4	6.1	10.6	9.5		9.4

Table 2, continued

III. Minimum Daily Temperature

	March 7-April 7				April 7-May 3				May 3-June 6			
	1	5	11	14[a]	1	5	11	14	1	5	11[a]	14
Mean value of Min. Daily Temp.	5.2	4.8	7.0		11.8	11.7	13.3	13.0	17.0	17.1		17.0
Standard deviation	2.3	2.7	2.3		1.5	1.7	1.5	1.4	2.4	2.6		2.7
Highest value of Min. Daily Temp.	9.8	9.4	11.6		14.5	14.2	16.1	15.9	22.6	22.8		21.8
Lowest value of Min. Daily Temp.	1.2	-2.1	2.7		9.5	7.0	8.8	10.0	12.3	13.3		11.4
Monthly Range of Min. Daily Temp.	8.6	11.5	8.9		5.0	7.2	7.3	5.9	10.3	9.5		10.4

IV. Daily Temperature Range

	March 7-April 7				April 7-May 3				May 3-June 6			
	1	5	11	14[a]	1	5	11	14	1	5	11[a]	14
Mean value of Daily ΔT	1.6	2.3	1.3	0.7	1.6	2.0	1.8	1.8	1.9	2.6		2.3
Standard deviation	0.7	1.0	0.8	0.4	0.7	1.2	1.2	0.9	0.9	1.1		1.0
Largest Daily ΔT for one month	3.4	4.6	3.0	1.9	3.6	4.6	5.4	3.5	5.4	5.3		5.2
Smallest Daily ΔT for one month	0.5	0.6	0.1	0.2	0.3	0.3	0.2	0.2	0.9	1.0		0.9

[a] Temperature Recorder malfunction

Table 3

Salinity Profiles in °/₀₀, March 7-May 3, 1980

Station	March 7	April 7	May 3	Differential among months, within stations
1	20	8[a]	15	12
3	18[a]	8[a]	4[a]	14
4	22[b]	18	20[b]	4
5	22[b]	19	20[b]	3
8	22[b]	20	16	6
10	21	18	16	5
11	22[b]	17	16	6
12	22[b]	16	16	6
14	22[b]	22[b]	14	8
Differential among stations, within months	4	14	16	

[a] Lowest monthly salinity

[b] Highest monthly salinity

Table 4

Continuously Recording Salinometer Data
(12:00 Noon, EST)
March 7-June 7, 1980, in °/₀₀

Date	Statistic*	Sta. 5	Sta. 11
March 7-April 7	N	0	31
	$\bar{x}$	-	19.8
	$S_{\bar{x}}$	-	3.0
April 7 May 3	N	22	0
	$\bar{x}$	14.3	-
	$S_{\bar{x}}$	4.2	-
May 4 June 6	N	19	21
	$\bar{x}$	17.4	16.4
	$S_{\bar{x}}$	1.0	1.0

*N = Number of days recorded; indicates extent of missing data.

$\bar{x}$ = Mean

$S_{\bar{x}}$ = Standard deviation

Explanation of Missing Data:
Sta. 1, 14 not in service
Sta. 5 not in service during March; Sta. 11 not in service During April

Table 5

Oyster Creek Nuclear Generating Station
Circulation and Dilution Flow in gal. x 10^6
for March 1-May 31, 1980

	Total Circulating Water Flow (gal. 10^6)	Total Dilution Flow (gal. 10^6)
March	0	22,437
April	0	18,514
May	5,277	18,369

Shipworm Populations

The species of Teredinidae found in Barnegat Bay continued to be *Bankia gouldi*, *Teredo navalis*, and *Teredo bartschi*, as in our previous reports. The species are reviewed in Turner, 1966. Tables 6-8 present the numbers of individuals alive and dead in the cumulative panels submerged May 5, 1979; the panel removed on May 3, 1980, is equivalent to a yearly panel. The living populations were largest at Stations 1, 8, and 14. The most common species was *B. gouldi*, although *T. navalis* was almost equally abundant at Station 14 (Waretown). Mortality was greatest in Oyster Creek. Most of the *Teredo* sp. and Teredinid sp. reported in Table 7 were *T. bartschi* at Stations 4-12 and *T. navalis* at Station 1, but the pallets were lost or loose in the tubes and could not be associated with any particular tube because of severe wood decay. The species at Station 14 is unknown. The largest living specimens were at Station 4 in Forked River (Table 9); there were no juveniles settling anywhere during this period.

The cumulative and the yearly panels (Tables 10-12) yielded similar results, because the panels were in the water for almost the same duration. Again, *Bankia gouldi* was dominant among living specimens and most *Teredo bartschi* were dead. There were no juveniles. Mortality was greatest in Oyster Creek.

Because of the very heavy shipworm attack in the summer and fall of 1979, many panels were completely riddled and several were lost. The very heavy mortality of adults in 1980 is attributable to the heavy attack and disintegration of the wood in Oyster Creek and Forked River, as well as to the shutdown of the OCNGS and consequent mortality to *Teredo bartschi*. Many of the otherwise empty shipworm burrows contained *Nereis succinea*, which eat the shipworms when the wood begins to crumble and expose the tubes.

One difference between the cumulative and yearly panels was the size ranges of living specimens (Table 13 versus Table 9). The largest living specimens in the yearly panels were at Stations 1 and 14. However, the burrow lengths suggested many large but dead specimens at other stations. The actual sizes of the living shipworms in the two panel series were comparable.

There were no living *Teredo bartschi* in the yearly panels, and only 4 in the cumulative panels. This difference is within the realm of sampling error.

Table 6

Numbers of Living Shipworms in Cumulative Panels Submerged May 5, 1979

Date Removed:	March 7					April 7			May 3				
Station	B.g.	T.n.	T.b.	T.sp.	Total	B.g.	T.n.	Total	B.g.	T.n.	T.b.	Teredinid sp.	Total
1	60	7	0	0	67	50	4	54	–	–	–	–	a
3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	18	4	0	0	22	3	3	6	9	6	0	0	15
5	23	7	0	0	30	16	10	26	17	3	0	0	20
8	56	9	1	1	67	40	9	49	46	5	1	11	63
10	5	1	2	0	8	6	0	6	2	3	0	1	6
11	–	–	–	–	a	–	–	a	–	–	–	–	a
12	0	0	0	0	0	0	0	0	0	2	0	0	2
14	22	16	0	0	38	25	19	44	28	23	0	0	51
Totals	184	44	3	1	232	140	45	185	102	42	1	12	157

[a]panel lost (riddled)

Table 7

Number of Living Shipworms plus Empty Tubes, Cumulative Panels Submerged May 5, 1979

	Date Removed: March 7						April 7					May 3					
Station	B.g.	T.n.	T.b.	T.sp.	T*	Total	B.g.	T.n.	T.sp.	T*	Total	B.g.	T.n.	T.b.	T.sp.	T*	Total
1	60	7	0	0	>93	>160	50	4	0	>162	>216	–	–	–	–	–	a
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	18	4	0	4	3	29	3	3	3	0	9	10	6	0	3	4	23
5	23	7	0	0	67	97	16	10	0	40	66	17	3	0	5	33	58
8	56	9	1	0	84	150	40	9	0	51	100	52	5	1	0	57	115
10	7	1	2	b	b	b	7	b	b	b	b	–	–	–	–	–	b
11	–	–	–	–	–	a	–	–	–	–	a	–	–	–	–	–	a
12	–	–	–	–	–	b	–	–	–	–	b	–	2	–	–	–	–
14	24	16	0	0	16	56	28	19	0	18	65	28	23	0	0	65	116
Totals	>188	>44	>3	>4	>263	>502	>144	>45	>3	>272	>464	>107	>39	>1	>8	>159	>312

[a] Panel lost (riddled)

[b] Panel riddled with empty tubes

* Teredinid

Table 8

Percentage of Specimens Alive when Collected, Cumulative Panels

Date Removed:	March 7			April 7			May 3		
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	67	>160	<42	54	216	25	a	a	-
3	0	0	-	0	0	-	0	0	-
4	22	29	76	6	9	67	15	23	65
5	30	97	31	26	86	30	20	58	34
8	67	150	45	49	100	49	63	115	55
10	8	b	< 2	6	b	< 1	6	b	< 1
11	a	a	-	a	a	-	a	a	-
12	0	b	0	0	b	0	2	b	< 1
14	38	56	68	44	65	68	51	116	44
Totals	232	>502	<46	185	>464	<40	157	>312	<50

[a] Panel lost (riddled)

[b] Panel riddled with empty tubes

Table 9

Length Ranges of Living Shipworms, in mm, Cumulative Panels

Station	Date Removed: March 7 B.g.	T.n.	T.b.	April 7 B.g.	T.n.	May 3 B.g.	T.n.	T.b.
1	10-76	15-33		16-52	27-30			
3								
4	88-180*	85-160*		124-230*	97-220*	110-265*	80-165*	
5	26-160	11-47		33-142	27-132	15-170	25-50	
8	15-100	20-71	7	16-165	19-93	15-145	20-75	30
10	20-140	45	6-12*	23-117		65-96	40-50	
11								
12							62-95	
14	30-154	37-150		50-210	40-150	38-185	21-140	

* Largest specimen of each species, each month

Table 10

Numbers of Living Shipworms in Yearly Panels

	Date Removed: March 7				April 7			May 3		
Station	B.g.	T.n.	T.sp.	Total	B.g.	T.n.	Total	B.g.	T.n.	Total
1	24	3	0	27	34	2	36	20	3	23
3	0	0	0	0	0	0	0	1	0	1
4	-	-	-	a	-	-	a	10	3	13
5	30	31	1	62	13	6	19	16	18	34
8	56	13	0	69	34	10	44	24	1	25
10	3	0	0	3	-	-	a	-	-	a
11	10	4	0	14	5	1	6	8	0	8
12	-	-	-	a	-	-	a	-	-	a
14	16	23	0	39	22	35	57	24	10	34
Totals	139	74	1	214	108	54	162	103	35	138

[a] Panel lost (riddled)

Table 11

Numbers of Living Shipworms, plus Empty Tubes, Yearly Panels

Date Removed:	March 7				April 7				May 3			
Station	B.g.	T.n.	Tere-dinid	Total	B.g.	T.n.	Tere-dinid	Total	B.g.	T.n.	Tere-dinid	Total
1	24	3	10	37	34	2	1	37	20	4	0	24
3	0	0	0	0	0	0	0	0	1	0	0	1
4	–	–	–	a	–	–	–	a	12	3	10	25
5	30	31	>139	>200	16	6	>168	>190	16	18	69	103
8	56	13	>121	>190	34	10	> 66	>110	25	0	>100	>125
10	3	b	b	b	–	–	–	a	–	–	–	a
11	10	4	b	b	5	1	b	b	8	b	b	b
12	–	–	–	a	–	–	–	a	–	–	–	a
14	16	23	27	66	22	35	48	105	24	10	8	42
Totals	139	74	>297	>510[b]	111	54	>283	>448[b]	106	35	>187	>328

[a] Panel lost (riddled)

[b] Panel riddled with empty tubes

Table 12

Percentage of Specimens that were Alive when Collected, Yearly Panels

Station	Date Removed: March 7 No. Living Specimens	March 7 Total No. Observed Tubes	March 7 % Alive	April 7 No. Living Specimens	April 7 Total No. Observed Tubes	April 7 % Alive	May 3 No. Living Specimens	May 3 Total No. Observed Tubes	May 3 % Alive
1	27	37	73	36	37	97	23	24	96
3	0	0	-	0	0	-	1	1	100
4	a	a	-	a	a	-	13	25	52
5	61	>200	<31	19	>190	<10	34	103	33
8	69	>190	<36	44	>110	<40	25	>125	<20
10	3	b	< 1	a	a	-	a	a	-
11	14	b	< 2	6	b	< 1	8	b	< 1
12	a	a	-	a	a	-	a	a	-
14	39	67	58	57	105	54	34	52	65
Totals	214	>510	<42	162	>448	<36	138	>328	<42

[a] Panel lost (riddled)

[b] Panel riddled with empty tubes

Table 13

Length Ranges of Shipworms, in mm, Yearly Panels

Station	Date Removed: March 7 B.g.	March 7 T.n.	April 7 B.g.	April 7 T.n.	May 3 B.g.	May 3 T.n.
1	60-162*	109-210*	15-140	86-115	72-243*	88-175*
3					205	
4					45-120	65-125
5	10-102	10-80	20-110	6-37	22-90	11-80
8	10-150	13-70	11-115	10-50	14-70	broken
10	45-120					
11	27-115	12-72	25-65	26	32-93	
12						
14	30-155	31-140	32-232*	15-185*	31-190	30-90

* Largest specimen of each species, each month

Wood-weight data (Tables 14 and 15) demonstrate the severe attack suffered primarily during 1979. There was no significant increase in damage between March and May, 1980. Many panels lost over 75% of their wood weight. Damage was greatest in Oyster Creek, where many panels were lost altogether despite their being tied on to the racks with twine in addition to the usual metal fasteners.

Table 16 presents data on the number of *Teredo navalis* found brooding larvae in the gills. No brooding *T. bartschi* were found, and none of the brooding *T. navalis* were from Oyster Creek.

Table 14

Percentage of Wood Weight Lost by Cumulative Panels Submerged May 5, 1979

Station	March 7, 1980	April 7, 1980	May 3, 1980
1	73.9	86.8	a
3	0.0	0.0	0.0
4	58.9	b	b
5	66.0	65.4	62.6
8	75.4	67.8	b
10	73.0	72.1	74.0
11	a	a	a
12	80.2	81.1	73.0
14	54.3	61.8	56.1

[a] Panel lost (riddled)

[b] Data missing or error in recorded wood weight

Table 15

Percentage of Wood Weight Lost by Yearly Panels

Station	March 7, 1980	April 7, 1980	May 3, 1980
1	57.6	55.5	53.0
3	0.0	0.0	5.0
4	a	a	58.7
5	77.1	75.5	69.8
8	74.5	76.9	75.6
10	82.9	a	a
11	78.1	82.7	73.7
12	a	a	a
14	66.1	60.1	62.5

[a] Panel lost (riddled)

Table 16

Teredo navalis with Larvae in the Gills

Station	Date	No. with larvae	Total N	% with larvae
4	Cum May	6	6	100
5	Cum May	1	3	33
8	Cum May	1	5	20
14	Cum May	6	23	26
5	Yr. May	2	18	11
14	Yr. May	4	10	40

CONCLUSIONS

The combination of heavy wood destruction in summer and fall, 1979, and the shutdown of the OCNGS in winter and spring, 1980, caused heavy mortality of shipworms in Oyster Creek and Forked River in 1980. Coupling these data with earlier observations of high numbers of shipworms when the station operated throughout the winter and early spring (Hoagland & Crocket, 1979; Hoagland & Turner, 1980), and low numbers when the plant was off (Hoagland *et al*. 1977), we now have a large amount of solid evidence that the shipworm outbreaks are correlated with the operation of the nuclear generating station at Oyster Creek.

Furthermore, *Teredo bartschi* population structure and size are more sensitive to the operation of the station than are population parameters of other species. There is a greater variation in *T. bartschi* population size, making it the major contributor to the shipworm outbreaks in both numbers and wood damage, despite its small size (usually less than 30 mm in length).

We recommend an intensive clean-up of old wood in Oyster Creek and the mouth and south branch of Forked River in the winter of 1980-81 in an effort to eliminate *Teredo bartschi* while its numbers are low. We are monitoring the population genetic structure of the species in order to evaluate if any future outbreaks are caused by re-introductions or by a few individuals surviving unfavorable periods such as the winter of 1979-80.

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*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.

***Available for purchase from 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' Lon. 74° 8'	N W
3	Stout's Creek	End of Raleigh Drive Gustav Walters' residence Estuarine control	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, N.J. 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, N.J. Temperature, salinity, siltation increase	39° 48.5' 74° 10.6'	N W

STATION NUMBER	NAME	DESCRIPTION	COORDINATES	
11	Crisman's Residence	Dock Ave. on Oyster Creek, Waretown, N.J. Temperature, salinity, siltation increase	39° 48.5' 74° 11.0'	N W
12	Gilmore's Residence	20 Dock Ave. on Oyster Creek Waretown, N.J. Temperature, salinity, siltation increase	39° 48.5' 74° 11.3'	N W
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' 74° 10.9'	N W
15	Carl's Boats	Washington & Liberty Sts Waretown, N.J. (on the bay)	39° 47' 74° 11'	N W
18	Barnegat Light	Marina adjacent to Coast Guard Station	39° 45.8' 74° 6.5'	N W

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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, at the mouth of Forked River and on the coast of the bay between the two creeks. Heavy mortality occurred in all species during winter and spring when the generating station was not operating. Very few T. bartschi were found alive in the spring panels; they were more affected than native species by the plant shutdown. Temperature and salinity tolerance tests begun during April and May, 1980, were not completed by the end of May because the adult shipworms proved to be very resistant to drastic changes in these physical parameters.

17. KEY WORDS AND DOCUMENT ANALYSIS

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