NUREG/CR-2727
Vol. 2

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

Progress Report
December 1981 - February 1982

Prepared by K. E. Hoagland, L. Crocket

Department of Malacology
Academy of Natural Sciences of Philadelphia

Prepared for
U.S. Nuclear Regulatory Commission

Availability of Reference Materials Cited in NRC Publications

Most documents cited in NRC publications will be available from one of the following sources:

1. The NRC Public Document Room, 1717 H Street, N.W.
   Washington, DC 20555
2. The NRC/GPO Sales Program, U.S. Nuclear Regulatory Commission,
   Washington, DC 20555
3. The National Technical Information Service, Springfield, VA 22161

Although the listing that follows represents the majority of documents cited in NRC publications, it is not intended to be exhaustive.

Referenced documents available for inspection and copying for a fee from the NRC Public Document Room include NRC correspondence and internal NRC memoranda; NRC Office of Inspection and Enforcement bulletins, circulars, information notices, inspection and investigation notices; Licensee Event Reports; vendor reports and correspondence; Commission papers; and applicant and licensee documents and correspondence.

The following documents in the NUREG series are available for purchase from the NRC/GPO Sales Program: formal NRC staff and contractor reports, NRC-sponsored conference proceedings, and NRC booklets and brochures. Also available are Regulatory Guides, NRC regulations in the *Code of Federal Regulations*, and *Nuclear Regulatory Commission Issuances*.

Documents available from the National Technical Information Service include NUREG series reports and technical reports prepared by other federal agencies and reports prepared by the Atomic Energy Commission, forerunner agency to the Nuclear Regulatory Commission.

Documents available from public and special technical libraries include all open literature items, such as books, journal and periodical articles, and transactions. *Federal Register* notices, federal and state legislation, and congressional reports can usually be obtained from these libraries.

Documents such as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings are available for purchase from the organization sponsoring the publication cited.

Single copies of NRC draft reports are available free upon written request to the Division of Technical Information and Document Control, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at the NRC Library, 7920 Norfolk Avenue, Bethesda, Maryland, and are available there for reference use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

GPO Printed copy price: $4.50

NUREG/CR-2727
Vol 2
RE

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

Progress Report
December 1981 - February 1982

Manuscript Completed: June 1982
Date Published: August 1982

Prepared by
K. E. Hoagland, L. Crocket

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

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 B8138

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.
	Vol. 3 March 1, 1981-May 31, 1981, 38 pp.
	Vol. 4 June 1 - Aug. 31, 1981, 44 pp.
NUREG/CR-2727	Vol. 1 Sept. 1 - Nov. 30, 1981, 40 pp.

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 winter of 1981, the generating station experienced a prolonged outage. The reproductive cycle of the shipworms was not extended. Teredo bartschi was very abundant at one station in Oyster Creek and moderately abundant at a second, but did not exist elsewhere in Barnegat Bay. Some specimens of Teredo bartschi contained larvae in the gills in February. According to laboratory experiments, Teredo navalis is able to remain active at temperatures as low as 4°C, whereas T. bartschi ceases activity (withdraws its siphons) at about 13°C.

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 most of the period of this report. Water circulation was also reduced.

2. In early December when the station was operating, the ΔT was about 4-5°C.

3. The salinity in Oyster Creek was similar to that of Barnegat Bay throughout the winter. The salinity at some tidal creek control stations reflected the presence of a layer of fresh water at the surface.

4. *Teredo bartschi* was found only at stations 11 and 12 in Oyster Creek. Attack at station 12 was heavier.

5. Outside of the *Teredo bartschi* infestation in Oyster Creek, borer attack was light in 1981. The only station showing even a moderate attack of *Bankia gouldi* was Station 1, Holly Park. The greatest numbers of *T. navalis* occurred at Station 1 and the stations in Forked River.

6. Mortality of shipworms in Oyster Creek was not as extensive as might have been predicted by reason of the winter shutdown of the generating station.

7. No larvae settled during the period of this report.

8. Wood destruction was greatest at Station 12 in Oyster Creek.

9. *Teredo bartschi* retained larvae in the gills through the winter months.

10. *Teredo bartschi* withdraws its siphons at a temperature of about 13-14°C, whereas *T. navalis* is active above 4°C.

TABLE OF CONTENTS

LIST OF TABLES

ACKNOWLEDGMENTS

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

ECOLOGICAL STUDIES OF WOOD-BORING BIVALVES

IN THE VICINITY OF THE OYSTER CREEK

NUCLEAR GENERATING STATION

December, 1981 - February, 1982

INTRODUCTION

Previous studies have shown a direct causal relationship between the effluent of the Oyster Creek Nuclear Generating Station and the proliferation of shipworms (Teredinidae) in Oyster Creek and adjacent portions of Barnegat Bay, New Jersey (Turner, 1974; Hoagland et al., 1977; Hoagland et al., 1978; Hoagland and Crocket, 1979; Hoagland and Turner, 1980; Hoagland et al., 1980). The effluent adds heat to the receiving waters, which extends the breeding season of teredinids, increases their growth rates, and reduces their winter mortality rates. It has allowed the establishment of a tropical-subtropical shipworm, Teredo bartschi, in Oyster Creek and Forked River. The design of the generating station's cooling system, taking salt water from Barnegat Bay up Forked River, through the plant, and out into Oyster Creek, has increased the salinity of these two creeks. Shipworms now can reside in these creeks, which previously were unsuitable in salinity level and constancy for the establishment of 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 J.C.P. & L. calculates average values of heavy metal input per month, exact data necessary to characterize the effluent completely are not available.

Stations 14 is at or near the southern limit of the thermal plume, on Barnegat Bay. During the January 1982, our racks and thermometer at Station 14 were destroyed by bulkheaders working in the area. A new station 14 has been established across Waretown Creek in Skipper's Cove, but that station was not yet operable in February. 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 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) Ordinarily, each month, a panel that has been in the water for 12 months is removed. This series of panels was omitted during the winter months of 1981-82. 3) Each May, a series of 12 panels is deployed. These panels are removed one a month. They provide information on the cumulative growth and maturation of individual borers as well as development of the boring and fouling communities. The cumulative monthly amount of wood destruction can be evaluated. These three panel series are called M, Y, and C, respectively. The C series is replicated at 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 idenfity shipworms from the X-rays in uncrowded panels, but X-rays do not provide quantitative data in most cases. Therefore, using the X-rays as guides, the panels are dissected. All the shipworms are removed, identified, examined for larvae in the gills, and measured (length only). They are preserved in 75% buffered alcohol. Identifications are first made by technicians, but all Teredo spp. are checked by 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 indicates mortality. If pallets are still present in the empty tubes, we can record the species of the dead shipworm.

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

A low temperature tolerance experiment was performed in December and

January with adult specimens of Teredo navalis and T. bartschi. Six panels containing T. navalis and six containing T. bartschi were taken from tanks in the laboratory. The animals had been collected at Stations 18 and 12, respectively, and had been acclimated for six months to laboratory conditions of 22-24$^{o}/_{oo}$ salinity and 20°C. Three panels containing each species were placed in outdoor water tables while 3 remained in the laboratory. The maximum number of siphons seen extending from each panel over a 3-day period was recorded at the outset of the experiment. The water temperature and the number of siphons per panel were recorded three times per day, at 9:00, 12:00, and 16:00 hours. Minimal temperature for activity of adults of each species was extracted from the data by noting the highest temperature at which no siphons were visible.

RESULTS AND DISCUSSION

Physical Factors

When the Oyster Creek Nuclear Generating Station was operating on December 3, the temperature in Oyster Creek was elevated about 4-5°C (Table 1). In early January, the water temperature was warmer than usual for that month, but a cold wave later in January caused the water temperature to drop. The continuous temperature recordings (Table 2) gave similar results. The minimum temperature recorded in Oyster Creek was -1.4°C, which should have been cold enough to kill Teredo bartschi, according to laboratory studies discussed in this report.

The salinity of Oyster Creek waters was similar to that of Barnegat Bay proper (Table 3). In February, at Stout's Creek and Holly Park (Potter's Creek), layers of nearly fresh water were present that could have caused death or damage to shipworms at the tops of bulkheadings and in wooden boats.

The precipitation in northern and central New Jersey was above average during the winter of 1981-82 (Table 4). In the month of January, the temperature was nearly 8°F below average. The power plant was not operating during all of this period except the first 10 days of December (Table 5), hence there was no significant $+\Delta T$ in Oyster Creek in the months of January and February (Tables 1 and 2).

Shipworm Populations

There were no shipworms in any monthly panels. The cumulative panels (Tables 6-7) contained a moderate attack of Bankia gouldi at Station 1 (Holly Park) and a lesser but considerable number of Teredo navalis at Station 1 and Stations 4, 5, and 8 in Forked River. There was a heavy infestation of T. bartschi at Station 12 in Oyster Creek, and a moderate attack at the nearby Station 11. No other stations harbored T. bartschi. Overall, the borer attack in Barnegat Bay in 1981 was moderate to light, excluding Oyster Creek.

A comparison of Tables 6 and 7, summarized in Table 8, shows that there had been very low mortality of adult Bankia gouldi in the cumulative panels. Mortality of Teredo navalis was higher, especially in Forked River. Although there was mortality of T. bartschi, it was not as complete as one might expect, considering the absence of a thermal effluent in January and early February when ambient water temperature was less than 5°C.

Table 1

Temperature Profiles in °C, Dec. 1981-Feb. 1982

Station	Dec. 3, 1981	Jan. 7, 1982	Feb. 5, 1982	Differential among months
1	5.0[b]	6.0[a]	2.0	4.0
3	7.3	6.0[a]	3.0[a]	4.3
4	5.2	5.0[b]	2.0	3.2
5	6.0	5.0[b]	2.5	3.5
8	7.0	6.0[a]	1.5[b]	5.5
10	10.5[a]	5.0[b]	2.0	8.5
11	10.5[a]	5.0[b]	2.0	8.5
12	10.5[a]	5.0[b]	2.5	8.0
14	7.0	-	-	-
Differential among stations	5.5	1.0	1.5	

[a] highest value

[b] lowest value

Table 2

Continuous Temperature Recorder Data (°C) for Dec. 3, 1981 - March 9, 1982

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

Date monthly chart was removed	January 7, 1982			February 5, 1982			March 9, 1982		
	1[a]	5[a]	11	1	5	11	1	5	11
Mean daily temp. at 1PM			3.4	1.6	-0.1	0.5	2.8	2.9	3.6
Standard Deviation			2.5	1.0	2.5	1.5	0.8	1.4	1.3
Highest value of temp. at 1 PM			10.0	4.5	5.8	4.9	4.3	7.2	6.3
Lowest value of temp. at 1 PM			0.1	0.1	~-2.0[b]	-1.3	1.2	1.3	1.1
Monthly Range of temp. at 1 PM			9.9	4.4	~7.8[b]	6.2	3.1	5.9	5.4

II. Maximum daily temperature

	January 7, 1982			February 5, 1982			March 9, 1982		
	1[a]	5[a]	11	1	5	11	1	5	11
Mean value of Max. Daily Temp.			3.7	1.8	0.3	0.9	3.4	3.6	4.0
Standard Deviation			2.6	1.0	2.2	1.6	0.8	1.8	1.3
Highest value of Max. Daily Temp.			10.1	4.6	6.5	4.9	5.0	9.0	6.7
Lowest value of Max. Daily Temp.			0.4	0.3	-1.8	-1.0	2.1	1.4	1.2
Monthly Range of Max. Daily Temp.			9.7	4.3	8.3	5.9	2.9	7.6	5.5

[a] Data missing or incomplete

[b] Recorder inaccurate in this range

Table 2, continued

III. Minimum Daily Temperature

	January 7, 1982			February 5, 1982			March 9, 1982		
	1[a]	5[a]	11	1	5	11	1	5	11
Mean value of Min. Daily Temp.			2.5	1.2	<-1.3	0.1	2.1	1.1	2.2
Standard deviation			2.5	1.0	2.7	1.3	0.8	1.7	1.2
Highest value of Min. Daily temp.			9.5	3.9	1.4	4.6	3.9	3.7	4.5
Lowest value of Min. Daily Temp.			-0.9	-0.4	~-2.0[b]	-1.4	0.9	-2.7	0.0
Monthly range of Min. Daily Temp.			10.4	4.3	~3.4	6.0	3.0	6.4	4.5

IV. Daily Temperature Range

	January 7, 1982			February 5, 1982			March 9, 1982		
	1[a]	5[a]	11	1	5	11	1	5	11
Mean ΔT Daily			1.2	0.6	1.6	0.7	1.3	2.5	1.8
Standard Deviation			0.8	0.4	2.0	0.6	0.6	1.9	0.8
Largest Daily ΔT for one month			4.8	1.8	a	2.1	2.4	8.0	3.8
Smallest Daily ΔT for one month			0.1	0.2	0.0	0.0	0.2	0.1	0.4

[a] Data missing or incomplete
[b] Recorder inaccurate in this range.

Table 3

Salinity Profiles in $^{o}/_{oo}$, Dec. 1981 - Feb. 1982

Station	Dec. 3	Jan. 7	Feb. 5	Differential among months
1	21	18	3*	18
3	22	16[b]	2[b]*	20
4	25	24	20	5
5	26[a]	25[a]	20	6
8	25	23	21[a]*	4
10	24	21	18*	6
11	24	22	21[a]	3
12	24	22	21[a]	3
14	15[b]	-	-	-
Differential among stations	11	9	19	

[a]highest value each month

[b]lowest value each month

*ice covered the water

Table 4

Average Temperature and Precipitation in New Jersey, Deviation from Normal. December, 1981 - February, 1982

	Temperature(°F)	Precipitation (inches)
December	-0.8°	+0.6"
January	-7.7°	+1.3"
February	+1.0°	-0.4"

Table 5

Oyster Creek Nuclear Generating Station Outages, Circulation and Dilution Flow in gal. x 10^6 for December, 1981 - February, 1982

	Total Water Flow (gal. x 10^6)	Outage Dates
December	25,152	Dec. 10-31
January	5,310	Jan. 1-31
February	15,608	Feb. 1-28

Table 6

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

Date Removed:	December 3, 1981				January 7, 1982				February 5, 1982			
Station	*B.g.*	*T.n.*	*T.b.*	Total	*B.g.*	*T.n.*	*T.b.*	Total	*B.g.*	*T.n.*	*T.b.*	Total
1	11	7	0	18	12	6	0	18	24	1	0	25
3	1	0	0	1	0	0	0	0	0	0	0	0
4	1	1	0	2	1	4	0	5	0	0	0	0
5	2	1	0	3	0	3	0	3	0	0	0	0
8	0	0	0	0	0	1	0	1	0	4	0	4
10	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	88	88	0	0	68	68	0	1	>100[a]	>101[a]
12	0	0	~1700	~1700	1	0	~840	~841[a]	0	0	~1000[a]	~1000[a]
14	0	0	0	0	-	-	-	b	-	-	-	b
Totals	15	9	~1788	~1812	14	14	~908	~936	24	6	>1100	>1130
1 Rep.	7	4	0	11	8	5	0	13	11	3	0	14
4 Rep.	0	1	0	1	0	4	0	4	1	1	0	2
8 Rep.	0	0	0	0	-	-	-	b	1	0	0	1
11 Rep.	0	1	13	14	0	0	13	13	0	0	0	0

[a]Difficult to distinguish numbers of living vs. dead shipworms, many of which were very small.

[b]No panel.

Rep. = Replicate panel.

Table 7

Numbers of Living Shipworms plus Empty Tubes, Cumulative Panels

Date Removed:	December 3, 1981						January 7, 1982					February 5, 1982			
Station	*B.g.*	*T.n.*	*T.b.*	*T.sp.*	Teredinid	Total	*B.g.*	*T.n.*	*T.b.*	Teredinid	Total	*B.g.*	*T.n.*	*T.b.*	Total
1	12	7	0	0	2	21	13	7	0	1	21	24	1	0	25
3	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
4	1	5	0	0	0	6	1	7	0	0	8	0	5	0	5
5	2	1	0	0	0	3	0	4	0	0	4	0	1	0	1
8	0	6	0	1	0	7	0	5	0	0	5	0	14	0	14
10	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
11	0	0	96	0	0	96	0	0	71	0	71	0	4	~160[a]	~164[a]
12	0	0	~2000	0	1	~2001	1	1	~1200[a]	0	~1202[a]	0	0	~1200[a]	~1200[a]
14	0	0	0	0	0	-	-	-	-	-	b	-	-	-	b
Totals	16	19	~2096	1	3	~2135	15	24	~1271	1	~1311	24	26	~1360	~1410
1 Rep.	8	4	0	0	0	12	8	8	0	0	16	11	3	0	14
4 Rep.	0	2	0	0	0	2	0	6	0	0	6	1	3	0	4
8 Rep.	0	0	0	0	0	0	-	-	-	-	b	1	4	0	5
11 Rep.	0	1	13	0	0	14	0	0	19	0	19	0	0	7	7

[a]Estimated from X-ray.
[b]No panel
Rep. = replicate panel

Table 8

Percentage of Specimens that were Alive when Collected, Cumulative Panels

Month Collected:	December 3, 1981			January 7, 1982			February 5, 1982		
Station	Number Living Specimens	Total no. tubes Observed	% Alive	Number Living Specimens	Total No. tubes Observed	% Alive	Number Living Specimens	Total No. tubes Observed	% Alive
1	18	21	86	18	21	86	25	25	100
3	1	1	100	0	0	-	0	0	-
4	1	6	17	5	8	63	0	5	0
5	3	3	100	3	4	75	0	1	0
8	0	7	0	1	5	20	4	14	29
10	0	0	-	0	0	-	0	1	0
11	88	96	92	68	71	96	>101	~164	>61
12	~1700	~2000	~85	~841	~1202	~70	~1000	~1200	~83
14	0	0	-	-	-	a	-	-	a
Totals	~1812	~2135	-	~936	~1311	-	~1129	~1410	-
1 Rep.	11	12	92	13	16	81	14	14	100
4 Rep.	1	2	50	4	6	67	2	4	50
8 Rep.	0	0	-	-	-	a	1	5	20
11 Rep.	14	14	100	13	19	68	0	7	0

[a]No panel

The pairs of replicate panels at stations 1 and 4 compared well (Table 7). However, those at stations 8 and 11 were not comparable. The great discrepancy between panels 11 and 11 rep. is caused by the patchy nature of the settlement of T. bartschi, and the placement of the particular separate racks on which the panels were placed. The 11C rack was at the end of the dock where water currents were strong, whereas the 11C replicate rack was in towards shore. This shows the difficulty of establishing true replicates where space is limited and the environment changes within a few meters.

Length ranges of shipworms from the cumulative panels are reported in Table 9. No growth increase could be detected over the winter months. In February, the largest specimens of Teredo navalis were in Oyster Creek. Similar comparisons of the size range of Bankia gouldi and T. bartschi could not be made, because these species were not found in both Oyster Creek and other localities. Crowding reduced the size of T. bartschi at Station 12 compared with Station 11. Small specimens of T. bartschi only 0.5 to 2 mm in length at stations 11 and 12 most likely settled in late fall.

The amount of wood lost to borers is recorded in Table 10. There is not a trend of increased wood destruction from December to February, indicating that little growth took place over those months. Wood destruction was greatest at Station 12 in Oyster Creek, where Teredo bartschi was responsible for most of the damage.

Table 11 shows that adults of Teredo bartschi maintained larvae in the gills over the winter. Column 5 shows that only large specimens, ≥20 mm, contained larvae. Yet column 6 shows that some of the largest specimens did not contain larvae. This pattern has been seen before in Oyster Creek. The sample size was small (column 9), but it appeared that the percent of adults carrying larvae (col. 8) did not decline significantly from December to February.

Shipworm Physiological Ecology

Table 12 presents data on the tolerances of adult Teredo navalis and T. bartschi to cold temperatures. Teredo navalis uniformly withdrew the siphons when the water temperature reached 3-4°C. After 2 days at 0°C, 75% of the animals were dead. Teredo bartschi was much more sensitive, withdrawing the siphons at 13-14°C. However, survival is possible when the animals are maintained above 6°C and possibly even lower.

Table 9

Length Ranges of Shipworms, in mm, Cumulative Panels
Submerged May 7, 1981

Date Removed:	December 3, 1981			January 7, 1982			February 5, 1982		
Station	*B.g.*	*T.n.*	*T.b.*	*B.g.*	*T.n.*	*T.b.*	*B.g.*	*T.n.*	*T.b.*
1	23-182	89-231		33-195	108-280*		53-160	115	
3	201								
4	220*	70-139		240*	110-235			92-142	
5	159-170	142			102-194			92	
8		26-84			40-110			35-108	
10								130	
11			1-105*			0.5-117*		159-230*	2-104*
12			0.5-72	155	160	0.5-78			0.5-85
14									
1 Rep.	44-198	74-321*		92-207	16-235		45-180*	60-170	
4 Rep.		15-74			51-137		115	35-116	
8 Rep.							155	11-70	
11 Rep.			1-87			0.5-48			8-64

*Largest specimen each species, each month.

Table 10

Percentage of Wood Weight Lost by Cumulative Panels Collected in Winter, 1981-82

Station	December 3, 1981	January 7, 1982	February 5, 1982
	Date Panel Collected		
1	18.0	28.6	22.7
3	6.8	0.0	0.0
4	8.4	14.8	7.2
5	7.7	11.9	5.8
8	7.1	9.8	10.7
10	0.0	0.0	6.4
11	10.0	11.3	15.7
12	48.8*	35.6*	31.4*
14	0.0	a	a
1 Rep.	19.7	31.3	22.4
4 Rep.	6.8	13.4	13.1
8 Rep.	0.0	a	7.7
11 Rep.	6.0	11.1	8.4

[a]panel lost

*Station with greatest destruction

Table 11

Percentage of Living *Teredo bartschi* Carrying Larvae in the Gills.

Sta.	Month Removed	Months Submerged	Max. Length of ship-worms with Larvae(mm)	Min. Length of ship-worms with Larvae(mm)	Max. length of ship-worms without Larvae (mm)	Min. length of ship-worms without Larvae (mm)	% of adult shipworms with Larvae	Sample size
11	Dec.	7	73	21	105	0.5	70	23
11	Dec.	7	55	40	87	1.0	57	7
12	Dec.	7	72	20	55	0.5	48	48
12	Jan.	8	78	20	72	0.5	23	40
12	Feb.	9	41	21	-	-	100	4

Table 12

Behavior of Adults of *Teredo navalis* and *T. bartschi*
Exposed to Reduced Temperatures

Three replicates. Asterisks represent critical temperature for each species.

Date (1981-1982)	Hour	Temp. (°C.)	No. Siphons *T. bartschi*	No. Siphons *T. navalis*	Temp. (°C.)	No. Siphons *T. bartschi*	No. Siphons *T. navalis*
Init. conditions		20	11,28,5	36,30,17	20	16,28,5	49,30,33
Dec.14	9	19	11,28,5	36,30,17	19	7,17,1	13,6,26
	12	16	8,16,3	15,11,8	17	-	-
	16	9	0,0,0	1,14,1	17	4,20,2	44,22,19
Dec. 15	9	5	0	1,23,1	17	6,20,2	35,22,22
	12	4	0	0,17,0	17	10,23,2	39,22,25
	16	4	0	0,19,0	18	9,21,2	35,22,25
Dec. 16	12	4	0	0,27,0	19	5,12,0	35,18,21
Dec. 17	9	1	0	0,0,0	12*	0,2,0*	35,9,28
	12	2	0	0,8,0	15	10,13,2	38,14,30
	16	3*	0	0,2,0*	20	9,24,2	46,24,33
Dec. 18	12	4*	0	0,22,0*	18	9,19,2	43,14,22
Dec. 21	9	-1	0	0	12*	0*	29,0,25
	12	0	0	0	20	12,30,2	28,20,20
Dec. 22	16	4	0	0	14*	4,12,1*	39,4,27
Dec. 23	9	7	0	0,27,0	13*	0,2,1*	36,0,24
	12	9	0	0,26,0	21	10,24,1	38,21,27
Dec. 24	9	5	0	0,25,0	18	7,24,1	17,19,29
Dec. 28	9	5	0	0,16,0	17	6,19,1	39,20,28

Table 12 continued

Dec. 29	9	5	0	0,22,0	18	9,20,1	37,24,27
Dec. 30	9	0*	0	0,1,0*	16	0,21,0	42,20,27
	12	3*	0	0,5,0*	18	3,22,2	41,23,28
	16	5	0	0,12,0	19	4,19,2	39,22,23
Dec. 31	9	-2	0	0,1,0	16	16,13,2	42,14,23
	12	0	0	0,0,0	17	7,21,2	38,21,28
	16	1	0	0,0,0	17	5,24,2	45,21,26
Jan. 4	9	7	0	0,13,0	14	6,14,0	43,21,23
Jan. 5	9	5	0	0,5,0	19	5,16,1	46,13,30
Jan. 6	9	3	0	0,3,0	15	1,8,1	42,20,29
Jan. 8	16	4	0	0,2,0	24	5,25,2	41,15,24
Jan. 11	9	Discontinued			7	0,0,0	30,0,18
	12				10*	0,0,0*	32,0,16*
	16				20	6,20,2	41,10,24
Jan. 12	9				30	7,24,2	-
	16				24	6,25,2	

CONCLUSIONS AND RECOMMENDATIONS

It appears that individuals of Teredo bartschi have adapted to survive the cold winters of Barnegat Bay, New Jersey, even when the Oyster Creek Nuclear Generating Staion is not operating. They do so only at two stations in Oyster Creek, however. Shipworms taken into the laboratory from Oyster Creek in 1981 still show significantly less tolerance to temperatures below 14°C than do the native T. navalis. Shipworms reduce their activity at temperatures above those that cause mortality.

We conclude that Teredo bartschi will not be eliminated from Oyster Creek easily. A concerted effort should be made to physically remove the contaminated wood, and to avoid the introduction of any untreated wood in Oyster Creek and Forked River. Wooden vessels entering Oyster Creek from the southern U.S., particularly Florida, should be inspected for shipworms.

REFERENCES

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

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

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

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

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

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

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

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

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

APPENDIX: STATION LOCALITIES

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

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

DISTRIBUTION LIST

DISTRIBUTION CATEGORY: RE

Supplemental Distribution: 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.1.
Waretown, New Jersey 08758

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

Mr. Charles Kochman
Compass Road
Waretown, New Jersey 08758

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

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

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

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

Part B

Battelle Columbus Laboratories
Clapp Laboratories
Duxbury, Massachusetts 02332

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

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

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

Mr. John Makai
Na[illegible]ek Research Station
St[illegible]
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

NRC FORM 335 (7-77)

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

1. REPORT NUMBER (Assigned by DDC): NUREG/CR-2727 Vol. 2

2. (Leave blank)

3. RECIPIENT'S ACCESSION NO.

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 December 1981 - February 1982

5. DATE REPORT COMPLETED: MONTH June, YEAR 1982

DATE REPORT ISSUED: MONTH August, YEAR 1982

6. (Leave blank)

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

9. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)
Department of Malacology
Academy of Natural Sciences
19th and the Parkway
Philadelphia, PA 19103

8. (Leave blank)

10. PROJECT/TASK/WORK UNIT NO.

11. CONTRACT NO.
NRC-04-82-009
FIN B8138

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, DC 20555

13. TYPE OF REPORT: Progress Report

PERIOD COVERED (Inclusive dates): December 1, 1981 - February 28, 1982

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 winter of 1981, the generating station experienced a prolonged outage. The reproductive cycle of the shipworms was not extended. *Teredo bartschi* was very abundant at one station in Oyster Creek and moderately abundant at a second, but did not exist elsewhere in Barnegat Bay. Some specimens of *Teredo bartschi* contained larvae in the gills in February. According to laboratory experiments, *Teredo navalis* is able to remain active at temperatures as low as 4°C, whereas *T. bartschi* ceases activity (withdraws its siphons) at about 13°C.

17. KEY WORDS AND DOCUMENT ANALYSIS

17a. DESCRIPTORS

Thermal Effects
Shipworms
Oyster Creek
Teredo bartschi
Teredo navalis
Bankia gouldi

17b. IDENTIFIERS/OPEN-ENDED TERMS

18. AVAILABILITY STATEMENT: Unlimited

19. SECURITY CLASS (This report): Unclassified

20. SECURITY CLASS (This page): Unclassified

21. NO. OF PAGES

22. PRICE: $

NRC FORM 335 (7-77)

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

FOURTH CLASS MAIL
POSTAGE & FEES PAID
USNRC
WASH. D. C.
PERMIT No. G67

120555078877 1 ANRE
US NRC
ADM DIV OF TIDC
POLICY & PUBLICATIONS MGT BR
PDR NUREG COPY
LA 212
WASHINGTON DC 20555

NUREG/CR-2727, Vol. 2 ECOLOGICAL STUDIES OF WOOD-BORING BIVALVES IN THE VICINITY OF THE OYSTER CREEK NUCLEAR GENERATING STATION AUGUST 1982