NUREG/CR-2727
Vol. 3

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

Progress Report
March-May 1982

Prepared by K. E. Hoagland

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 $4.75

NUREG/CR-2727
Vol. 3

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

Manuscript Completed: September 1982
Date Published: November 1982

Prepared by
K. E. Hoagland

Academy of Natural Sciences of Philadelphia
Department of Malacology
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.
	Vol. 2 December, 1981-February, 1982, 28 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. The adult population of *Teredo bartschi* survived the winter and spring of 1981-82 better than it did previous cold periods without a thermal effluent. Lack of an effluent was due to a prolonged outage of the generating station. There was no spring outbreak of shipworms. The introduced species appears established at one station near but outside of Oyster Creek. Three teredinid species coexist in Oyster Creek. Larvae of *T. bartschi* and *T. navalis* have similar responses to reduced salinity. *Bankia gouldi* is the fastest-growing of the teredinids found in New Jersey, and has the lowest annual mortality.

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 winter and spring. One outage lasted from mid December to mid April.

2. When the station was operating, April and May, the ΔT was only about 3°C. Beginning in mid-April, the temperatures were high enough at all stations for gonad development to begin.

3. The salinity in Oyster Creek was 2-4 ‰ lower than Barnegat Bay. Some water was being pumped even when the generating station was not operating.

4. All salinities at all stations were high enough to support shipworms. There was no drought, however.

5. Teredo bartschi was found at stations 11 and 12 in Oyster Creek and Station 8 between Oyster Creek and Forked River, within the influence of the effluent from the nuclear generating station.

6. The lighter shipworm attack in spring, 1982, compared with other years, is attributed to the prolonged outage of the generating station.

7. When density is low, Bankia gouldi causes more damage to wood per individual than the other species.

8. A significant percentage of Teredo bartschi, at least 25%, are able to survive winter temperatures without the presence of a thermal effluent. This may be the result of natural selection.

9. No larvae settled during the period of this report, yet some specimens of Teredo bartschi were able to maintain larvae in the gills through the year.

10. Newly-released larvae of both species show osmotic stress below 7 $^{o}/_{oo}$ at a temperature of 20°C.

11. The fouling community in Barnegat Bay is diverse in May, with the settlement of many species of sedentary invertebrates.

TABLE OF CONTENTS

LIST OF TABLES

ACKNOWLEDGMENTS

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

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

March - May, 1982

INTRODUCTION

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

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

METHODS

Stations

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

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

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

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

Field work

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

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

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

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

Laboratory Work

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

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).

Physiological Experiment

Newly-released veligers of *Teredo navalis* and pediveligers of *T. bartschi* were placed in filtered seawater of 22 ‰, 20°C. The salinity was reduced gradually by injecting water of lower salinity through a pipet, allowing for mixing to take place via a magnetic stirrer. The rate of reduction was approximately 3 ‰ per hour. The behavior of 50 individuals of *T. navalis* and 10 of *T. bartschi* was observed for 3-minute periods every 30 minutes. The point at which the larvae ceased to swim normally was recorded.

RESULTS AND DISCUSSION

Physical Factors

Temperature profiles (Tables 1, 2) show a 16°C heating of the water of Barnegat Bay from March to May, 1982. There was only a 2.5 to 3.5° difference among stations for any month. In Table 1, only on the May 9 date are temperatures recorded when the power plant was operating. Then, the ΔT was about 3°C. As in previous months, the temperatures at Station 3 were about 2°C above ambient due to a thermal addition unrelated to the power plant. More detail is available in Table 2. The higher average temperatures at station 11 versus station 1 in the first month are an artifact, due to the chart at station 1 stopping on April 1. The average ΔT in the other months was about 3 °C. There was no evidence of recirculation of the thermal effluent into Forked River in the month of May.

Salinity profiles (Table 3) show freshwater runoff affecting stations 1 and 3. Table 4 indicates some lack of rain in New Jersey in March, but not in April and May. The northern portions of the drainage area contributed normal or above-normal amounts of water to the area in the spring months. The Oyster Creek area had salinities 2-4 ‰ lower than Barnegat Bay (station 8). Even when the plant was not operating, enough water was being pumped to maintain salinities close to those of Barnegat Bay (Table 5). All salinities at all stations listed in Table 3 were high enough to support shipworms, although station 3 had salinities lower than those usually associated with natural populations of *Teredo navalis*. Our laboratory experiments have given a value of ~22‰ for the optimal salinity for *T. bartschi* in Oyster Creek.

Shipworm Populations

There were no shipworms in any of the one-month panels submerged in the spring of 1982. This pattern has held true throughout our seven-year study of teredinids in Barnegat Bay. Successful reproduction and settlement of teredinids is limited to summer and fall.

Tables 6-7 enumerate the adult teredinids found in panels submerged May 7, 1981, and removed the following spring. The panels from the last month, May, 1982, are equivalent to the yearly panels. Most of the shipworms removed from the panels were *Teredo bartschi*, although this introduced warm-water species was found alive in significant numbers only at two stations (both in Oyster Creek within the thermal effluent).

Table 1

Temperature Profiles in °C, March - May 1982

Station	March 9, 1982	April 12, 1982	May 9, 1982*	Differential among months
1	3.0[b]	8.0[b]	19.5	16.5
3	5.5[a]	10.0	21.0	15.5
4	3.0[b]	9.0	19.0	16.0
5	4.0	9.0	19.0	15.0
8	3.0[b]	10.5[a]	18.5[b]	15.5
10	5.0	8.0[b]	22.0[a]	17.0
11	4.0	9.0	22.0[a]	18.0
12	4.0	10.0	22.0[a]	18.0
14	-	-	20.0	-
Differential among stations	2.5	2.5	3.5	

[a]highest value

[b]lowest value

*plant on

Table 2

Continuous Temperature Recorder Data (°C) for March 9 - June 9, 1982

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

Date monthly chart was removed	April 12, 1982		May 9, 1982		June 9, 1982		
	1[a]	11[b]	1	11	1	5	11
Mean daily temp. at 1PM	7.7	8.8	14.6	17.7	18.8	18.4	22.3
Standard Deviation	1.4	1.9	3.1	3.5	1.7	1.8	2.3
Highest value of temp. at 1 PM	9.4	10.6	19.1	22.0	21.3	21.9	27.2
Lowest value of temp. at 1 PM	3.2	4.0	7.3	8.4	14.6	14.4	15.7
Monthly Range of temp. at 1 PM	6.2	6.6	11.8	13.6	6.7	7.5	11.5

II. Maximum daily temperature

	April 12, 1982		May 9, 1982		June 9, 1982		
	1[a]	11[b]	1	11	1	5	11
Mean value of Max. Daily Temp.	8.2	9.3	15.3	18.3	19.6	19.2	23.0
Standard Deviation	1.4	2.0	3.0	3.4	1.6	1.8	2.8
Highest value of Max. Daily Temp.	10.0	12.7	19.5	22.5	21.8	22.5	27.6
Lowest value of Max. Daily Temp.	3.7	4.2	7.9	8.6	15.2	14.8	15.7
Monthly Range of Max. Daily Temp.	6.3	8.5	11.6	13.9	6.6	7.7	11.9

[a]Data incomplete; chart stopped on April 1.
[b]Chart stopped on April 8.

Table 2, continued

III. Minimum Daily Temperature

	April 12, 1982		May 9, 1982		June 9, 1982		
	1[a]	11[b]	1	11	1	5	11
Mean value of Min. Daily Temp.	6.6	6.3	13.3	15.5	17.9	17.2	20.6
Standard deviation	1.5	2.3	3.0	3.7	1.6	1.7	2.8
Highest value of Min. Daily temp.	8.5	10.1	17.6	20.0	20.4	20.7	26.2
Lowest value of Min. Daily Temp.	1.9	2.1	6.8	6.4	14.3	14.0	14.9
Monthly range of Min. Daily Temp.	6.6	8.0	10.8	13.6	6.1	6.7	11.3

IV. Daily Temperature Range

	April 12, 1982		May 9, 1982		June 9, 1982		
	1[a]	11[b]	1	11	1	5	11
Mean ΔT Daily	1.6	3.0	2.0	2.9	1.7	2.0	2.3
Standard Deviation	0.7	1.6	0.8	1.1	0.7	0.9	1.0
Largest Daily ΔT for one month	2.9	6.2	3.9	5.4	3.4	3.8	5.5
Smallest Daily ΔT for one month	0.3	0.8	0.7	0.6	0.5	0.3	0.5

[a]Data incomplete; chart stopped on April 1.
[b]Chart stopped on April 8.

Table 3

Salinity Profiles in °/₀₀, March - May, 1982

Station	March 9	April 12	May 9	Differential among months
1	22	19	19	3
3	16[b]	18[b]	18[b]	2
4	24	27[a]	24	3
5	25[a]	26	24	2
8	24	26	25[a]	2
10	21	23	23	3
11	22	23	22	1
12	21	23	22	2
14	-	-	23	-
Differential among stations	9	9	7	

[a]highest value each month

[b]lowest value each month

Note: Accuracy is ±1°/₀₀

Table 4

Average Temperature and Precipitation in New Jersey, Deviation from Normal. March - May, 1982

	Temperature(°F)	Precipitation (inches)
March	-1.0°	-1.6"
April	-1.00	+1.1"
May	+1.0°	+2.9"

Table 5

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

	Total Water Flow (gal. x 10^6)	Outage Dates
March	6,720	March 1-31
April	27,776	April 1-15
May	32,400	May 24-27

Table 6

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

Date Removed:	March 9, 1982				April 12, 1982				May 9, 1982			
Station	B.g.	T.n.	T.b.	Total	B.g.	T.n.	T.b.	Total	B.g.	T.n.	T.b.	Total
1	20	8	0	28	9	6	0	15	20	7	0	27
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	2	1	0	3	0	0	0	0
5	0	0	0	0	0	0	0	0	2	0	0	2
8	2	0	0	2	1	2	0	3	1	0	2	3
10	0	0	0	0	0	0	0	0	0	0	0	0
11	2	0	64	66	2	1	4	7	0	1	16	17
12	0	0	22	22	0	0	88	88	0	1	15	16
Totals	24	8	86	118	14	10	92	116	23	9	33	65
1 Rep.	2	5	0	7	6	8	0	14	3	8	0	11
4 Rep.	0	0	0	0	1	0	0	1	0	0	0	0
8 Rep.	0	0	0	0	2	0	0	2	2	0	0	2
11 Rep.	0	0	36	36	0	0	30	30	0	0	0	0

Rep. = Replicate panel.

Table 7

Numbers of Living Shipworms plus Empty Tubes, Cumulative Panels

Date Removed:	March 9, 1982				April 12, 1982				May 9, 1982			
Station	B.g.	T.n.	T.b.	Total	B.g.	T.n.	T.b.	Total	B.g.	T.n.	T.b.	Total
1	20	8	0	28	9	6	0	15	20	9	0	29
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	5	0	5	2	10	0	12	0	7	0	7
5	0	1	0	1	1	2	0	3	2	4	0	6
8	2	5	0	7	1	9	0	10	1	4	47	52
10	0	0	0	0	0	0	0	0	0	0	0	1
11	2	0	120	122	2	3	65	70	0	3	23	26
12	0	0	100	100	0	0	115	115	0	2	95	97
Totals	24	19	220	263	15	30	180	225	23	29	165	217
1 Rep.	2	5	0	7	6	8	0	14	3	9	0	12
4 Rep.	0	3	0	3	1	2	0	3	1	1	0	2
8 Rep.	0	0	0	0	2	0	0	2	2	3	0	5
11 Rep.	0	0	56	56	0	0	41	41	0	1	7	8

Rep. = Replicate panel.

All three of the species of teredinids were found in Oyster Creek. Both Teredo navalis and Bankia gouldi were most abundant at Holly Park, the northernmost station. Specimens of Teredo bartschi were found at Bayside Beach Club on the bay between Oyster Creek and Forked River but most were dead. The replicate panel pairs were similar in species composition and abundance. The overall attack of shipworms was heaviest in Oyster Creek, followed by Bayside Beach Club and Holly Park. There were no shipworms at the control creek station #3, and very few in Forked River.

A comparison of tables 6-8 reveals that mortality of Bankia gouldi was very light. Only two of 79 specimens (2%) had died since the panels were deployed. Both were in Forked River. On the other hand, 62 of 110 Teredo navalis (56%) and 392 of 669 T. bartschi (59%) had died. By station, mortality was least at Holly Park and greatest in Forked River. Because the generating station was not operating during most of the period, mortality in Oyster Creek and Forked River was as high as elsewhere. However, our past studies have shown that adult mortality of the two Teredo species is high every year at all stations, regardless of the presence of the thermal effluent.

Length ranges of the shipworms removed from the cumulative panels are given in Table 9. Changes in the size ranges from month to month are due to sampling variance and mortality of large specimens. There is no trend of larger size in Oyster Creek, and none was expected due to prolonged outages of the generating station in the past year.

Tables 10 and 11 present the numbers of living teredinids and the total number, respectively, found in yearly panels. No yearly panels were deployed in March, 1981, because of ice cover in Barnegat Bay. The species composition and abundances at the various stations are quite similar to the 10, 11, and 12-month cumulative panels reported in tables 6 and 7. This result is expected because no larval settlement occurred during the short period when one set of panels was submerged and the other was not. As before, Teredo bartschi was limited to stations 8, 11, and 12.

Mortality was virtually nonexistent in Bankia gouldi, but was 75% in T. navalis and 76% in T. bartschi. The greatest shipworm attack was at stations 11 and 12 in Oyster Creek, followed by Holly Park and Barnegat Bay near Oyster Creek (station 8). The lack of shipworms at station 10 near the mouth of Oyster Creek is probably due to its being in an arti-

Table 8

Percentage of Specimens that were Alive when Collected, Cumulative Panels

Month Collected:	March 1982			April 1982			May 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	28	28	100	15	15	100	27	29	93
3	0	0	-	0	0	-	0	0	-
4	0	5	0	3	12	25	0	7	0
5	0	1	0	0	3	0	2	6	33
8	2	7	29	3	10	30	3	52	6
10	0	0	-	0	0	-	0	0	-
11	66	122	54	7	70	10	17	26	65
12	22	100	22	88	115	77	16	97	16
Totals	118	263	45	116	225	52	65	217	30
1 Rep.	7	7	100	14	14	100	11	12	92
4 Rep.	0	3	0	1	3	33	0	2	0
8 Rep.	0	0	-	2	2	100	2	5	40
11 Rep.	36	56	64	30	41	73	0	8	0

Rep. = Replicate panel.

Table 9

Length Ranges of Shipworms in Cumulative Panels

Date Removed:	March, 1982			April, 1982			May, 1982		
Station	B.g.	T.n.	T.b.	B.g.	T.n.	T.b.	B.g.	T.n.	T.b.
1	28-205	30-140	-	41-153	130-220	-	38-207	7-217*	-
3	-	-	-	-	-	-	-	-	-
4	-	30-220*	-	82-85	12-132	-	-	43-172	-
5	-	115	-	170	87-92	-	162-236*	10-145	-
8	170-215*	16-81	-	106	7-123	-	151	33-54	2-40
10	-	-	-	-	-	-	-	-	-
11	105-187	-	2-109*	200-210*	95-360*	3-105*	-	95-180	2-87*
12	-	-	3-69	-	-	2-76	-	180-185	2-87*
1 Rep.	68-84	106-191	-	98-152	70-193	-	36-149	48-152	-
4 Rep.	-	21-91	-	129	46-180	-	93	134	-
8 Rep.	-	-	-	190-210*	-	-	161-230	38-117	-
11 Rep.	-	-	2-44	-	-	3-43	-	84	6-40

*Largest specimen each species, each month.

Table 10

Numbers of Living Shipworms in Yearly Panels

Date Removed:	April 12, 1982				May 9, 1982			
Station	*B.g.*	*T.n.*	*T.b.*	Total	*B.g.*	*T.n.*	*T.b.*	Total
1	16	2	0	18	26	0	0	26
3	1	0	0	1	0	0	0	0
4	0	1	0	1	0	0	0	0
5	2	0	0	2	1	1	0	2
8	5	1	0	6	3	2	6	11
10	0	0	0	0	0	0	0	0
11	0	0	35	35	0	0	21	21
12	0	0	78	78	0	0	0	0
Totals	24	4	113	141	30	3	27	60
1 Rep.	19	1	0	20	8	0	0	8
11 Rep.	0	0	38	38	0	1	11	12

Table 11

Numbers of Living Shipworms plus Empty Tubes, Yearly Panels

Date Removed:	April 12, 1982				May 9, 1982				
Station	B.g.	T.n.	T.b.	Total	B.g.	T.n.	T.b.	Tsp.*	Total
1	17	2	0	19	26	0	0		26
3	1	0	0	1	0	0	0		0
4	0	1	0	1	0	2	0		2
5	2	8	0	10	1	3	0		4
8	5	5	0	10	3	10	8	20	41
10	0	0	0	0	0	0	0		0
11	0	0	86	86	0	0	64		64
12	0	0	110	110	0	2	64		64
Totals	25	16	196	237	30	17	136	20	201
1 Rep.	19	1	0	20	8	0	0		8
11 Rep.	0	1	380	381	0	1	90		91

*Most are probably *T. bartschi*

ficial lagoon with poor general circulation into Oyster Creek and the bay. As in the cumulative panels, mortality was light in Holly Park (Table 12). It was heavy in Oyster Creek.

Table 13 gives the lenth ranges of the specimens removed from the yearly panels. As in Table 9, which gives lengths for the cumulative panels, there is no pattern associated with the nuclear generating station because the generating station was not operating during most of the winter and spring (from mid December to mid April).

The percentage of the wood of each panel that was destroyed by the teredinids is presented in Table 14. Despite the greater number of specimens in panels from Oyster Creek, the greatest damage was done at Holly Park. This is because the dominant species at Holly Park, Bankia gouldi, grows faster and reaches a larger size than does Teredo bartschi, which dominated in Oyster Creek.

No sign of reproductive activity was seen in specimens of Bankia gouldi and Teredo navalis removed from the spring panels. However, many specimens of Teredo bartschi [illegible] carry larvae in the gills through the winter and spring (Table 15). Interestingly, the maximum length of shipworms with larvae was consistently less than that of specimens without larvae. Teredo bartschi is supposed to be protandrous, in which case the largest individuals should be female. Histological examination of some of the large T. bartschi without larvae is underway. The percent of adults carrying larvae did not change significantly from March to May, but it varied considerably among replicate panels (eg. 50% and 11% in March replicates from [illegible] 11).

Fouling Organisms

Table 16 lists the major macroscopic fouling organisms at each station for the month of May, in order of abundance. Abundance was determined as the coverage of space on racks and panels. It is clear that many invertebrates and some algae already had settled in May, even though teredinids did not. The greatest number of taxa occurred at station 4; the lowest number occurred at station 3 where salinity is lowest. No taxon was found at every station. Even stations adjacent to one another such as 10 and 11 varied greatly in species composition and rank abundance. A detailed analysis of patterns will be given in our final report. It can be noted now that the green alga Entermorpha intestinalis dominated in the Forked River area, while Electra sp. was dominant in the main channel of Oyster Creek. We have sent a sample of

Table 12

Percentage of Specimens that were Alive when Collected
1982 Yearly Panels

Month Collected:	April 1982			May 1982		
Station	Number Living Specimens	Total No. tubes Observed	% Alive	Number Living Specimens	Total No. tubes Observed	% Alive
1	18	19	95	26	26	100
3	1	1	100	0	0	-
4	1	1	100	0	2	0
5	2	10	20	2	4	50
8	6	10	60	11	41	27
10	0	0	-	0	0	-
11	35	86	41	21	64	33
12	78	110	71	0	64	0
Totals	141	237	59	60	201	30
1 Rep.	20	20	100	8	8	100
11 Rep.	38	381	10	12	91	13

Table 13

Length Ranges of Shipworms, in mm, Yearly Panels

Date Removed:	April 12, 1982			May 9, 1982		
Station	B.g.	T.n.	T.b.	B.g.	T.n.	T.b.
1	25-155	14-115	-	56-166	-	-
3	70	-	-	-	-	-
4	-	87	-	-	118-129	-
5	147-176	42-240*	-	180	114-170	-
8	140-175	17-115	-	150-230*	32-160	19-42
10	-	-	-	-	-	-
11	-	-	2-103	-	-	5-95
12	-	-	3-77	-	175-190*	1-76
14	No Panel			No Panel		
1 Rep.	48-202*	154		46-222	-	-
11 Rep.	-	72	2-116*	-	107	2-96*

*Largest specimen each species, each month.

Table 14

Percentage of Wood Weight Lost by Panels Collected in Spring, 1982

Date Removed:	March 9	April 12		May 9	
Station	Cumulative	Cumulative/Yearly		Cumulative/Yearly	
1	35.5[a]	21.4	26.1	33.2[a]	46.5[a]
3	0.0	0.0	5.0	8.6	6.1
4	9.5	12.1	6.9	11.6	4.1
5	5.0	10.0	14.3	9.9	9.9
8	14.1	8.7	17.8	7.9	12.9
10	8.5	7.4	5.7	2.0	3.9
11	16.6	17.1	12.0	9.2	5.7
12	10.4	9.9	7.7	9.9	7.4
1 Rep.	16.3	24.3[a]	27.6[a]	20.5	b
4 Rep.	9.9	9.4	b	10.8	b
8 Rep.	6.9	11.4	b	12.1	b
11 Rep.	11.6	7.2	20.4	7.0	b

[a] Station with greatest destruction, each month.
[b] No panel. Used in lab studies.

Table 15

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	Panel Composition
11	March	10	62	16	109	2	50	40 adults, 64 total living
11	March	10	36	36	44	2	11	9 adults, 36 total living
12	March	10	43	31	45	3	20	15 adults, 22 total living
11	April	11	28	28	58	23	25	4 adults, 4 total living
11	April	11	43	43	24	3	8	12 adults, 30 total living
12	April	11	39	14	46	2	21	38 adults, 88 total living

Table 15 cont.

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	Panel Composition
11	April	12	72	49	116	2	14	22 adults, 38 total living
12	April	12	67	29	77	3	23	62 adults, 78 total living
8	May	12	42	37	38	19	33	6 living, all adults
11	May	12	-	-	87	3	0	14 adults, 16 total living
11	May	12	46	25	95	5	28	18 adults, 21 total living
12	May	12	-	-	-	-	-	All dead

Table 16. Most Abundant Macroscopic Fouling Organisms on Racks and Panels May, 1982

STATION

1	3	4	5
Campanulareid hydroid	*Balanus eburneus*	*Enteromorpha intestinalis*	*Enteromorpha intestinalis*
Balanus eburneus	*Corophium* spp.	*Bowerbankia* sp.	*Codium fragile*
Anemone: striped + yellow	Anemone: striped	*Electra* sp.[b]	*Ilyanassa obsoleta* + eggs
Botryllus schlosseri	Parchment tubes	*Polysiphonia harveyi*	*Hydroides dianthus*
Blue-green algae	Blue-green algae	*Codium fragile*	*Electra* sp.[b]
Electra sp.[b]	*Nereis succinea*	*Mytilus edulis*	*Doradella obscura*
Hydroides dianthus		*Botryllus schlosseri*	Campanulareid Hydroid
Corophium spp.		*Amanthia* sp.	Blue-green algae
Nereis succinea		*Balanus eburneus*	
Enteromorpha intestinalis		*Hydroides dianthus*	
Neopanope sayi		*Microciona prolifera*	
Parchment tubes		*Ulva lactuca*	
		Parchment tubes	
		Amphipoda spp.	
		Bittium alternatum	

[a] In order of abundance; most abundant first.

[b] May be *Membranipora*

Table 16, continued

STATION

8	10	11	12
Enteromorpha intestinalis	*Dasya*	*Electra* sp.[b]	*Electra* sp.[b]
Ulva lactuca	*Bowerbankia* sp.	*Enteromorpha intestinalis*	*Balanus eburneus* + eggs
Polysiphonia harveyi	*Balanus eburneus*	*Balanus eburneus* + eggs	*Bowerbankia* sp.
Dasya	*Molgula manhattensis*	*Polysiphonia harveyi*	*Barentsia* sp.
Amanthia	*Hydroides dianthus*	*Bowerbankia* sp.	
Molgula manhattensis	*Neopanope sayi*	*Barentsia* sp.	*Enteromorpha intestinalis*
Agardhiella	*Electra* sp.[b]	Anemone:striped	
Balanus eburneus	*Enteromorpha*	*Mytilus edulis*	
Hydroides dianthus	*Polysiphonia harveyi*	*Hydroides dianthus*	
Blue-green algae	Amphipoda spp.	*Crepidula convexa*	
Electra sp.[b]	Blue-green algae		
Neopanope sayi			

[a]In order of abundance; most abundant first.

[b]May be *Membranipora*

Electra sp. to a bryzoan taxonomist; it may actually be a member of the genus Membranipora. Oyster Creek stations are also characterized by growth of such encrusting organisms as the Entoproct Barentsia sp., the bryozoan, Bowerbankia sp., and the barnacle Balanus eburneus. Other species of barnacles may have been present as young individuals, but they were not identified in the field.

Shipworm Physiological Ecology

Reduction of salinity causes stress and eventual death to larvae of teredinids, but the point at which such stress is evident may differ according to the species. Swelling and loss of ability to swim are signs of osmotic stress in teredinid larvae. Using these criteria, 50 veligers of Teredo navalis and 10 pediveligers of T. bartschi were observed for an 8-hour period as salinity was gradually reduced from 22°/₀₀. All the larvae used in the experiment had been released from adults during the previous 48 hours and were observed to swim normally. Control animals swam normally throughout the course of the experiment.

Virtually no change in behavior was observed for Teredo navalis until 5 hours into the experiment when 6 °/₀₀ was reached. Then, 40% of the larvae quite suddenly showed abnormal swimming, swelling, or both. Twenty percent of the pediveligers of T. bartschi showed osmotic stress at 10°/₀₀ and 60% at 7°/₀₀. At 10 °/₀₀, 50% of the pediveligers exhibited burrowing behavior, while only 20% of the controls exhibited such behavior. These results suggest the hypothesis that lower salinity elicits burrowing behavior. A repeat trial of the low salinity experiment with another 10 Teredo bartschi gave different results. All specimens appeared normal until 4°/₀₀ was reached, when all appeared stressed.

CONCLUSIONS

The outbreak of teredinids in Oyster Creek and neighboring portions of Barnegat Bay does not occur when the Oyster Creek Nuclear Generating Station is not operating in winter and early spring. Mortality of adults, especially Teredo species, is high, and there is no early reproduction. I predict on the basis of the data in this report that an outbreak of Teredo bartschi will not occur until at least the end of the summer of 1982 (September-October). If it does occur, stations 12, 11 and 8 are the most likely centers of reproduction of the introduced species. The population bottleneck is not as severe in 1982 as it was in past years, because individuals survived the winter at 3 stations rather than one. At least 25% of the individuals of T. bartschi survived; perhaps due to natural selection, the population has become more cold-tolerant than those found in Florida.

The growth of shipworms is minimal during early spring. Teredo bartschi can retain larvae over the winter and spring. Because the largest specimens of Teredo bartschi contained no larvae, the possibility exists that they are male and that sex change in the species is more complicated than simple protandry. A moderate attack of Bankia gouldi causes more wood destruction than a moderate attack of T. bartschi.

The tolerances of newly-released larvae of Teredo navalis and Teredo bartschi to low salinity are similar; around 6-7 °/oo causes severe stress. Signs of stress appear suddenly if salinity is reduced at a rate of 3 °/oo per hour. Pediveligers of T. bartschi seem to have a slightly greater variance in lower salinity tolerance; this may be due to either the composition of the population or more likely, the later developmental stage of the larvae. It is hypothesized that reduction in salinity within physiological tolerance may elicit a burrowing response in pediveligers of T. bartschi.

The fouling community diversifies rapidly in spring. The fouling com-munity is highly variable from month to month and from station to sta-tion. Diversity is lowest in Stout's Creek (station 3), where salinity is low. The operation of the nuclear generating station, by raising the salinity of Oyster Creek and Forked River, has increased the biomass and diversity of fouling organisms in both creeks, so that the fouling community is now more like that occurring in Barnegat Bay.

REFERENCES

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

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

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

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

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

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

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

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

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

APPENDIX: STATION LOCALITIES

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

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

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

DISTRIBUTION LIST

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
Nacote Creek Research Station
Star Route
Absecon, New Jersey 08201

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

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

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

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

NRC FORM 335
(7.77)

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

1. REPORT NUMBER (Assigned by DDC)
NUREG/CR-2727 Vol. 3

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

2. (Leave blank)

3. RECIPIENT'S ACCESSION NO.

7. AUTHOR(S)
K. E. Hoagland

5. DATE REPORT COMPLETED
MONTH September | YEAR 1982

9. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)
Department of Malacology
Academy of Natural Sciences of Philadelphia
19th and the Parkway
Philadelphia, PA 19013

DATE REPORT ISSUED
MONTH November | 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, DC 20555

10. PROJECT/TASK/WORK UNIT NO.

11. CONTRACT NO.
B8138

13. TYPE OF REPORT
Quarterly Progress Report

PERIOD COVERED (Inclusive dates)
March 1, 1982 - May 30, 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. The adult population of Teredo bartschi survived the winter and spring of 1981-82 better than it did previous cold periods without a thermal effluent. Lack of an effluent was due to a prolonged outage of the generating station. There was no spring outbreak of shipworms. The introduced species appears established at one station near but outside of Oyster Creek. Three teredinid species coexist in Oyster Creek. Larvae of T. bartschi and T. navalis have similar responses to reduced salinity. Bankia gouldi is the fastest-growing of the teredinids found in New Jersey, and has the lowest annual mortality.

17. KEY WORDS AND DOCUMENT ANALYSIS

Thermal Effects
Shipworms
Oyster Creek
Teredo bartschi
Teredo navalis
Bankia gouldi

17a. DESCRIPTORS

17b. IDENTIFIERS/OPEN-ENDED TERMS

18. AVAILABILITY STATEMENT
Unlimited

19. SECURITY CLASS (This report)
Unclassified

21. NO. OF PAGES
34

20. SECURITY CLASS (This page)
Unclassified

22. PRICE
$

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. 3

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

NOVEMBER 1982