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Analysis of Populations of Boring and Fouling Organisms in the Vicinity of the Oyster Creek Nuclear Generating Station

Quarterly Progress Report
March - May 1979

Prepared by K. E. Hoagland, L. Crocket, J. Harms

Wetlands Institute
Lehigh University

Prepared for
U. S. Nuclear Regulatory Commission

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ABSTRACT

The growth, distribution, and species composition of marine borers (primarily shipworms) and fouling organisms 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 18 localities. Our most recent findings covering March-May, 1979, are that at least one subtropical species of the borer family Teredinidae continues to live in Oyster Creek and Forked River.

Despite dredging activity in Oyster Creek and unscheduled plant shut-downs, some *T. bartschi* survived. No settlement of larvae on one-month panels occurred. Much of the fouling in Oyster Creek died due to the dredging activities, and anoxic conditions occurred at stations 11 and 12. This illustrates the continued instability of the Oyster Creek-Forked River area since establishment of the Generating Station.

SUMMARY OF FINDINGS

The purpose of this investigation is to monitor the levels of shipworm infestation in areas adjacent to the Oyster Creek Nuclear Generating Station, particularly its water intake and discharge systems. Furthermore, we are following species composition and breeding and settlement of all boring and fouling invertebrates that associate themselves with our wooden test panels at 18 stations. We record temperature and salinity, and remove and add panels on a monthly basis, except at 4 stations where temperatures and salinity are recorded constantly.

Our major findings are:
1. The power plant was not operating during the period March 26 - April 8, 1979 and May 2 - May 31, 1979.
2. Shipworm larvae did not settle on monthly panels.
3. *Teredo bartschi* was found in Oyster Creek and the mouth of Forked River, but *T. bartschi* in Forked River were dead.
4. No. *T. furcifera* specimens were found.
5. The heaviest shipworm attack is in Oyster Creek, the Holly Park area, the mouth of Forked River, and one station on Long Beach Island.
6. High mortality of shipworms occurred in very crowded panels and those that became covered with anoxic mud (in Oyster Creek).
7. Fouling declined in Oyster Creek because of anoxic mud. Algae were particularly affected.
8. Larvae in the gills of dead and decomposing shipworms were also dead.
9. Fouling data did not show effects of the Generating Station, but the plant was not operating during most of this critical spring period when it could have made a difference.

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ACKNOWLEDGMENTS

We thank the many residents of Oyster Creek who have cooperated in our field work. Ruth D. Turner has continued to play an important role in the study. James McKinley, Cindy Brown, and Ruth Hermansen provided technical assistance. Eugenia Böhlke of the Academy of Nautral 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 IN THE SERIES

Analysis of Populations of boring and fouling organisms in the vicinity of the Oyster Creek Nuclear Generating Station with discussion of relevant physical parameters over the period:

1. April 30 - November 30, 1976. 61 pp.
   by K. Elaine Hoagland, Ruth D. Turner, and Margaret Rochester.
   Released Jan. 1, 1977.

2. December 1, 1976 - February 28, 1977. 61 pp.
   by K. Elaine Hoagland, Ruth D. Turner, and Margaret Rochester.
   Released June 1, 1977.

3. March 1 - May 31, 1977 26 pp. + 1 Appendix
   by K. Elaine Hoagland, Margaret Rochester, and Ruth D. Turner.
   Released June 21, 1977.

4. June 1 - August 31, 1977.
   by K. Elaine Hoagland, Margaret Rochester, and Lauralynn Crocket.
   Released October 25, 1977.

5. September 1 - November 30, 1977. 43 pp.
   by K. Elaine Hoagland, Lauralynn Crocket, and Margaret Rochester.
   Released March 10, 1977.

6. December 1, 1977 - February 28, 1978. 44 pp.
   by K. Elaine Hoagland, Lauralynn Crocket, and Margaret Rochester. NUREG/CR-0223.
   Released July, 1978.

7. March 1, 1978 - May 31, 1978. 32 pp.
   by K. Elaine Hoagland, Lauralynn Crocket, and Margaret Rochester. NUREG/CR-0380.
   Released January, 1979.

8. September 1, 1977 - August 31, 1978. Annual Progress Report. 113 pp. By K. Elaine Hoagland and Lauralynn Crocket. NUREG/CR-0634. Released 1979.

9. September, 1978 - November, 1978 64 pp. by K. Elaine Hoagland and Lauralynn Crocket, NUREG/CR-0812. Released June, 1979.

10. December 1, 1978 - February 28, 1979 52 pp. by K. Elaine Hoagland, Lauralynn Crocket, and J. Harms. NUREG/CR-0896.

ANALYSIS OF POPULATIONS OF BORING AND FOULING ORGANISMS IN THE VICINITY OF THE OYSTER CREEK NUCLEAR GENERATING STATION

with Discussion of Relevant Physical Parameters
Over the Period
March 1, 1979 - May 31, 1979

INTRODUCTION

This progress report covers data collected over the period March 1, - May 31, 1979. The methods are identical to those given in earlier reports. The period was marked by several shutdowns of the generating station due to technical difficulties. A loss of data was caused by malfunction of one thermometer, but all other operations were normal. The locations of our stations are given in Appendix A. In the spring of 1979, stations 6 and 17 were discontinued, although four panels were placed at each, to be removed in the fall. The purpose is to continue to check species composition at these sites.

MAJOR PHYSICAL EVENTS

Temperature

Tables 1 and 2 show the temperatures recorded at the time of sampling and the continuous temperature recorder data. The Generating Station was not operating during the periods March 26 - April 8 and May 2 - May 31, 1979; these were unscheduled outages.

The March 4 data (Table 1) indicate local solar warming in shallow creeks (stations 3, 6, and 20), as compared with deeper and larger bodies of water (stations 1, 2, 17, 18, and 19). All three months (Table 2) showed lower temperature at station 1 than at the other three stations for which continuous data are available.

The temperature was greater in 1979 than in 1978 (Hoagland et al, seventh report, 1978, referenced on p. x.) This was due to general meterological events. The ice was gone by March 4, in 1979. Despite the intermittent plant shutdowns, the temperature was, on the average, highest in Oyster Creek (Table 2). The range was also greatest in Oyster Creek, because of the plant shutdowns. By the end of March, temperatures were high enough $> 10^\circ C$ in Oyster Creek for shipworm metabolism to rise and for gonad development to begin.

Salinity

Monthly salinity profiles are in Table 3, and continuous salinometer data are in Table 4. The salinometer at station 1 was out of the water in February to prevent ice damage to the instrument. Salinities were lower in 1979 than in 1978, especially in March and April, due to heavier rains. As usual, Oyster Creek and Forked River salinities were intermediate between the tidal creeks and open bay stations. Forked River salinities were higher than those in Oyster Creek. The salinities in both of the creeks affected by the Generation Station were high enough to support shipworms. However, salinity at several of the control stations (stations 2, 7, and 20) went below that required for at least one species of shipworm.

Other Factors

Anaerobic mud occurred at stations 11 and 12 in Oyster Creek following dredging in March. The panels removed in May were black 1/3 of the way up from the bottom. The panels were resting in mud, due to the heavy siltation following dredging of the creek.

Because of the condition of the panels, field inspection of shipworms was made in May. Drs. Turner and Hoagland found a few live *Teredo bartschi* containing well-developed larvae in the gills along with a few *Bankia gouldi* in two panels. Two other panels contained no living shipworms.

Table 1

Temperature Profiles, in Degrees Centigrade, March 4 and May 5, 1979*

Station	March 4	May 5	Differential within stations between months
1	3.3	17.2	13.9
2	3.3	18.3[a]	15.0
3	7.8[a]	17.5	9.7
4	5.6	16.1	10.5
5	4.4	17.2	12.8
6	6.1	c	c
7	5.6	15.6	10.0
8	5.6	16.1	10.5
9	6.7	17.2	10.5
10	7.2	16.7	9.5
11	7.2	17.2	10.0
12	7.8[a]	17.8	10.0
13	7.8[a]	16.7	8.9
14	6.1	16.1	10.0
17	4.2	c	c
18	2.8[b]	13.3[b]	10.5
19	2.8[b]	14.4	11.6
20	5.6	16.7	11.1
Differential among stations	6.0	5.0	

a highest value

b lowest value

c no data, stations discontinued

* April values omitted due to instrument inaccuracy. Stations 15 and 16 have been discontinued.

Table 2

Continous Temperature Recorder Data (°C) for March 5 - June 7, 1979
Stations 1, 5, 11, 14

I. Temperature at 1:00 P.M.

	March 5-April 6				April 7-May 5				May 5-June 7			
	1	5	11	14	1	5	11	14	1	5	11	14
Mean Daily Temp. at 1 PM	7.5	8.4	10.7	8.3	11.5	12.1	16.0	13.0	18.4	19.9	20.0	18.5
Standard deviation	2.1	2.0	2.4	1.5	3.3	3.0	3.5	2.8	1.7	2.1	2.8	1.6
Highest value of Temp. at 1 PM	12.2	12.3	16.2	10.9	15.7	15.8	22.2	17.4	22.3	25.0	28.1	21.9
Lowest value of Temp. at 1 PM	4.2	5.0	5.7	5.4	6.7	7.8	9.4	7.9	15.0	16.4	15.9	15.4
Monthly Temp. Range at 1 PM	8.0	7.3	10.5	5.5	9.0	8.0	12.8	9.5	7.3	8.6	12.2	6.5

II. Maximum Daily Temperature

	March 5-April 6				April 7-May 5				May 5-June 7			
	1	5	11	14	1	5	11	15	1	5	11	14
Mean value of Max. Daily Temp.	7.5	9.5	12.3	9.0	12.2	13.2	17.1	14.0	19.5	20.4	20.3	19.9
Standard Deviation	2.1	2.1	2.2	4.3	3.3	3.4	4.1	3.4	1.8	2.0	2.9	1.8
Highest value of Max. Daily Temp.	12.2	13.6	16.9	12.5	16.5	17.5	23.6	17.6	23.6	25.0	28.9	23.0
Lowest value of Max. Daily Temp.	4.2	5.7	8.6	6.3	7.5	8.1	7.8	8.3	16.0	16.4	16.4	15.8
Monthly Range of Max. Daily Temp.	8.0	7.9	8.3	6.2	9.0	9.4	15.8	9.3	7.6	8.6	12.5	7.2

Table 2, Continued

III. Minimum Daily Temperatures

	March 5-April 6, 1979				April 7-May 5, 1979				May 6-June 7, 1979			
	1	5	11	14	1	5	11	14	1	5	11	14
Mean value of min. Daily Temp.	6.6	7.2	9.8	7.6	10.8	11.3	15.2	12.0	17.9	19.2	18.7	17.9
Standard Deviation	2.0	2.6	2.4	1.6	3.4	3.9	3.8	3.2	1.8	2.1	2.7	1.5
Highest value of Min. Daily Temp.	9.8	11.9	16.1	10.0	15.3	15.8	20.4	16.7	20.8	23.7	26.1	20.7
Lowest value of Min. Daily Temp.	2.7	0.8*	4.4	4.6	5.4	0.8*	4.2	7.3	14.5	14.8	15.4	15.0
Monthly Range of Min. Daily Temp.	7.1	11.1	11.7	5.4	9.9	15.0	16.2	9.4	6.3	8.9	10.7	5.7

IV. Daily Temperature Range

	March 5-April 6, 1979				April 7-May 5, 1979				May 6-June 7, 1979			
	1	5	11	14	1	5	11	14	1	5	11	14
Mean Daily ΔT	1.7	2.3	2.5	2.2	1.4	1.9	2.3	2.0	1.6	1.2	1.7	1.9
Standard Deviation	0.8	1.2	1.3	0.9	0.8	1.6	1.2	0.9	1.0	0.7	0.9	1.0
Largest Daily ΔT for one month	3.9	5.3	6.4	3.7	3.3	4.8	5.8	4.0	4.4	3.2	3.5	4.4
Smallest Daily ΔT for one month	0.3	0.1	0.1	0.2	0.1	0.1	0.6	0.7	0.4	0.2	0.4	0.5

* reading is abnormally low and probably represents instrument error.

Table 3

Salinity Profiles in $^{o}/00$, 1979

Station	March 4	April 7	May 5	Differential within stations among months
1	14.0	9.0	16.0	7.0
2	c	5.0	9.0	4.0
3	c	c	16.0	-
4	17.0	c	22.0	5.0
5	16.0	18.0	22.0	6.0
6	15.0	c	18.0	3.0
7	2.0	c	6.0	4.0
8	c	c	20.0	-
9	15.0	c	22.0	7.0
10	10.0	c	17.0	7.0
11	12.0	15.0	18.0	6.0
12	7.5	c	21.0	13.5
13	9.0	c	15.0	6.0
14	c	16.0	21.0	5.0
17	11.0	19.0	22.0	11.0
18	17.0	20.0 a	24.0	7.0
19	18.0 a	20.0 a	25.0	7.0
20	1.0 b	0.0 b	4.0 b	4.0
Differential among stations	17.0	20.0	21.0	

Note: a highest value

b lowest value

c missing data

Table 4

Continuous Recording Salinometer Readings at 12:00 Noon, EST
February 4 - May 5, 1979 ($^{o}/oo$)

Dates	Statistic*	Sta. 1	Sta. 5	Sta. 11	Sta. 14
Feb. 4, 1979 to	N	-	26	29	30
March 4, 1979	$\bar{X}$	-	17.2	12.2	20.1
	S_X	-	4.0	2.2	3.5
March 5, 1979 to	N	34	-	33	34
April 7, 1979	$\bar{X}$	12.0	-	11.1	16.7
	S_X	2.2	-	1.2	2.8
April 8, 1979 to	N	26	27	29	28
May 5, 1979	$\bar{X}$	15.2	16.6	14.1	18.3
	S_X	2.0	1.2	1.5	2.6

*N, number of days recorded, indicates the extent of missing data.

$\bar{X}$ = mean; S_X = Standard Deviation.

SHIPWORMS

Monthly Panels

There were no shipworms in any monthly panel during March - May, 1979. This is consistent with our findings during the same periods in 1977 and 1978.

Yearly Panels

Data from yearly panels collected March - May, 1979, are found in Tables 5 - 9. Some March yearly panels were absent because last March ice prevented them from being placed in the water. The greatest number of living shipworms in any yearly panel was at station 1 in April. All specimens in this panel were *Bankia gouldi*. Other stations with large numbers of living shipworms were stations 2, 8, 18, 11, and 12. The latter two stations in Oyster Creek showed significant reduction in numbers from March to April, coinciding with dredging activity. On March 4, there was an oily substance in the water at stations 11 and 12, and dredging near station 12 was causing siltation on the test racks.

The greatest number of species alive at any one station was two. *T. bartschi* was found only in Oyster Creek, and numbers declined significantly between March and May. Dead *T. bartschi* were found at station 8. The number of *T. navalis* at station 18, Long Beach Island, was significantly greater than at any other station.

The greatest mortality occurred at stations 11, 12, and 18. No specimens of *T. navalis* were found in Oyster Creek, but this species was found at all other stations with shipworm attack.

Comparing March, 1978 with March, 1979, the numbers of shipworms were the same order of magnitude, but higher in 1979 at stations 10 - 14 and 17. In April and May, 1979, the numbers were higher at stations 14 and 17 but were otherwise similar in the two years. Data for 1978 can be found in the references on p. x.

There is natural winter mortality in crowded ponds, especially those covered by heavy fouling. The mortality in Oyster Creek was quite

Table 5

Numbers of Living Shipworms in Panels Submerged for One Year

Date Removed:	March 4, 1979				April 7, 1979				May 5, 1979			
Station	B.g.	T.b.	T.n.	Total	B.g.	T.b.	T.n.	Total	B.g.	T.b.	T.n.	Total
1				a	5			5	6			6
1 rep				a	56			56				a
2				a	22			22	19			19
3				a				0				0
3 rep				a				a				0
4	1			1	10			10	7		1	8
5	5		1	6	6		1	7	13		2	15
6				a				0				b
7				0				0				0
8	22		4	26	36		5	41	24		3	27
10		10		10		1		1	1	2		3
11		23		23		2		2	1			1
11 rep		28		28		14		14		4		4
12		21		21		3		3				0
14	13		3	16	4			4	8			8
14 rep	6			6	10		1	11				a
17	1		8	9	1		9	10			2	2
18				a			23	23				a
19				0				0				0
Total	42	54	16	112	84	6	38	128	79	2	8	89

a No panel

b Station discontinued

rep = Replicate Panel Data (not included in totals)

Table 6

Numbers of Living Shipworms Plus Empty Tubes in Panels Submerged for One Year

Date Removed:	March 4, 1979					April 7, 1979					May 5, 1979			
Station	B.g.	T.b.	T.n.	Tubes Only	Total	B.g.	T.b.	T.n.	Tubes Only	Total	B.g.	T.b.	T.n.	Total
1					a	5				5	7			7
1rep					a	56		1		57				riddled
2					a	22				22	19			19
3					a					0				0
3rep					a					a				0
4	1				1	10				10	7		1	8
5	5		1		6	6		1		7	13		2	15
6					a					0				b
7					0					0				0
8	22		5	87	114	36		6	10	52	24	18	3	45
10		15			15		10			10	2	7		9
11		>460*			>460*		> 40*			> 40*	1	> 2*		> 3*
11rep		53			53		>280*			>280*		>414*		>414*
12		>460*			>460*		>300*			>300*		>253*		>253*
14	14		3		17	4				4	8			8
14rep	6				6	10		1		11				a
17	1		8		9	1		9		10			2	2
18					a			>23*		>23*				a
19			7		7			3		3			23	23
Total														
Total	43	>935	24	87	>1089	84	>350	>42	10	>486	81	>280	31	>392

a No panel
b Station discontinued
rep = Replicate Panel Data (not included in totals)
* Panel riddled with tubes, number under estimated.

Table 7

Percentage of Specimens that were Alive when Collected, Yearly Panels

Month Collected:	March 4, 1979			April 7, 1979			May 5, 1979		
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	a	a	–	5	5	100	6	7	85.7
1 rep	a	a	–	56	57	98.2	a	a	–
2	a	a	–	22	22	100	19	19	100
3	a	a	–	0	0	–	0	0	–
3 rep	a	a	–	a	a	–	0	0	–
4	1	1	100	10	10	100	8	8	100
5	6	6	100	7	7	100	15	15	100
6	a	a	–	0	0	–	b	b	–
7	0	0	–	0	0	–	0	0	–
8	26	114	22.8	41	52	78.8	27	45	60
10	10	15	66.7	1	10	10	3	9	33.3
11	23	>460*	< 5.0	2	> 40*	< 5	1	> 3*	< 33.3*
11 rep	28	53	52.8	14	>280*	< 5	4	>414*	< 1.0*
12	21	>460*	<4.6	3	>300*	< 1	0	>253*	0
14	16	17	94.1	4	4	100	8	8	100
14 rep	6	6	100	11	11	100	a	a	–
17	9	9	100	10	10	100	2	2	100
18	a	a	–	23	>23*	–	a	a	–
19	0	7	0	0	3	0	0	23	0
Totals	112	>1089	<10.3	128	>486	<26.3	89	>392	<22.7

a No panel
b Station discontinued
* Panel riddled with empty tubes, number underestimated
rep = Replicate Panel Data (not included in totals)

Table 8

Percentage Weight Loss by Yearly Panels, Removed March - May, 1979

Station	Month Removed		
	March 4	April 7	May 5
1	a	13	6
1 rep	a	45	a
2	a	33	26
3	a	0	0
3 rep	a	a	0
4	a	21	13
5	19	8	32
6	a	0	b
7	4	0	0
8	54	56	54
10	8	2	6
11	61	64	64
11 rep	72	70	52
12	44	63	49
14	27	13	23
14 rep	26	39	a
17	36	44	25
18	a	72	a*
19	8	0	7

a Data missing
b Station discontinued
* More than 30% weight loss

Table 9

Length Ranges of Living Specimens, in mm, Yearly Panels

Date Removed:	March 4, 1979			April 7, 1979			May 5, 1979		
Station	B.g.	T.b.	T.n.	B.g.	T.b.	T.n.	B.g.	T.b.	T.n.
1				130-215			65-196		
1 rep				15-215					
2				64-240			34-273		
3									
3 rep									
4	214			60-260*			60-266		143
5	90-275		96	40-212		182	16-250		73-140
6									
7									
8	30-213		69-104	39-187		8-172	21-244		65-182
10		1-60*			34*		295*	8-15*	
11		6-50			10-12		152		
11 rep		4-24			4-18			8-15*	
12		10-57			7-9				
14	26-193		62-225*	120-198			115-262		
14 rep	47-305*			90-182		156			
17	18		110-170	150		60-190*			165-260*
18						8-62			
19									

* Largest specimen each month, each species.

likely increased by both dredging during March and plant shutdowns during the months of March and May. Mortality was much lower in February.

The extent of mortality differed by species, being greatest in T. bartschi and least in B. gouldi. This may reflect several factors: 1) a lack of adaptation of many individuals of T. bartschi to cold conditions when the Generating Station shuts off; 2) dredging activities that were unique to Oyster Creek, where T. bartschi occurs in the greatest numbers; and 3) a real difference in lifespan and population dynamics among the species. The last possibility will be investigated in future laboratory and field studies. The second possibility undoubtedly explains much of the mortality, but not all, since mortality of T. bartschi occurred at stations in Forked River and Forked River Beach, outside the influence of the dredging. Therefore, the first possibility remains likely.

Many of the empty shipworm tubes contained the errant polychaete Nereis succinea and young anemone specimens, mostly Diadumene leucolena.

Numerous stations suffered an attack of shipworms great enough to cause wood loss of greater than 30% (Table 8). The highest weight loss occurred at stations 11, 18, 8, and 12, in that order. Only at station 1 was there a significant difference in attack between replicate panels, and this is due to patchy larval settlement. There was no important difference in shipworm attack among the March - May yearly panels; they are essentially replicates in terms of shipworm number (but not size) because they were exposed to the same number of shipworm larvae at the same time. Comparison with our 1978 annual report reveals that wood destruction was greater in spring, 1979.

The sizes of shipworms in the yearly panels are reported in Table 9 and Appendix B. T. bartschi was largest at station 10, where crowding was least. The largest specimens of B. gouldi for the three months were at stations 14, 4, and 10, all within range of the thermal effluent. However, the size differences were not statistically significant. T. navalis was largest at stations 14 and 17.

Cumulative Panels

Shipworm data from panels deployed May 31, 1978 and collected March - May, 1979, are shown in Tables 10 - 14. There were few differences in shipworm attack between the cumulative and the yearly panels, because the larval settlement period was the same and the time in the water was nearly the same. During the extra time the yearly panels were in the water, there was no shipworm attack at most stations. There was no noticeable growth of shipworms between March and May (see Tables 9 and 14), increasing the similarity between the two panel series and amonth the three months' panels. There was no evidence of new shipworm settlement on the cumulative or yearly panels.

Differences that were observed between cumulative and yearly panels were a larger population of shipworms in the 8 "Y" than the 8 "C" panels, and larger populations of shipworms in the 10 and 17 "C" than the 10 and 17 "Y" panels (compare Tables 6 and 11). These differences cannot be attributed to chance, because they are consistent for all three pairs of panels. The most likely explanation is greater proximity of settling larvae to one test rack than to the other. One other difference is the higher mortality in the cumulative than yearly panels at several stations (#2, 4, 10, 19) during the month of April, as reflected in the May 5th data (Table 12). The cause is unknown.

The sizes of specimens in the cumulative panels are close to those in the yearly panels (compare Tables 9 and 14; Figures in Appendix B). Again, the largest specimen of each species was, with 2 exceptions, at a station influenced by the Generating Station.

Although very few T. bartschi were found in cumulative panels during May, trash wood and extra panels removed that month at station 12 in Oyster Creek did contain several living specimens with larvae in the gills (see p. 3).

Reproduction

Table 15 provides the details on reproduction during March - May. The percent of T. bartschi carrying larvae was somewhat lower than in previous months. Nevertheless, Teredo bartschi did hold its larvae within the gills throughout the winter months. At stations 8 and 10 - 12, adults died, spilling the larvae into the burrow. In all cases seen, these larvae also died, but it is not impossible that a few could remain viable if ready to be released and if temperature and salinity were within tolerance.

Teredo navalis contained no larvae until May, when larvae were found in two individuals at Manahawkin (station 17) and four at Forked River (station 5). Reproduction activity in Teredo navalis was not observed until June in 1978.

Table 10

Numbers of Living Shipworms, Cumulative Panels Submerged May 31, 1978

Date Removed:	March 4, 1979 (9 months)				April 7, 1979 (10 months)				May 5, 1979 (11 months)			
Station	B.g.	T.b.	T.n.	Total	B.g.	T.b.	T.n.	Total	B.g.	T.b.	T.n.	Total
1	30		2	32	33		1	34	19			19
2	89			89	81			81	71		1	72
3				0				0				0
4	3		1	4				0	1			1
5	2			2	6		1	7	3		2	5
6	9			9	1			1				b
7				0				0				0
8	7		1	8	5			5	12			12
9				0	2			2				0
10	2	3		5				0	2			2
11		3		3		5		5				0
12		10		10				0	1	1		2
13	4			4				0	1			1
14	12		2	14	7			7	13			13
17			19	19	1		28	29				b
18				0				a				a
19	1		12	13			8	8			4	4
20				0				0				0
20 rep												0
Tot Total	159	16	37	212	136	5	38	179	123	1	7	131

a Panel missing

b Station discontinued

Table 11

Numbers of Living Shipworms Plus Empty Tubes, Cumulative Panels, Submerged May 31, 1978

Date Removed:	March 4, 1979 (9 months)				April 7, 1979 (10 months)				May 5, 1979 (11 months)			
Station	B.g.	T.b.	T.n.	Total	B.g.	T.b.	T.n.	Total	B.g.	T.b.	T.n.	Total
1	30		2	32	33		1	34	19			19
2	89			89	81			81	109		1	110
3				0				0				0
4	3		1	4	4			4	2		3	5
5	2			2	7		1	8	3		2	5
6	9			9	2			2				b
7				0				0				0
8	7	1	1	9	5	2		7	14			14
9			1	1	2		1	3				0
10	2	>353*		>355*		>300*		>300*	2	317		319
11		>300*		300*		>250*		>250*		>453*		>453*
12		>500*		500*		>300*		>300*	1	>198*		>200*
13	4			4				0	1			1
14	12		2	14	7			7	13			13
17			19	19	1		28	29				b
18			>10*	>10*				a				a
19	1		12	13			8	8			7	7
20				0				0				0
Total	159	>1164	48	>1371	142	>852	39	>1033	164	>968	13	>1146

[a]Panel missing.

[b]Station discontinued.

*Panel riddled with empty tubes, number underestimated.

Table 12

Percentage of Specimens that were Alive When Collected, Cumulative Panels

Month Collected:	March 4, 1979			April 7, 1979			May 5, 1979		
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	32	32	100	34	34	100	19	19	100
2	89	89	100	81	81	100	72	110	65.5
3	0	0	-	0	0	0	0	0	-
4	4	4	100	0	4	0	1	5	20
5	2	2	100	7	8	87.5	5	5	100
6	9	9	100	1	2	50	b	b	-
7	0	0	-	0	0	-	0	0	-
8	8	9	88.9	5	7	71.4	12	14	85.7
9	0	1	0	2	3	67	0	0	-
10	5	>355*	<1.4	0	>300*	0	2	319	0.6
11	3	>300*	<1.0	5	>250*	<2.0	0	>453*	0
12	10	>500*	<2.0	0	>300*	0	1	>200	<0.5
13	4	4	100	0	0	-	1	1	100
14	14	14	100	7	7	100	13	13	100
17	19	19	100	29	29	100	b	b	-
18	0	>10*	<10*	a	a	-	a	a	-
19	13	13	100	8	8	100	4	7	57.1
20	0	0	-	0	0	-	0	0	-
Totals	212	>1361	<15.6	179	>1033	<17.3	130	>1146	<11.4

[a] Panel missing

[b] Station discontinued

* Panel riddled with empty tubes, number underestimated

Table 13

Percentage Weight Loss by Cumulative Panels, Submerged May 31, 1978, Removed March-May, 1979

	Month Removed		
Station	March 4	April 7	May 5
1	29	51*	15
2	62*	67*	52*
3	5	6	4
4	17	21	8
5	8	14	12
6	23	8	b
7	1	1	0
8	17	17	27
9	1	8	0
10	43*	33*	36*
11	79*	83*	57*
12	41*	38*	41*
13	21	2	9
14	33*	26	25
17	a	39*	b
18	57*	a*	a*
19	14	8	2
20	1	2	0
20 rep			0

a Data missing
b Station discontinued
* More than 30% weight loss

Table 14

Length Ranges of Living Specimens, in mm, Cumulative Panels Submerged May 31, 1978

Date Removed:	March 4, 1979			April 7, 1979			May 5, 1979	
Station	B.g.	T.b.	T.n.	B.g.	T.b.	T.n.	B.g.	T.n.
1	16-156		145-155	7-168		185*	34-207	
2	15-136			18-114			23-162	107
3								
4	98-300		168				195	
5	190-210			115-260		169	70-94	177-305*
6	131-227			148				
7								
8	8-210		185	168-249			77-243	
9				182-191				
10	164-200	14-29					145-310*	
11		5-11			10-37*			
12		14-37*					173	
13	145-332*						300	
14	37-228		82-135	109-275*			28-225	
17	62-180			39		68-181		
18								
19	104		67-227*			35-175		25-205
20								

* Largest specimen each month, each species

Table 15

The Percentage of Live Teredo Specimens Found With Larvae in The Gills

Species, Station and Panel*	Max. size of shipworms with larvae (mm)	Min. size of shipworms with larvae (mm)	Max. size of shipworms without larvae (mm)	Min. size of shipworms without larvae (mm)	% of shipworms with larvae (followed by N)
T. bartschi					
10 C Mar.	25	25	29	14	33.3 (3)
12 C Mar.	37	37	25	14	20 (10)
10 Y Mar.	60	27	7	1	50 (10)
11 Y Mar.	43	27	50	6	24 (23)
12 Y Mar.	57	23	30	10	10 (21)
T. navalis					
5 C May	305	177	-	-	100 (2)
5 Y May	140	140	73	73	50 (2)
17 Y May	260	260	165	165	50 (2)

*C = Cumulative; Y - yearly panel

FOULING ORGANISMS

Tables 16 - 22 give presence-absence data for the most common fouling organisms. The format is the same as in our earlier reports. There was little evidence of growth and settlement of fouling organisms on panels removed in March. However, new settlement was apparent at some stations in April and May. Electra crustulenta (Table 16) is rare in low salinities (stations 3, 7). It did survive the winter, and was most abundant at the two northernmost stations (1, 2), the mouth of Forked River (4), Forked River Beach (8), and Waretown (14). Settlement in Oyster Creek is weakly related to the Generating Station in that salinities are high enough for growth to occur. The major encrusting bryozoans on Long Beach Island have been identified as Schizoporella unicornis and Cryptosula pallasiana. Earlier recordings of E. crustulenta at these stations were due to a technician's error.

The encrusting tube polychaetes Hydroides dianthus and Mercierella enigmatica prefer to settle on metal or cement rather than wood. M. enigmatica tubes, but no live specimens, were found at stations 3 and 4. Station 4 was the only place where both polychaetes were found. Some H. dianthus (Table 17) remained alive during the winter and spring at several stations but no settlement occurred. Likewise, no settlement occurred in the Spring of 1978. H. dianthus is rare in the Generating Station effluent.

The colonial tunicate Botryllus schlosseri (Table 18) remained on the cumulative and yearly panels through March 4 at four localities. All colonies except one were dead by April. There was no settlement during the period covered by this report. Only a trace of one colony appeared in Oyster Creek in March, on a cement block. It was absent from Oyster Creek entirely in the spring of 1978. However, in 1978, colonization began earlier (in late April). B. schlosseri can be considered an annual species in Barnegat Bay.

The green alga Enteromorpha intestinalis (Table 19) is common at the mouth of Forked River. On Long Beach Island, the common species is Enteromorpha prolifera. In past years E. intestinalis has been common at this time of year in Oyster Creek. We can implicate the dredging activity in the failure of the alga to be a dominant element of the spring fauna in 1979.

The barnacle Balanus eburneus usually settles in early summer. It did not settle in the spring of 1978 or 1979 (Table 20). However, adults remained alive at all stations. Barnacles, mostly B. crenatus, did settle on Long Beach Island during March and April, but some were too small to identify certainly.

The solitary tunicate _Molgula manhattensis_ (Table 21) did not settle on monthly panels during the period of this report. Some settlement did occur in 1978. As in 1978, distribution of adults was scattered; none occurred at low-salinity stations and few occurred in Oyster Creek. Some solitary tunicates settled on monthly panels at Long Beach Island (Station 19) in the month before March 4, but the species has not been identified.

There was considerable growth and settlement of campanulareid hydroids during March and April, especially at stations 1, 4, 5, 14, 18, and 19. At Long Beach Island, an athecate hydroid also proliferated. Hydroids were common in Oyster Creek during 1978, but were absent in 1979. As with the algae, the difference could be due to recent dredging activity. Campanulareids are absent from low salinity stations.

Table 16

Distribution of Some Common Fouling Organisms:

Electra crustulenta

	Station												
	1	2	3	4	5	6	7	8	10	11	12	14	17
A. Monthly													
March							no fouling						
April	XR	O	O	O	O	O	O	O	O	O	O	O	O
May	O	O	O	X	O	O	O	O	O	O	O	X	O
B. Cumulative													
March	X	X	O	X	X	X	O	X	O	O	O	X	X
April	X	X	O	X	X	O	O	X	O	X	X	X	X
May	X	X	O	X	X	O	O	X	X	X	X	X	O
G. Yearly													
March	-	-	-	X	X	-	O	X	X	XR	X	X	O
April	X	X	O	X	X	X	O	X	O	X	X	X	X
May	X	X	X	X	X	O	O	X	X	X	X	X	X

X: Present
XR: Present but Rare
-: No panel
O: Absent

Table 17

Distribution of Some Common Fouling Organisms:

Hydroides dianthus

Station

	1	2	3	4	5	6	7	8	10	11	12	14	17	18	19
A. Monthly: NO SETTLEMENT															
B. Cumulative															
March	O	X	X	X	X	O	O	X	O	O	O	X	X	X	X
April	O	X	O	O	X	O	O	O	O	O	O	X	X	-	O
May	O	X	O	O	O	O	O	O	O	O	O	X	O	-	O
C. Yearly															
March	-	-	-	X	X	-	O	X	O	O	O	X	X	-	X
April	O	XR	O	X	X	O	O	X	O	O	O	X	X	X	O
May	O	X	O	X	X	O	O	X	O	O	O	X	X	-	O
D. On Block or Rack Only															
March	X						X		X	X					
April	X					X			X	X					
May	X								X	X					

X: Present
XR: Present but Rare
-: No panel
O: Absent

Table 18

Distribution of Some Common Fouling Organisms:

Botryllus schlosseri

	Station														
	1	2	3	4	5	6	7	8	10	11	12	14	17	18	19
A. Monthly: NO SETTLEMENT															
B. Cumulative															
March	0	0	0	0	X	0	0	X	0	0	0	X	0	0	X
April	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
May	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
C. Yearly															
March	-	-	-	X	X	-	0	X	0	0	0	X	0	-	0
April	0	0	0	0	0	0	0	0	0	0	0	X	0	0	0
May	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
D. On Block or Rack Only															
March						X				X					
April															
May															

X: Present
XR: Present but Rare
-: No panel
0: Absent

Table 19

Distribution of Some Common Fouling Organisms:

Enteromorpha spp.*

Station

	1	2	3	4	5	6	7	8	10	11	12	14	17	18	19
A. Monthly: NO SETTLEMENT															
B. Cumulative															
March	0	0	0	X	0	0	0	0	0	0	0	X	0	0	X
April	X	0	0	X	X	0	0	0	0	0	0	0	0	-	X
May	X	X	0	X	X	0	0	X	0	X	0	XR	0	-	X
C. Yearly															
March	-	-	-	X	0	-	0	X	0	0	0	0	0	-	0
April	X	0	0	X	0	0	0	0	0	0	0	0	0	0	X
May	0	0	0	X	X	0	0	0	0	0	0	X	0	-	X

X = Present
XR = Present but rare
\- = Panel missing
0 = Absent
* : *Enteromorpha prolifera* at station 19; *E. intestinalis* elsewhere

Table 20

Distribution of Some Common Fouling Organisms:

Balanus eburneus

	Station 1	2	3	4	5	6	7	8	10	11	12	14	17	18	19
A. Monthly: NO SETTLEMENT															
B. Cumulative															
March	X	X	X	X	X	X	XR	0	X	X	X	X	X	X	X
April	X	X	X	X	X	X	X	0	X	X	0	X	X	–	X
May	X	X	X	X	X	0	X	X	X	X	0	X	0	–	X
C. Yearly															
March	–	–	–	X	X	–	0	X	X	X	X	X	X	–	X
April	0	X	X	XR	X	X	0	X	X	X	X	X	0	X	0
May	X	X	X	X	X	0	0	0	X	X	X	X	0	–	0

X = Present
XR = Present but rare
– = No Panel
0 = Absent

Table 21

Distribution of Some Common Fouling Organisms:

Molgula manhattensis

Station

	1	2	3	4	5	6	7	8	10	11	12	14	17	18	19
A. Monthly: NO SETTLEMENT															
B. Cumulative															
March	O	X	O	O	X	O	O	X	O	X	O	X	X	O	X
April	O	X	O	O	O	O	O	X	O	O	O	X	X	–	O
May	O	O	O	O	X	O	O	O	O	O	O	O	O	–	O
C. Yearly															
March	–	–	–	O	X	–	O	X	X	O	O	X	X	–	O
April	O	O	O	O	X	X	O	X	O	O	O	X	X	O	O
May	O	O	O	O	X	O	O	X	O	O	O	O	X	–	O
D. On Block or Rack Only															
March				X							X				
April															
May															

X: Present
XR: Present but Rare
–: Panel missing
O: Absent

Table 22

Distribution of Some Common Fouling Organisms:

<u>campanulareid</u> species

	Station														
	1	2	3	4	5	6	7	8	10	11	12	14	17	18	19
<u>Monthly</u>															
March		---no fouling---													
April	0	0	0	0	X	0	0	0	0	0	0	X	0	X	X
May	0	0	0	0	X	0	0	0	0	0	0	X	0	X	X
<u>Cumulative</u>															
March	X	X	0	X	X	0	0	0	0	0	0	X	0	0	X
April	X	0	0	X	X	0	0	0	0	0	0	X	0	-	X
May	X	0	0	X	X	0	0	0	0	0	0	X	0	-	X
<u>Yearly</u>															
March	-	-	-	X	X	-	0	X	0	0	0	X	0	-	X
April	X	0	0	X	X	0	0	X	0	0	0	X	X	X	0
May	0	0	0	X	0	0	0	0	0	0	0	X	0	-	X

X = Present
XR = Present but rare
\- = No Panel
0 = Absent

DISCUSSION

The spring, 1979 period can best be described as one of unstable physical conditions which contributed to high mortality of both boring and fouling organisms in Oyster Creek. However, enough viable specimens of I. bartschi and B. gouldi remained to start a new outbreak in the summer period. Control stations continued to show about the same level of shipworm attack and had the same species composition as in the previous year. The major new finding since winter is the lack of live specimens of Teredo bartschi in Forked River and its mouth.

Even outages of considerable duration in December, March, and May were insufficient to eliminate all T. bartschi, the subtropical species. It may be adapting genetically to cooler temperatures. The high population numbers, rapid growth, and early maturation of this species make rapid adaptation a possibility.

It was unusual not to find Teredo navalis in Oyster Creek. We expect that this is a local anomaly or a result of its lower numbers settling in Fall than usual. It could have been excluded from late settling by the high concentrations of T. bartschi.

APPENDIX A: 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
2	Mouth of Cedar Creek	Last Lagoon toward mouth South Side Estuarine control	39° 52' 74° 8.5'	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 due to reverse flow	39° 49.4' 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
7	Grant's Boats	Middle Branch, Forked River just S. of State Marina	39° 49.6' 74° 11.6'	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

STATION NUMBER	NAME	DESCRIPTION	COORDINATES	
** 9	Intake Canal	House closest to intake canal Salinity effect; strong current upstream	39° 49.2' 74° 12.2'	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
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
** 13	Rte 9 Bridge	Oyster Creek just below discharge canal. Temperature, salinity increase	39° 48.7' 74° 12'	N W
14	Cottrell's Clam Factory	End of North Harbor Rd. Waretown, N. J. (Mouth of Waretown Creek) Within reported thermal plume	39° 47.7' 74° 10.9'	N W
+15	Carl's Boats	Washington & Liberty Sts. Waretown, N. J. (on the bay) To test for tropical species and increases in populations of borers as a result of breeding elsewhere	39° 47' 74° 11'	N W
+16	Iggie's Marina	East Bay Ave, Barnegat, N.J. Same purpose as Loc. 15	39° 44.8' 74° 11.6'	N W
17	Manahawkin Bay	At bridge to Long Beach Island Same purpose as Loc. 15	39° 40' 74° 13'	N W

STATION NUMBER	NAME	DESCRIPTION	COORDINATES	
** 18	Barnegat Light	Marina adjacent to Coast Guard Station	39° 45.8' 74° 6.5'	N W
** 19	Long Beach Island	Bayview Marina	39° 45.2' 74° 6.9'	N W
#20	Cedar Creek	Opposite home of Mr. and Mrs. Sokolich 415 Terry Ave. Inland from Station 2, at point where stream narrows.	39° 52.1' 74° 9.5'	N W

** Stations new as of May 27, 1977

Stations new as of May 31, 1978

+ Stations discontinued as of June 1, 1978

APPENDIX B

HISTOGRAMS OF LENGTHS OF SHIPWORMS

Figures B-1 through B-6 graphically illustrate the size distributions of living shipworms removed in the months of March-May, 1979 when N >10. Extensive mortality has caused some distortion of these histograms, because we cannot determine the size distribution of the deceased individuals. Some feeling of the size of survivors relative to those that perished can be gained by comparing our data from September-February, 1978-1979 (see p. x). For example, a quick comparison of September cumulative with March cumulative panels indicates that B. gouldi mortality was probably greatest in the small size classes, <20 mm.

The distribution of size approaches a normal distribution in B. gouldi under crowding but not when numbers per panel are low (Fig. B-1). This may indicate a strong genetic component to growth rate, possibly one associated with protandry. It may also indicate a longer settlement period occurring when spatfall is less intense early in the summer (station 14 as opposed to station 2). However, size distribution in T. bartschi tends to be skewed towards the smaller size classes (Figure B-2).

Distributions of size in yearly panels are flatter than those in cumulative panels, and size ranges are greater. In some cases, however, direct comparisons cannot be made between panels from the same station because of lost panels or high mortality. Comparisons between March and April (e.g., stations 1 and 2, B. gouldi, cumulative panels) show insignificant growth. However, the May cumulative panels showed fewer individuals and in a few cases (station 1), larger size than in March and April.

Figure B-1

March Cumulative Panels

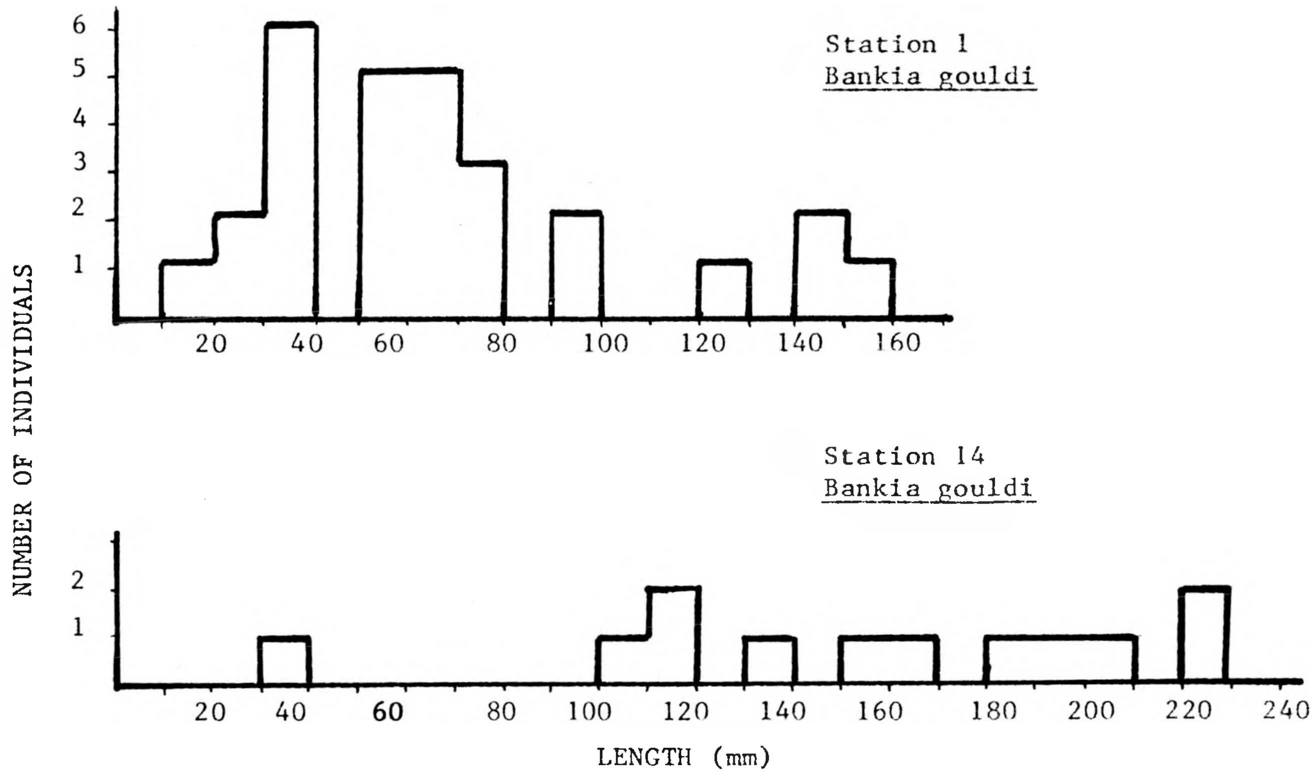


Figure B-1, continued
March Cumulative Panels

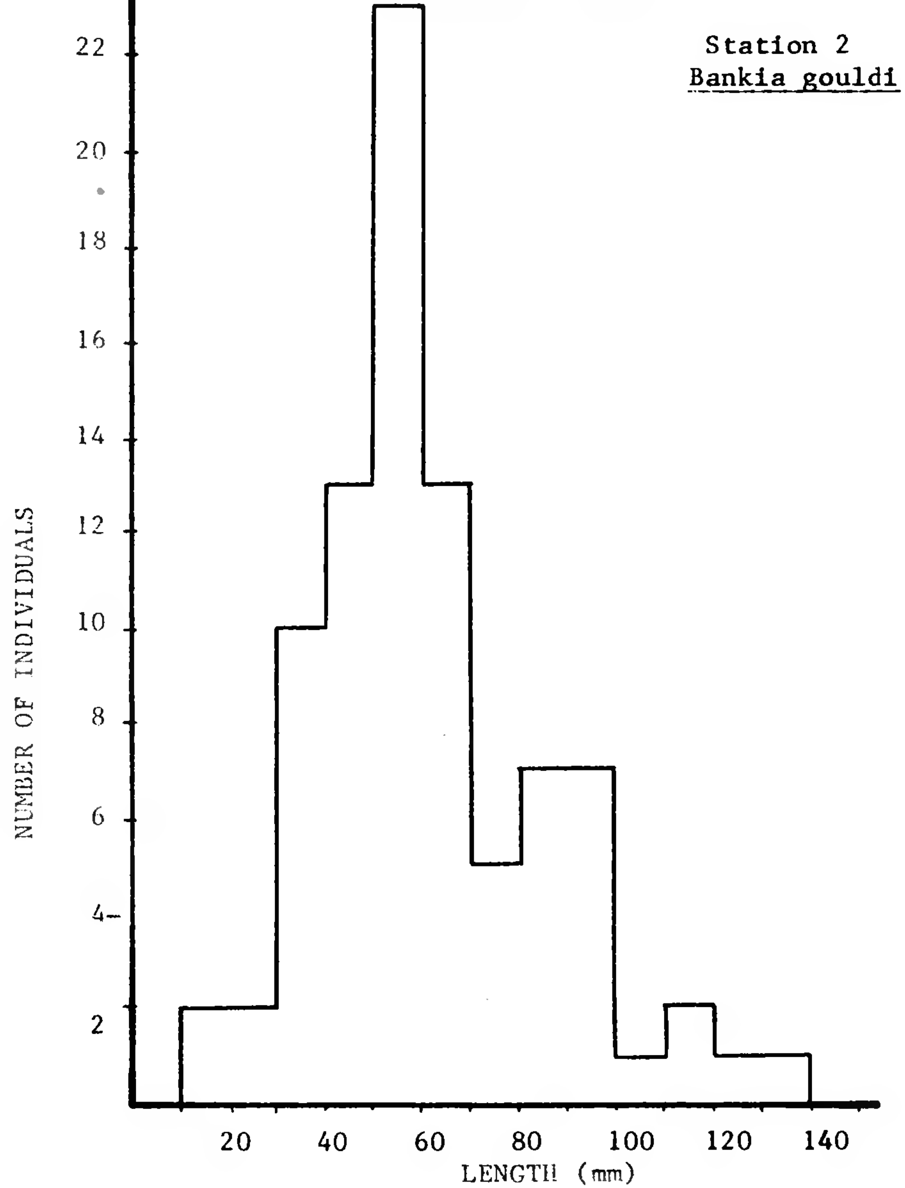


Figure B-2

March Yearly Panels

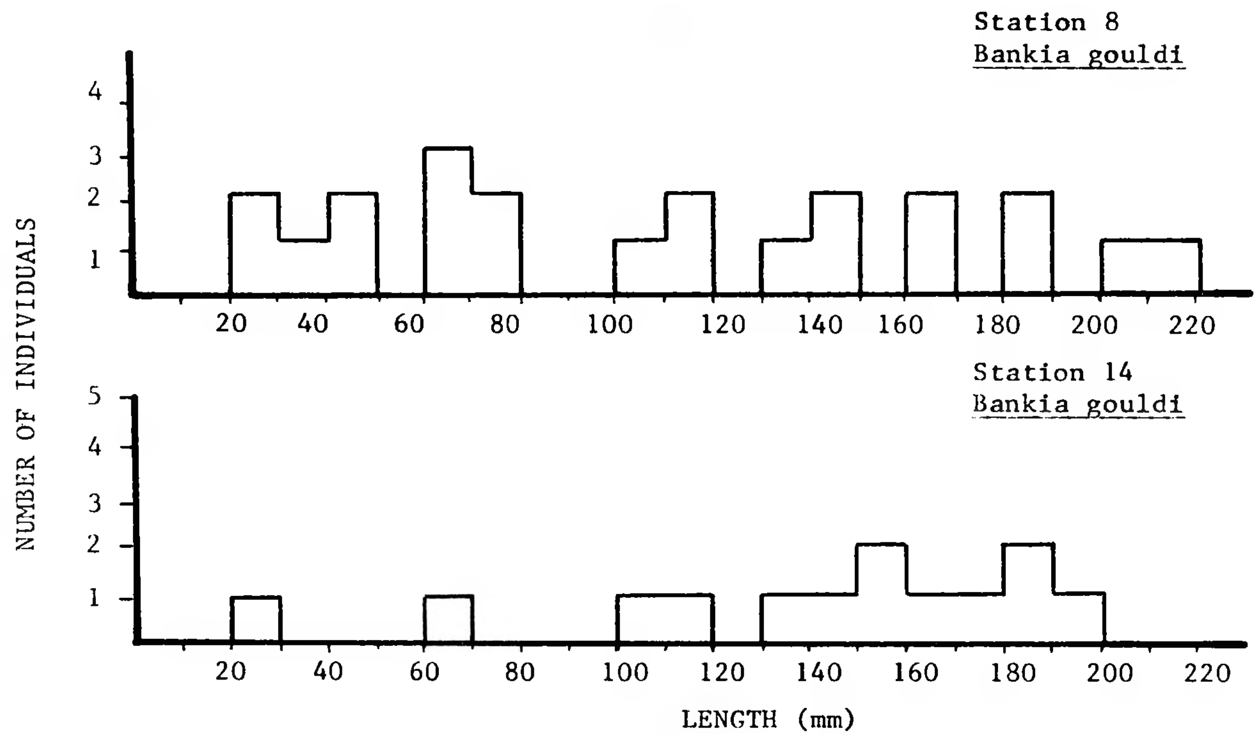


Figure B-2, continued
March Yearly Panels

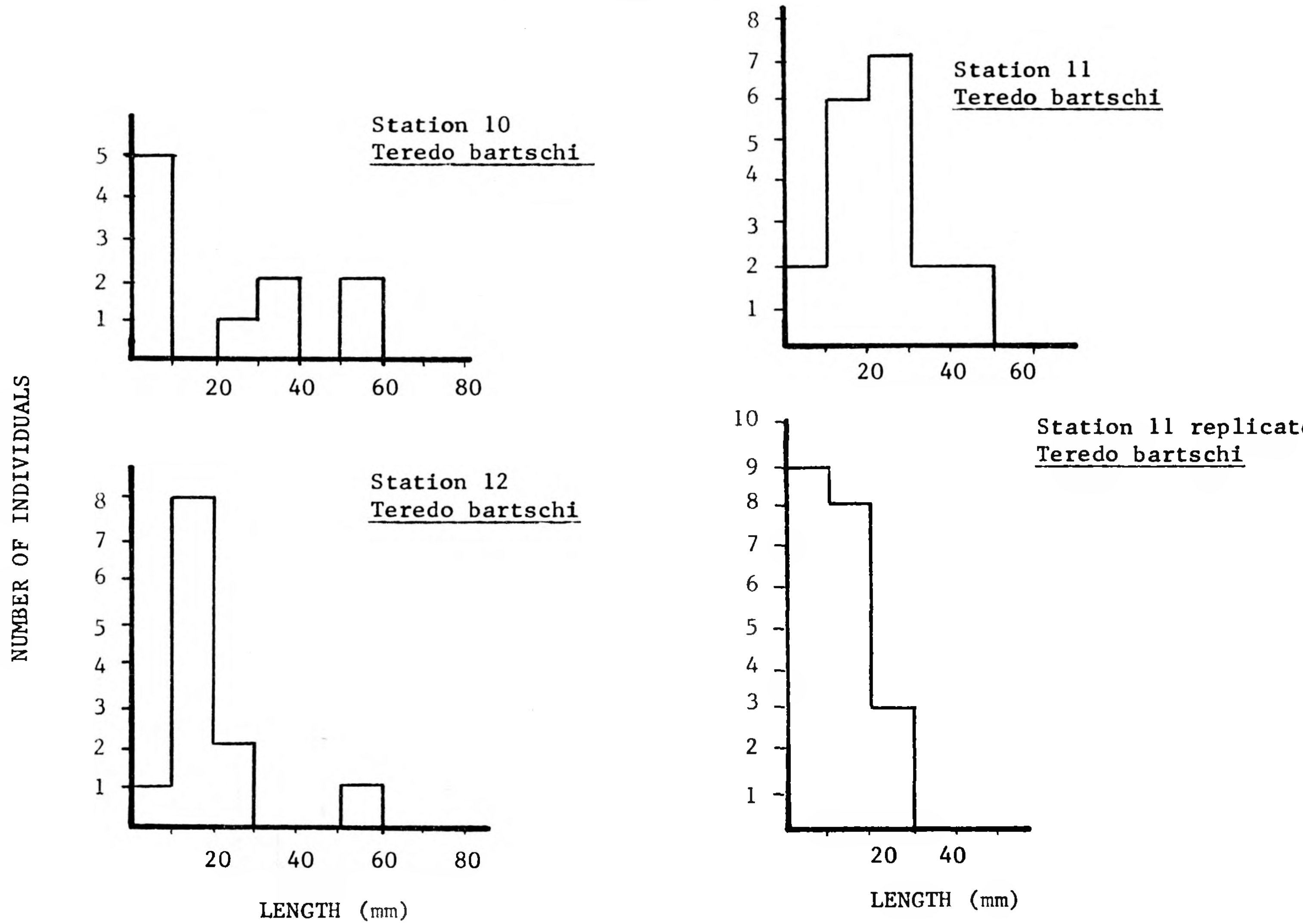


Figure B-3
April **Cumulative Panels**

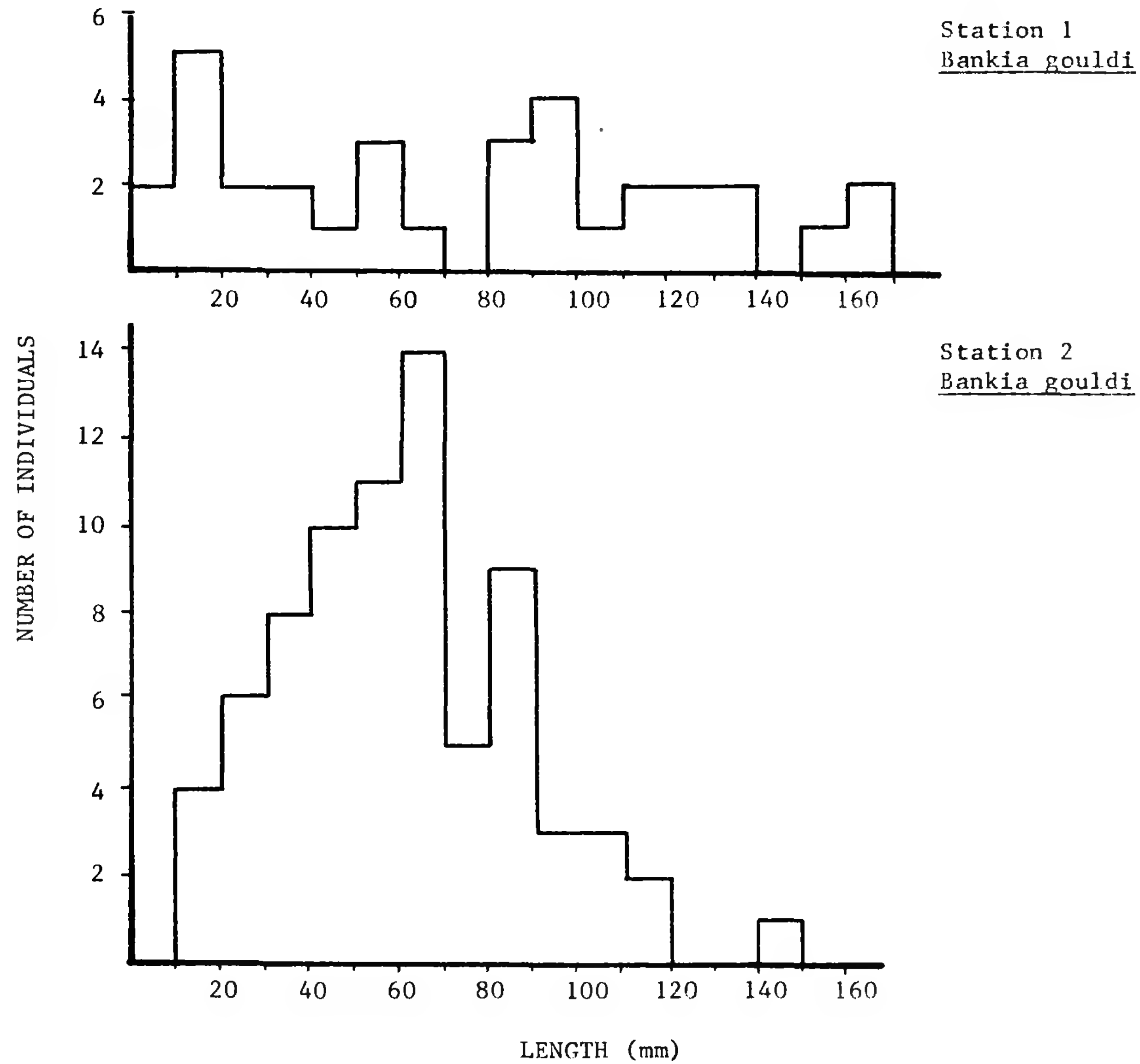


Figure B-4

April Yearly Panels

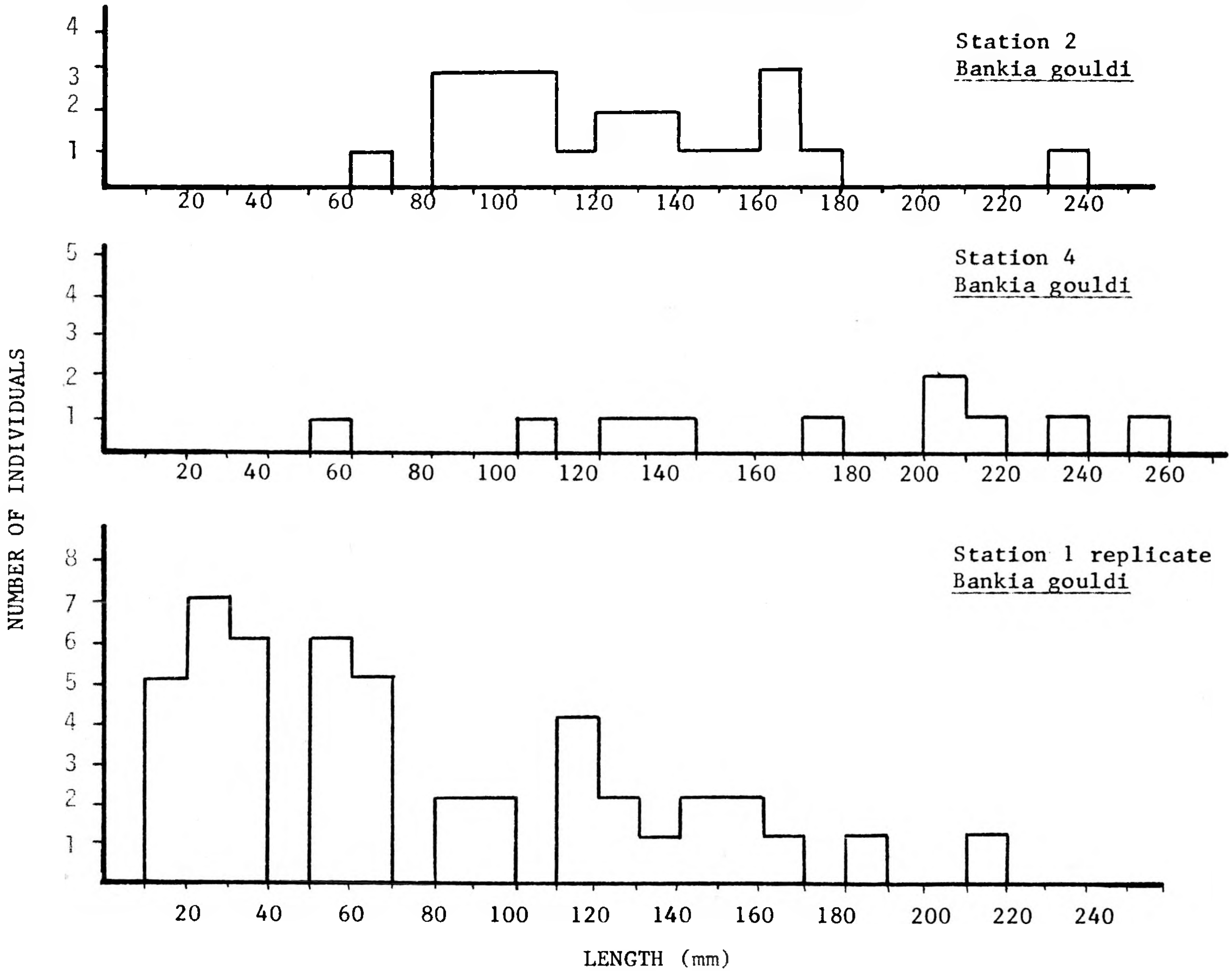


Figure B-4, continued

April Yearly Panels

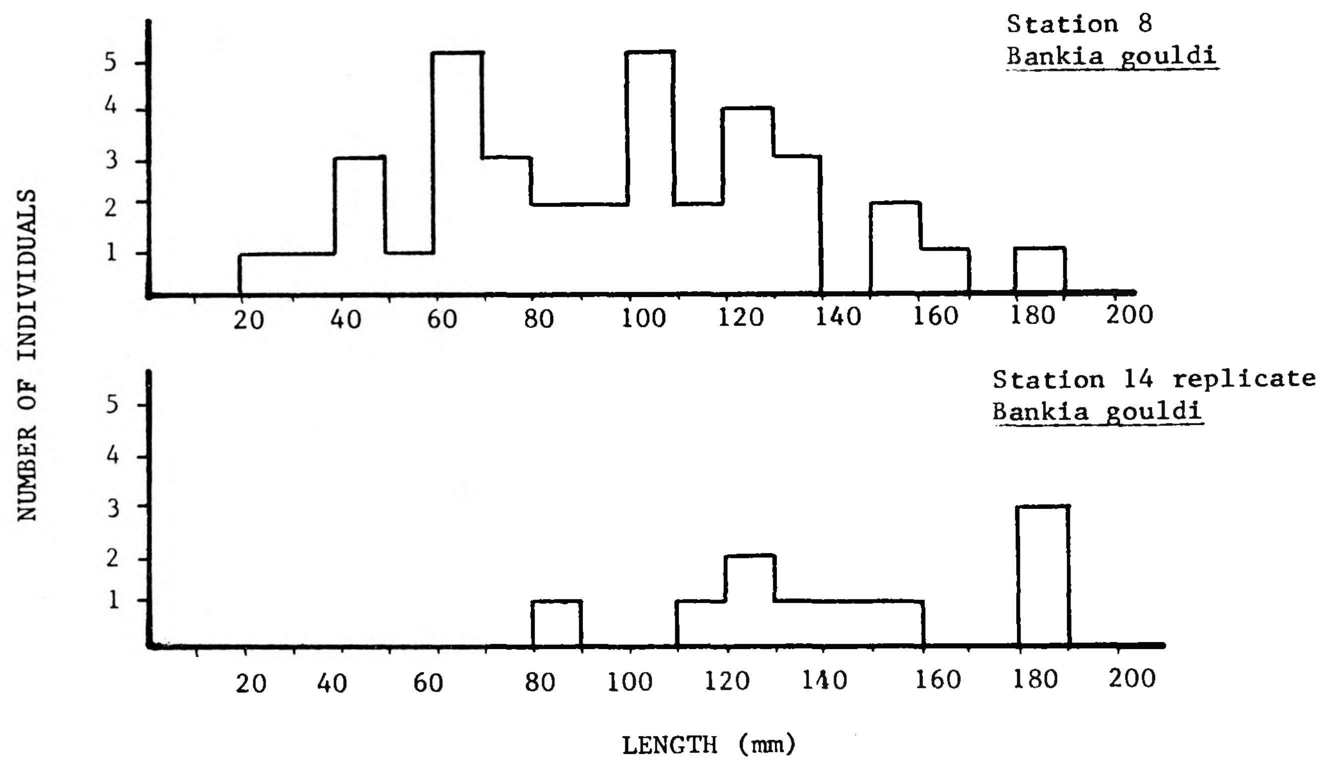


Figure B-4, continued

April Yearly Panels

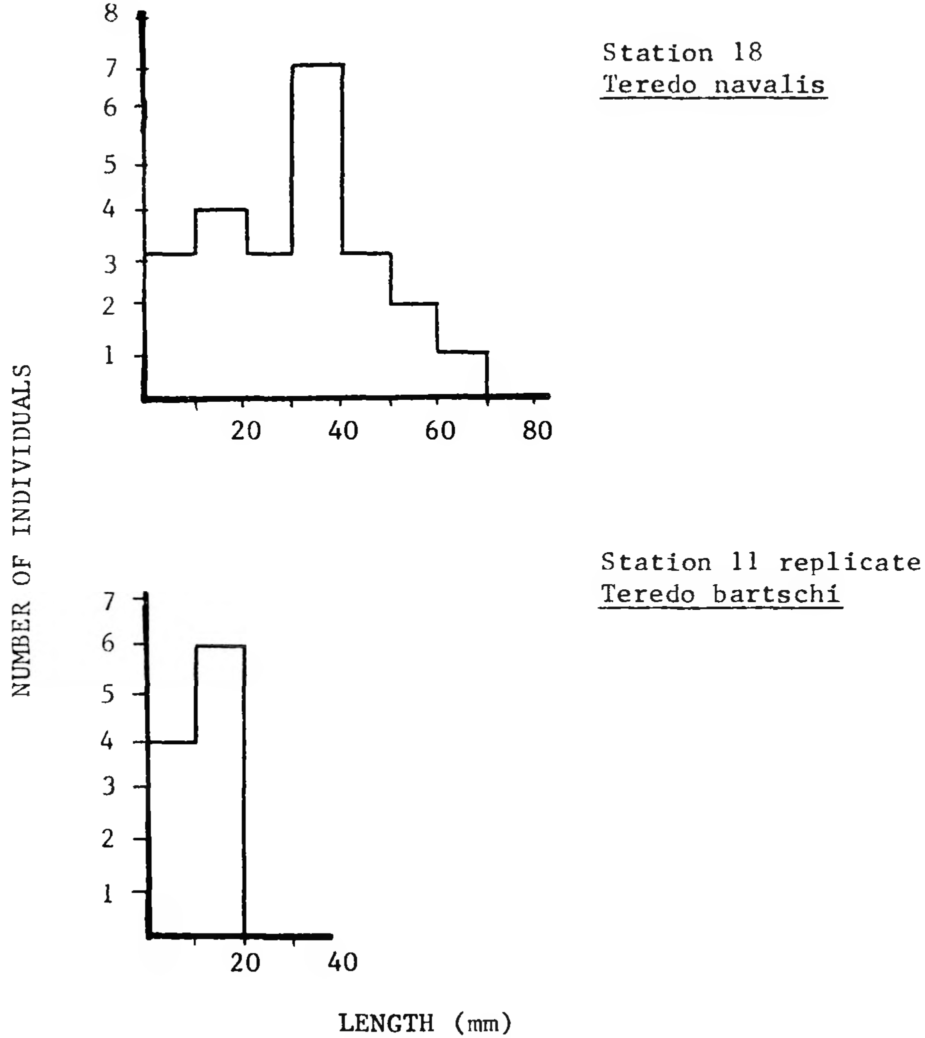


Figure B-5

May Cumulative Panels

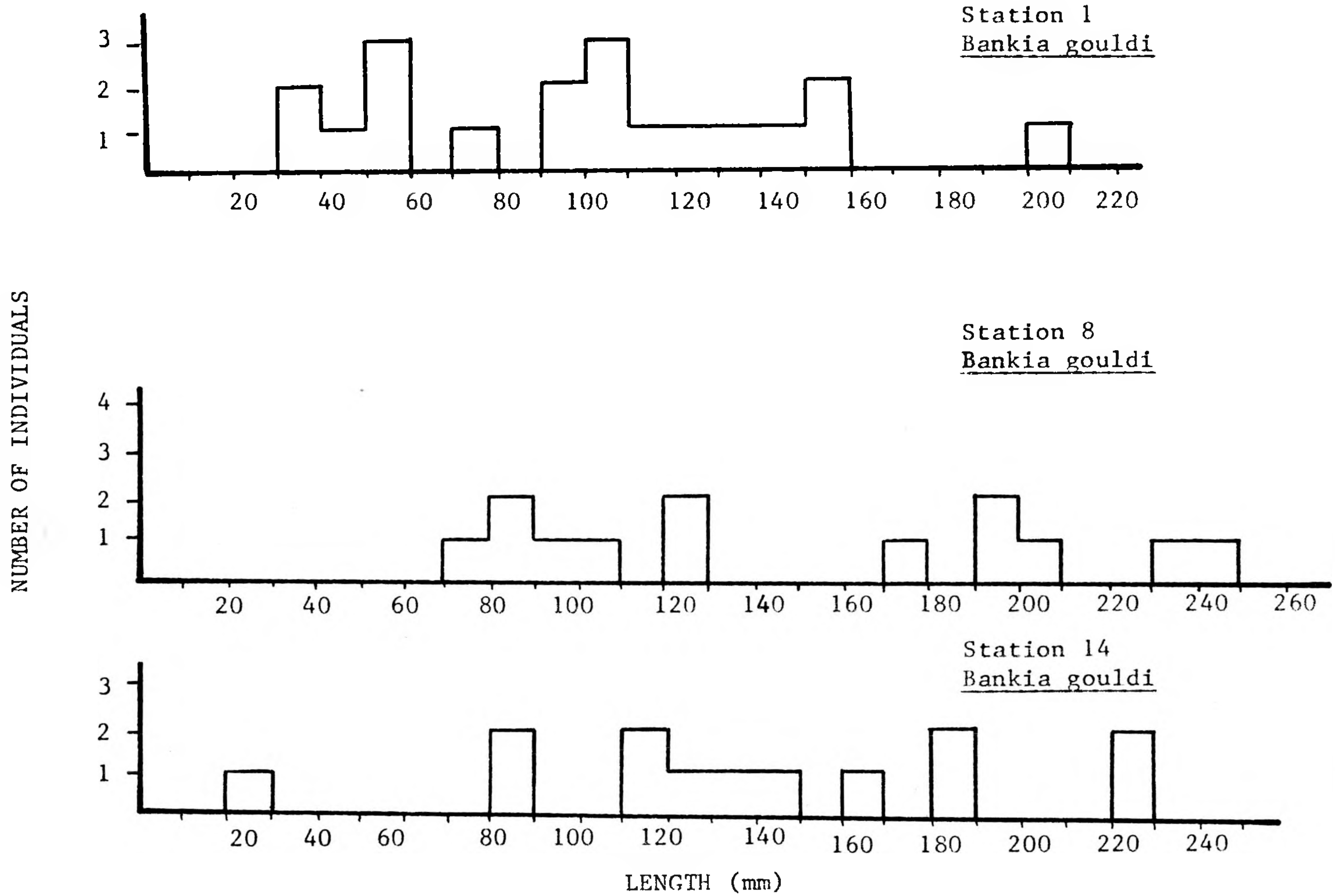
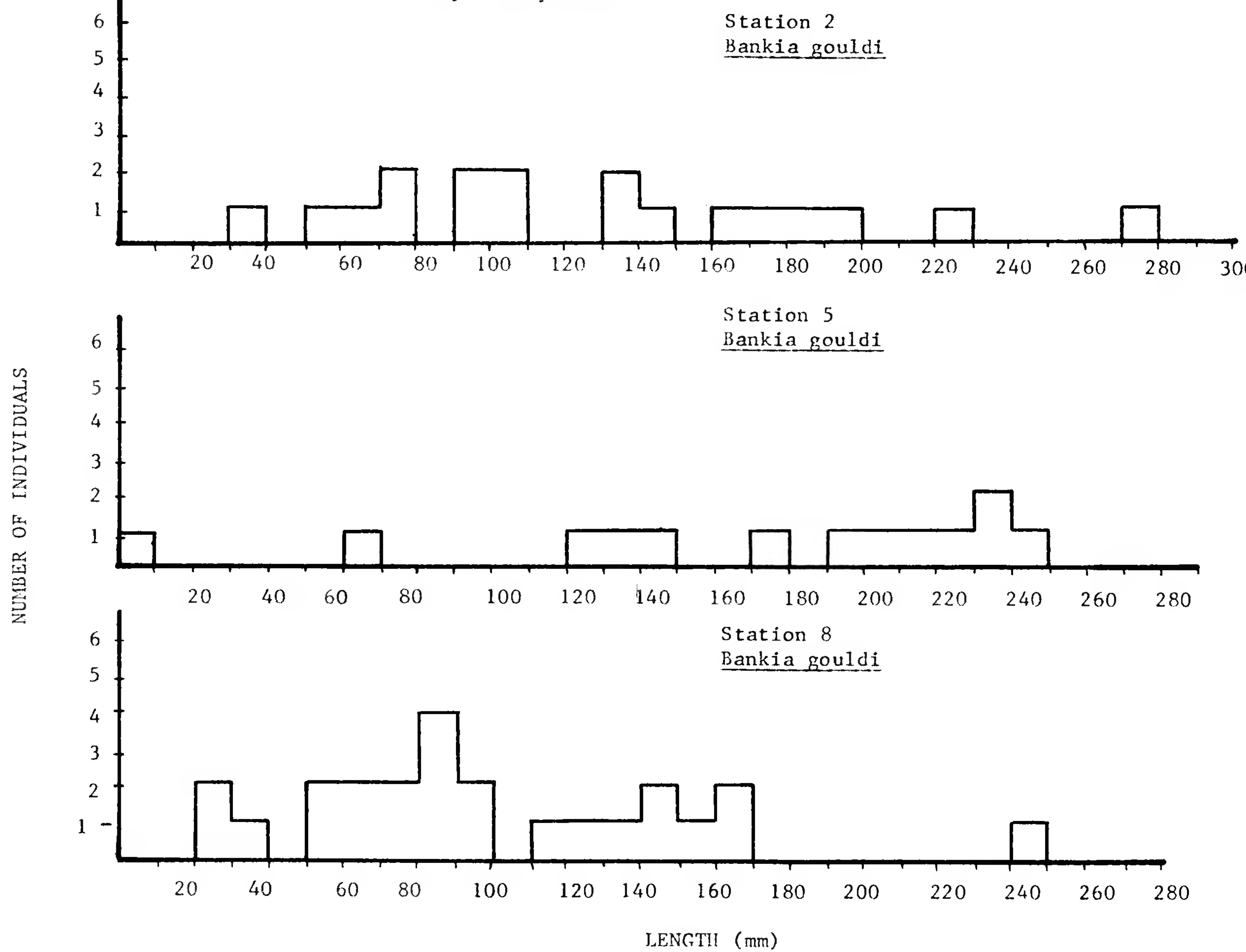


Figure B-6

May Yearly Panels



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16. ABSTRACT *(200 words or less)*
The growth, distribution, and species composition of marine borers (primarily shipworms) and fouling organisms 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 18 localities. Our most recent findings covering March-May, 1979, are that at least one subtropical species of the borer family Teredinidae continues to live in Oyster Creek and Forked River.

Despite dredging activity in Oyster Creek and unscheduled plant shutdowns, some T. bartschi survived. No settlement of larvae on one-month panels occurred. Much of the fouling in Oyster Creek died due to the dredging activities, and anoxic conditions occurred at stations 11 and 12. This illustrates the continued instability of the Oyster Creek-Forked River area since establishment of the Generating Station.

17. KEY WORDS AND DOCUMENT ANALYSIS

17a. DESCRIPTORS

shipworms
Teredinidae
Teredo bartschi
Oyster Creek
Forked River
Barnegat Bay

17b. IDENTIFIERS/OPEN-ENDED TERMS

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