NUREG/CR-0812

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

Quarterly Report
September 1978 - November 1978

K. E. Hoagland
L. Crocket

Wetlands Institute

Prepared for
U. S. Nuclear Regulatory Commission

Available from
National Technical Information Service
Springfield, Virginia 22161.

305 221

NUREG/CR-0812
RE

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

Quarterly Report
September 1978 - November 1978

K. E. Hoagland
L. Crocket

Wetlands Institute
(Lehigh University)
Stone Harbor, NJ 08247

Manuscript Completed: March 30, 1979
Date Published: June 1979

Prepared for
Division of Safeguards, Fuel Cycle and Environmental Research
Office of Nuclear Regulatory Research
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555
NRC FIN No. B5744

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 September-November, 1978, are that at least one subtropical species of the borer family Teredinidae continues to live in Oyster Creek; it now breeds at the mouth of Forked River. The subtropical *Teredo bartschi* living in Oyster Creek retained well-developed larvae in the gills through November, while the native species *B. gouldi* spawned out. The gonads of *B. gouldi* were vanishingly small in November. Larvae of *T. bartschi* settled in Oyster Creek and larvae of the native *T. navalis* settled on Long Beach Island in September, but no later. The last *B. gouldi* of the season settled in August. The greatest wood damage occurred at station 12 in Oyster Creek. Increased siltation on rocks in Oyster Creek decreased both the abundance and the diversity of fouling organisms. The introduced polychaete *Mercierella enigmatica* has been found in Oyster Creek as well as stations to the north.

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 temperature and salinity are recorded constantly.

Our major findings are:

1. The power plant was not operating during the period September 4-5 and September 16-November 30.
2. The water temperature in Oyster Creek ran about 5.5^{o}C lower this year than during the same period last year. Despite the plant shutdown, the temperature in September was slightly higher at Oyster Creek than at other stations.
3. Recirculation of heated effluent water did not occur during this period of time, because the plant was not operating.
4. Shipworm larvae settled on monthly panels in August and September.
5. Teredo bartschi was found in Oyster Creek and the mouth of Forked River. In November, straight-hinge larvae were observed in the gills of specimens in Forked River for the first time.
6. No T. furcifera specimens were found.
7. The shipworms in Oyster Creek were reproducing at a size as small as 4 mm long, due to extreme crowding.
8. The heaviest attack is now in Oyster Creek and the mouth of Forked River. One station on Long Beach Island is also heavily infested.
9. Unusually high mortality of shipworms occurred in very crowded panels.
10. Fouling declined in Oyster Creek because of heavy silt. Algae were particularly affected. Barnacles were not affected.
11. The non-endemic polychaete worm Mercierella enigmatica was found for the first time in Oyster Creek. It appears to be spreading from north to south in Barnegat Bay.
12. The ratio of gonad weight to total body weight tends to be higher for B. gouldi in Oyster Creek than B. gouldi at other localities. This implies greater reproductive potential. However, numbers of specimens from Oyster Creek were low, and the results were not statistically significant.

TABLE OF CONTENTS

ABSTRACT iii

SUMMARY OF FINDINGS iv

LIST OF FIGURES vi

LIST OF TABLES vii

ACKNOWLEDGMENTS ix

PREVIOUS REPORTS IN SERIES x

INTRODUCTION 1

MAJOR PHYSICAL EVENTS 2

Temperature

Salinity

SHIPWORMS 9

FOULING ORGANISMS 43

DISCUSSION 55

References 57

APPENDIX 59

DISTRIBUTION LIST 63

LIST OF FIGURES

	Page
1. Monthly Temperatures, September 1978 - November 1978	4
2. Histograms of Lengths of Shipworms from Yearly Panels	
A. September	16
B. October	19
C. November	22
3. Histograms of Lengths of Shipworms from Cumulative Panels .	
A. September	29
B. October	32
C. November	35

LIST OF TABLES

		Page
1.	Temperature Profiles, in Degrees Centigrade, September 9 - November 4, 1978	3
2.	Constant Temperature Recorder Data (^{o}C) for September 9 - December 2, 1978, Stations 1,5,11,14	5
3.	Salinity Profiles in $^{o}/_{oo}$	7
4.	Constant Recording Salinometer Readings at 12:00 Noon, August 8 - November 4, 1978 ($^{o}/_{oo}$)	8
5.	Numbers of Living Shipworms in Monthly Panels	11
6.	Length Ranges of Living Shipworms, in mm, Monthly Panels	12
7.	Numbers of Living Shipworms in Panels Submerged for One Year	13
8.	Numbers of Living Shipworms plus Empty Tubes, Panels Submerged for One Year	14
9.	Length Ranges of Living Shipworms, in mm, Yearly Panels	15
10.	Numbers of Living Shipworms, Cumulative Panels Submerged May 31, 1978	26
11.	Numbers of Living Shipworms plus Empty Tubes, Cumulative Panels Submerged May 31, 1978	27
12.	Length Ranges of Living Shipworms, in mm, Cumulative Panels Submerged May 31, 1978	28
13.	Percentage Weight Loss by Cumulative Panels Submerged May 31, 1978	38
14.	Percentage Weight Loss by Yearly Panels, Removed September - November, 1978	39
15.	Gonad Ash-Free Dry Weights, Bankia gouldi	41
16.	The Percentage of Teredo specimens Found with Larvae in the Gills	42

Page

17. Distribution of Some Common Fouling Organisms: Electra crustulenta 44

18. Distribution of Some Common Fouling Organisms: Hydroides dianthus 45

19. Distribution of Some Common Fouling Organisms: Botryllus schlosseri 46

20. Distribution of Some Common Fouling Organisms: Enteromorpha spp. 47

21. Distribution of Some Common Fouling Organisms: Balanus eburneus 48

22. Distribution of Some Common Fouling Organisms: Molgula manhattensis 49

23. Distribution of Some Common Fouling Organisms: Campanulareid spp. 50

24. Sedentary Species Richness, September, 1978 51

25. Sedentary Species Richness, October, 1978 52

26. Sedentary Species Richness, November, 1978 53

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, Jamie Harms, and William King provided technical assistance. Eugenia Böhlke of the Academy of Natural Sciences of Philadelphia served as X-ray technologist. Virginia Ohori of J.C.P. & L. provided data on the operation of the Generating Station.

PREVIOUS REPORTS 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:

Report No.

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.

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
September 1, 1978 - November 30, 1978

INTRODUCTION

This progress report covers data collected over the period Sept. 1, 1978 - Nov. 30, 1978. The methods are identical to those given in earlier reports. The period was marked by a prolonged shutdown of the generating station for refueling. A loss of data was caused by malfunction of salinometers, but all other operations were normal. A lost rack at station 2 was recovered intact. The locations of our stations are given in the Appendix.

MAJOR PHYSICAL EVENTS

Temperature

Table 1 and Figure 1 show the temperatures recorded at the time of sampling each month. On September 9, the Generating Station had been operating for 3 days following a 2-day shutdown. Oyster Creek temperatures were only 1-4° above control stations; there was great variance in the temperatures at the control stations. During October and November when the Station was down for refueling, Oyster Creek stations were among the coolest. As has occurred in previous months, the warmest station outside of Oyster Creek was in Stout's Creek (#3).

The constant temperature recorders (Table 2) provide more comprehensive data, but at only 4 stations. It can be seen that the mean daily ΔT was higher in Oyster Creek than at the other stations, although the largest single daily ΔT occurred in Forked River, in all three months. The temperature in Oyster Creek was about 5.4°C lower in fall, 1978, than in fall, 1977, due to the Station shutdown.

Salinity

Tables 3 and 4 present salinity data for Oyster Creek (Stations 10-13), Forked River (Stations 4-9) and control stations. As we noted in previous reports, Oyster Creek and Forked River are similar in salinity, and fall between the tidal creeks and Barnegat Bay stations. Usually, the salinity is slightly lower at Oyster Creek relative to Forked River. The highest values are usually at Long Beach Island. The greatest month-to-month change in salinity comes at stations 1,2, 3, and 14, that are influenced by variation in outflow of fresh water from tidal creeks.

At station 1, some data taken early in the month were excluded. This is because the probe was checked and found to be clogged with silt. After it was cleaned, the salinity rose by 8 $^{o}/_{oo}$. This problem has not been found at the other stations.

Table 1

Temperature Profiles, in Degrees Centigrade, September 9-November 4, 1978

Station	September 9	October 8	November 4	Differential within stations among months
1	c	15.0	11.1	3.9
2	20.6	12.8b	10.0b	10.6
3	22.2	18.3a	15.0a	7.2
4	18.9b	c	12.2	6.7
5	18.9b	12.8b	11.7	7.2
6	20.6	13.3	12.2	8.4
7	22.2	16.7	12.8	9.4
8	19.2	13.9	11.9	7.3
9	19.4	14.4	12.2	7.2
10	22.8	14.4	11.1	11.7
11	23.3	14.4	11.1	12.2
12	24.7a	14.4	12.8	11.9
13	23.9	15.0	11.1	12.8
14	21.7	16.1	11.1	10.6
15	21.4	c	11.1	10.3
16	19.7	c	11.1	8.6
17	19.7	16.4	11.1	8.6
18	19.4	16.1	12.8	6.6
19	19.4	16.1	12.2	7.2
20	20.0	14.4	10.3	9.7
Differential among stations	5.8	5.5	5.0	

Note: a highest value

b lowest value

c no data

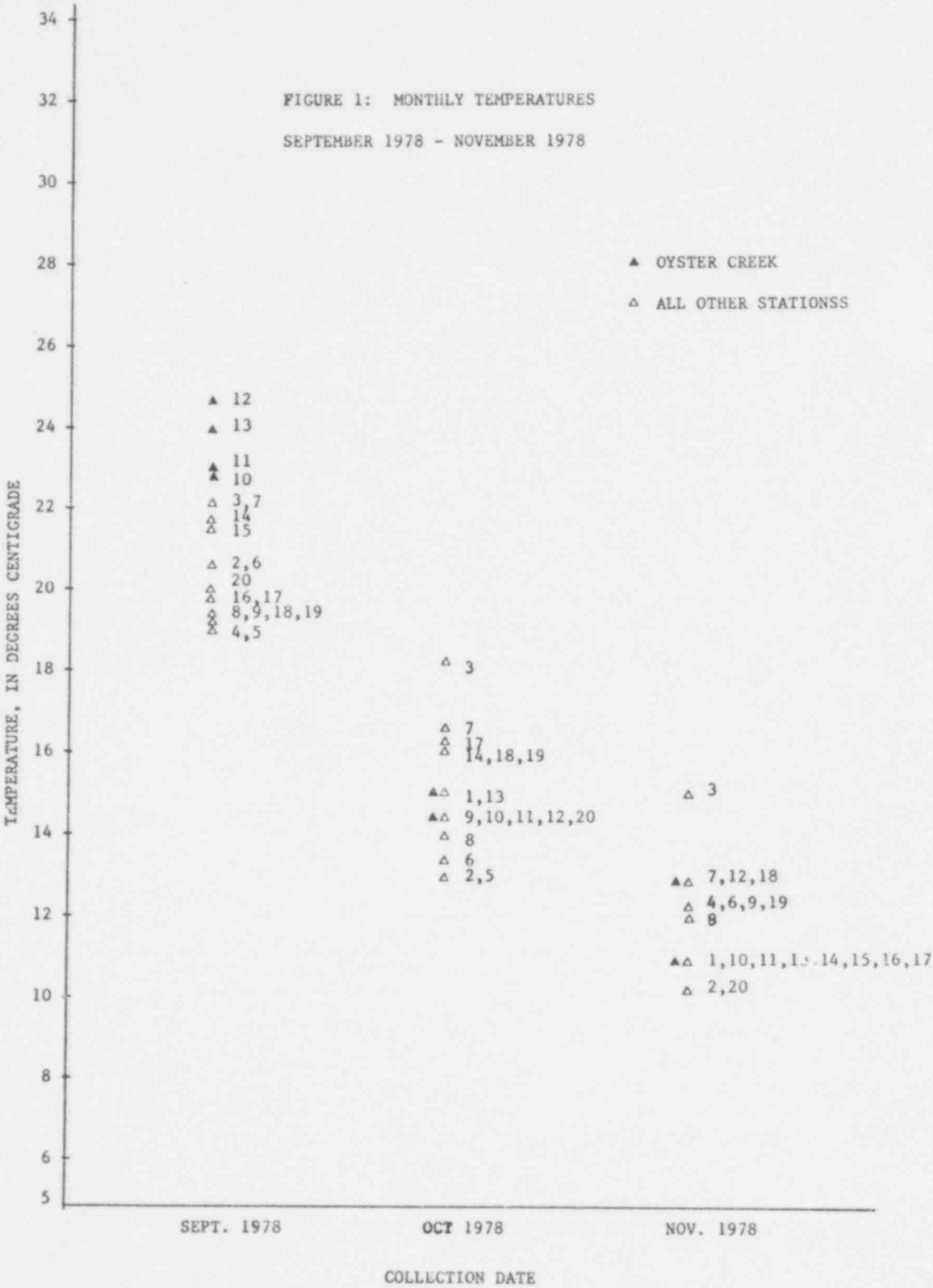


FIGURE 1: MONTHLY TEMPERATURES

SEPTEMBER 1978 - NOVEMBER 1978

Table 2

Constant Temperature Recorder Data (^{o}C) for Sept. 9 - Dec. 2, 1978
Stations 1,5,11,14

I. Temperature at 1:00 PM

	Sept.9 - Oct 8,1978				Oct 8 - Nov 4, 1978				Nov 4 - Dec 2, 1978			
	1	5	11	14	1	5	11	14	1	5	11	14
Mean Daily Temp at 1 PM	18.8	18.9	*	19.7	13.5	14.1	*	14.9	9.3	10.0	*	10.9
Standard Deviation	1.6	1.9		1.6	1.6	1.6		1.7	3.0	3.0		2.0
Highest value of Temp. at 1 PM	21.4	23.0		22.8	17.3	17.8		18.3	13.0	13.6		13.3
Lowest value of Temp. at 1 PM	16.3	16.1		17.6	11.3	11.9		12.7	4.2	5.0		4.9
Monthly Temp. Range at 1 PM	5.1	6.9		5.2	6.0	5.9		5.6	8.8	8.6		8.4

II. Maximum Daily Temperatures

	Sept.9 - Oct 8, 1978				Oct 8 - Nov 4, 1978				Nov 4 - Dec 2, 1978			
	1	5	11	14	1	5	11	14	1	5	11	14
Mean value of Max. Daily Temp.	19.8	20.1	21.5	19.9	14.1	14.9	14.9	15.1	9.6	10.6	11.1	11.4
Standard Deviation	1.9	1.7	3.0	1.7	1.6	1.4	1.8	1.8	3.0	2.7	2.6	1.8
Highest value of Max. Daily Temp.	23.5	23.0	28.6	23.2	17.8	17.8	18.6	18.5	13.3	13.7	13.6	13.6
Lowest value of Max. Daily Temp.	16.9	17.1	16.7	17.7	11.9	13.1	12.2	12.8	4.8	6.0	[illegible]	6.4
Monthly Range of Max. Daily Temp.	6.6	5.9	11.9	5.2	5.9	4.7	6.4	5.7	8.5	7.7	8.8	[illegible]

* Recorder running fast. Temperature at precisely 1 PM could not be evaluated with certainty.

Table 2, Continued

III. Minimum Daily Temperatures

	Sept 9 - Oct 8, 1978				Oct 8 - Nov 4, 1978				Nov 4 - Dec 2, 1978			
	1	5	11	14	1	5	11	14	1	5	11	14
Mean value of min. Daily Temp.	18.3	18.4	19.6	18.7	12.8	13.5	12.9	13.9	8.7	9.5	9.6	10.5
Standard Deviation	1.7	1.7	3.1	1.5	1.5	1.3	1.5	1.5	3.0	2.8	2.4	2.0
Highest value of Min. Daily Temp.	21.7	21.5	26.8	22.1	16.7	16.7	17.2	17.1	12.6	12.9	12.6	13.1
Lowest value of Min. Daily Temp.	15.5	15.8	14.2	16.6	10.7	11.6	10.9	12.1	3.9	4.9	4.6	4.9
Monthly Range of Min. Daily Temp.	6.2	5.7	12.6	5.5	6.0	5.1	6.3	5.0	8.7	8.0	8.0	8.2

9

IV. Daily Temperature Range

	Sept 9 - Oct 8, 1978				Oct 8 - Nov 4, 1978				Nov 4 - Dec 2, 1978			
	1	5	11	14	1	5	11	14	1	5	11	14
Mean Daily ΔT	1.4	1.7	1.9	1.2	1.4	1.5	2.0	1.2	0.9	1.1	1.4	0.8
Standard Deviation	0.8	1.1	1.0	0.6	0.6	1.1	1.0	0.6	0.4	0.7	0.8	0.5
Largest Daily ΔT for one month	3.3	4.7	3.9	2.2	2.4	4.8	4.5	2.5	1.8	3.3	2.8	1.8
Smallest Daily ΔT for one month	0.3	0.1	0.2	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2

Table 3

Salinity Profiles, in $^{o}/_{100}$

Station	September 9	October 8	November 4	Differential within stations among months
1	15.0	26.5	10.0	16.5
2	10.0	17.5	10.0	7.5
3	13.0	21.0	14.0	8.0
4	21.0	c	23.0	2.0
5	21.5	20.5	24.0	3.5
6	21.5	22.0	17.0	5.0
7	14.0	19.0	17.0	5.0
8	19.0	24.5	23.0	5.5
9	23.0	24.5	22.0	2.5
10	19.5	24.0	19.0	5.0
11	21.0	22.5	18.0	4.5
12	20.5	25.0	21.0	4.5
13	14.0	19.0	12.0	5.0
14	17.5	30.0 a	22.5	12.5
15	23.0	c	23.0	0.0
16	22.5	c	23.0	0.5
17	23.5	25.0	23.0	1.5
18	25.5	26.0	32.5 a	7.0
19	28.5 a	29.0	27.0	2.0
20	5.0 b	10.0 b	8.0 b	5.0
Differential among stations	23.5	20.0	24.5	

Note: a highest value

b lowest value

c missing data

305 237

Table 4

Constant Recording Salinometer Readings at 12:00 Noon,
August 8 - November 4, 1978 ($^{0}/oo$)

Dates	Statistic*	Sta. 1	Sta. 5	Sta. 11	Sta. 14
Aug 8, 1978 to Sept 9, 1978	N	0	33	0	0
	$\bar{X}$	-	19.4	-	-
	S_x	-	1.5	-	-
Sept 9, 1978 to Oct 8, 1978	N	13	28	0	0
	$\bar{X}$	10.1	17.8	-	-
	S_x	1.3	1.9	-	-
Oct 8, 1978 to Nov 4, 1978	N	28	28	27	0
	$\bar{X}$	19.6	19.0	16.7	-
	S_x	29	1.5	1.7	-

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

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

SHIPWORMS

Monthly Panels

Table 5 presents data on numbers and species of shipworms settling during August and September. No shipworms settled past October 8, at least, none that survived long enough to make an impression on the wood. In August, Bankia gouldi settled at control stations but only Teredo bartschi settled in Oyster Creek. Heavy settlement occurred at Holly Park (B. gouldi), Long Beach Island (T. navalis), and Oyster Creek (T. bartschi). In September, successful settlement was sparse, and restricted to T. navalis on Long Beach Island and T. bartschi at one station in Oyster Creek.

Remarkable growth of young B. gouldi occurred during the month of August (Table 6). Ten specimens exceeded 49 mm in length. Significant growth occurred among all three species, at all stations where there was settlement. For example, 3 out of 59 specimens of T. bartschi retrieved in the September monthly station 11 panel had achieved a length of 10 mm; the others were from 1-9 mm. Five specimens of T. navalis from station 18 had achieved a length of 20 mm or more, although 510 were less than 10 mm and 101 were between 10 and 20 mm. No significant growth occurred in juveniles that settled in September or the first week of October.

Yearly Panels

Panels submerged in the fall of 1977 and removed in the fall of 1978 are described in Tables 7-9. Shipworm attack, in terms of numbers, was highest at stations #11 and 12 (Oyster Creek), with significant attack also occurring at stations #2 (mouth of Cedar Creek), 8 (between Oyster Creek and Forked River), and 18 (Long Beach Island). Each area is infested primarily by a one species, in each case a different one, except for station 8 where both B. gouldi and T. bartschi occur in high numbers. A few pairs of replicated panels, notably at station 1 and 11-November, differed by an order of magnitude.

Mortality occurred most heavily in the crowded panels of stations 11 (October), 12 (Sept.), and 18. At station 18, mortality was too high to estimate accurately. Size ranges of the specimens (Table 9, Fig. 2) showed that very small specimens of T. navalis existed only at station 18; small and presumably young specimens of T. bartschi existed at all but station 4. There were a few small B. gouldi at stations 1 and 2; all other panels contained only adults. The largest specimens occurred at stations 8, 11, 12, 14, 15, and 17.

Cumulative Panels

Tables 10 and 11 present the numbers and species of shipworms taken from cumulative panels that had been submerged for 3, 4, and 5 months. The heaviest infestation was at stations 1, 2, 10-12, and 18. Attack at station 10 near the mouth of Oyster Creek was stronger than showed up in the yearly panels, but was still lower than at stations 11 and 12. Species deployment was as in yearly panels. Station 13 near the thermal discharge point was not infested by T. bartschi, but a few T. navalis and B. gouldi were present.

At station 18, where the panels were falling apart by October, mortality was very high and could not be estimated accurately. It was at least 90% for the November panel. At Oyster Creek, significant mortality was not seen until October 8; the greatest mortality occurred at station 12.

The largest specimens were found at stations 4, 10, 12, and 17. Live specimens of B. gouldi less than 5 mm long occurred only at station 1 in September. Small T. bartschi and T. navalis were common in September and October, but small T. navalis were absent in November (Table 12, Fig. 3).

Wood Destruction

A quantitative estimate of wood borer damage is presented in Tables 13 and 14. The highest damage in the summer of 1978 was at station 11 in Oyster Creek, followed by 18 (Long Beach Island), 12 (Oyster Creek), 1 (Holly Park), 17 (Manahawkin), and 10 (lagoon off Oyster Creek). A similar pattern is seen for panels submerged 12 months, except that damage was considerably less at station 10 and greater at station 8 (Bayside Beach Club) than would be predicted from the summer data alone. Damage at station 17 includes boring by the isopod Limnoria.

Table 5

Number of Living Shipworms in Monthly Panels

Dates Submerged

	Aug 8 - Sept 9, 1978				Sept 9 - Oct 8, 1978			
Station	B.g.	T.b.	T.n.	Total	B.g.	T.b.	T.n.	Total
1	35			35				0
2	1			1				0
3				0				0
4				0				0
5	2			2				0
6				0				0
7				0				0
8	2			2				0
9				0				0
10		3		3				0
11		74		74				0
12		56		56		5		5
13				0				0
14	1			1				0
17				0 *				0
18			712	712 #			2	2
19			4	4			1	1
20				0				0
Totals	41	133	716	890	0	5	3	8

* 1 dead

4 dead

B.g. = Bankia gouldi
T.b. = Teredo bartschi
T.n. = Teredo navalis
T.sp.= Teredo species (unidentified)

305 211

Table 6

Length Ranges of Living Shipworms, in mm, Monthly Panels

Dates	Aug 8 - Sept 9, 1978			Sept 9 - Oct 8, 1979	
Station	B. g.	T.b.	T.n.	T.b.	T.n.
1	3-92 *				
2	2				
3					
4					
5	2-15				
6					
7					
8	10-11				
9					
10		5-6			
11		1 14 *			
12		1-8		<2 *	
13					
14	26				
17					
18			1-28 *		2 *
19			2-8		2 *
20					

* largest specimen each month, each species

Table 7

Numbers of Living Shipworms in Panels Submerged for One Year

Date Removed:	Sept 9, 1978				Oct 8, 1978				Nov 4, 1978			
Station	B.g.	T.b.	T.n.	Total	B.g.	T.b.	T.n.	Total	B.g.	T.b.	T.n.	Total
1	1	0	0	1	3	0	0	3	7	0	0	7
1 Rep	21	0	1	22	34	0	0	34	53	0	0	53
2	16	0	0	16	10	0	0	10	107	0	0	107
3	0	0	0	0	0	0	0	0	0	0	0	0
3 Rep	0	0	0	0	0	0	0	0	0	0	0	0
4	4	0	1	5	4	0	1	5	5	1	1	7
5	13	0	0	13	11	0	2	13	11	0	1	12
6	1	0	0	1	0	0	0	0	1	0	0	1
7	0	0	0	0	0	0	0	0	0	0	0	0
8	17	8	0	25	23	8	0	31	42	9	1	52
10	3	16	0	19	2	12	0	14	1	19	0	20
11	0	1261	0	1261	0	393	0	393	0	1744	0	1744
11 Rep	0	980		980	0	459	1	460	0	496	0	496
12	0	729	1	730	0	884	0	884	0	670	0	670
14	9	0	4	13	10	0	1	11	7	0	0	7
14 Rep	4	0	0	4	2	0	0	2	3	0	0	3
15	4	0	0	4	3	0	0	3	4	0	0	4
16	0	0	0	0	1	0	0	1	1	0	0	1
16 Rep	0	0	0	0	0	0	0	0	1	0	0	1
17	0	0	2	2	2	0	14	16	0	0	9	9
18	No Panel				1	0	494	495	0	0	465	465
19	0	0	2	2	1	0	5	6	1	0	7	8
Total	93	2994	11	3098	107	1756	518	2381	244	2939	484	3667

Table 8

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

Date	Sept 9, 1978					Oct 8, 1978					Nov 4, 1978				
Station	B.g.	T.b.	T.n.	Tsp.	Total	B.g.	T.b.	T.n.	Tsp.	Total	B.g.	T.b.	T.n.	Tsp.	Total
1	1	0	0	0	1	3	0	0	0	3	7	0	0	0	7
1 Rep	21	0	1	0	22	34	0	0	0	34	53	0	0	0	53
2	16	0	0	0	16	10	0	0	0	10	107	0	0	0	107
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 Rep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	4	0	2	0	6	4	0	1	0	5	5	1	2*	0	8*
5	13	0	0	0	13	11	0	2	0	13	11	0	1	0	12
6	1	0	0	0	1	0	0	0	0	0	1	0	0	0	1
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	17	8	0	0	25	23	8	0	0	31	42	9	1	0	52
10	3	16	0	0	19	3*	12	1*	0	16*	1	19	0	0	20
11	0	1261+*	0	0	1261+*	0	524*	0	0	524*	0	1744	0	0	1744
11 Rep	0	1127*	0	0	1127*	0	559*	1	0	560*	0	496	0	0	496
12	0	875*	1	0	876*	0	894*	0	0	894*	0	670	0	0	670
14	9	0	4	0	13	10	0	2*	0	12*	7	0	0	0	7
14 Rep	4	0	0	0	4	2	0	0	0	2	3	0	0	0	3
15	4	0	0	0	4	3	0	0	0	3	4	0	0	0	4
16	0	0	0	0	0	1	0	0	0	1	1	0	0	0	1
16 Rep	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
17	0	0	2	0	2	2	0	14	0	16	0	0	9	0	9
18	-	-	-	-	-	1	0	494+*	0	495+*	0	0	465+*	0	465+*
19	0	0	2	0	2	1	0	5	0	6	1	0	7	0	8
Total	93	3287+	12	0	3392+	108	1997	520+	0	2625+	244	2939	485+	0	3668+

* Mortality occurred. Compare numbers with Table 7.
\+ Some dead specimens could not be counted.

Table 9

Length Ranges of Living Shipworms, in mm, Yearly Panels

Date Removed:	Sept 9, 1978			Oct 8, 1978			Nov 4, 1978		
Station	B.g.	T.b.	T.n.	B.g.	T.b.	T.n.	B.g.	T.b.	T.n.
1	45			56-133			7-247		
1 Rep	6-201		43	16-245			19-219		
2	7-137			2-170			43-198		
3									
3 Rep									
4	31-90		93	28-212		122	91-210	49	134
5	9-183			32-240		138-140	90-208		50
6	112						230		
7									
8	14-224*	3-14			18-34		32-160	3-40	85
10	28-212	5-47		156-200	5-60		268		
11		1-72			3-100*			2-83	
11 Rep		2-86			2-68	168		1-118*	
12		1-95*	117		2-97			1-115	
14	87-199		42-150*	40-270*		120	125-268		
14 Rep	105-176			115-185			195-271		
15	73-144			173-261			142-293*		
16				42			193		
16 Rep							133		
17			30-45	162-201		42-175*			85-160*
18				32		2-117			2-78
19			109	192		30-174	142		22-143

* Largest specimen each month, each species.

FIGURE 2: HISTOGRAMS OF LENGTHS OF SHIPWORMS TAKEN FROM PANELS

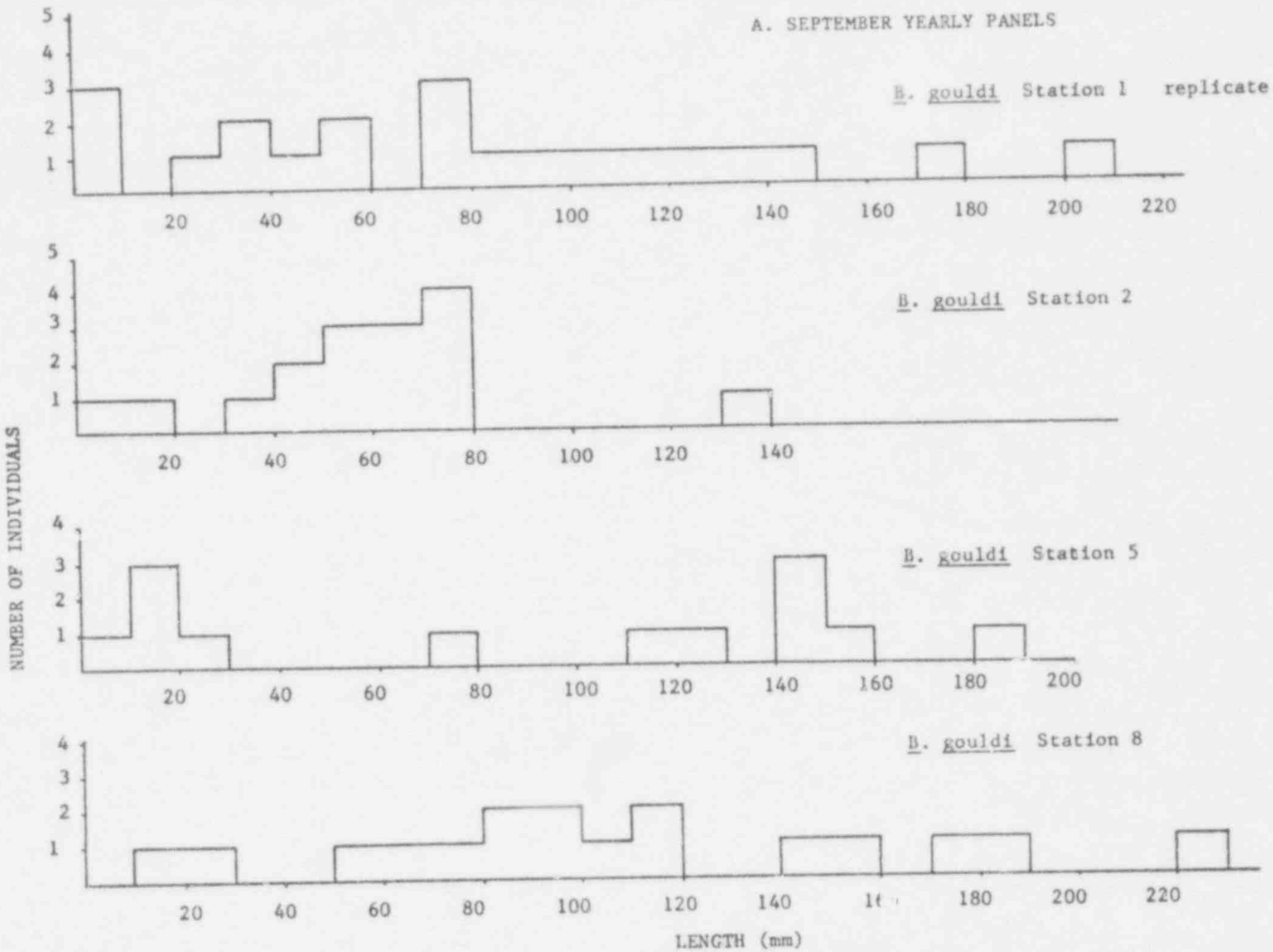
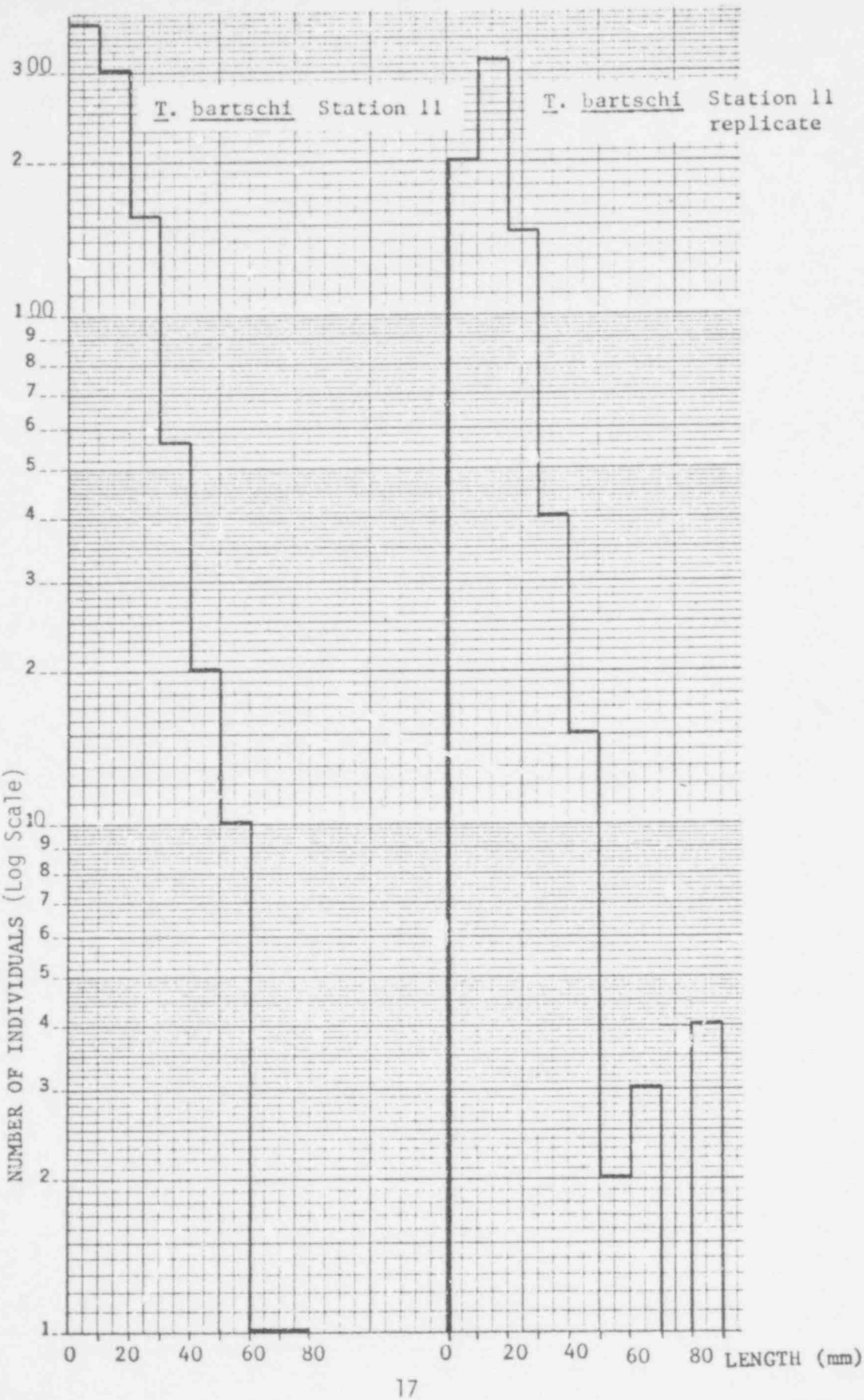
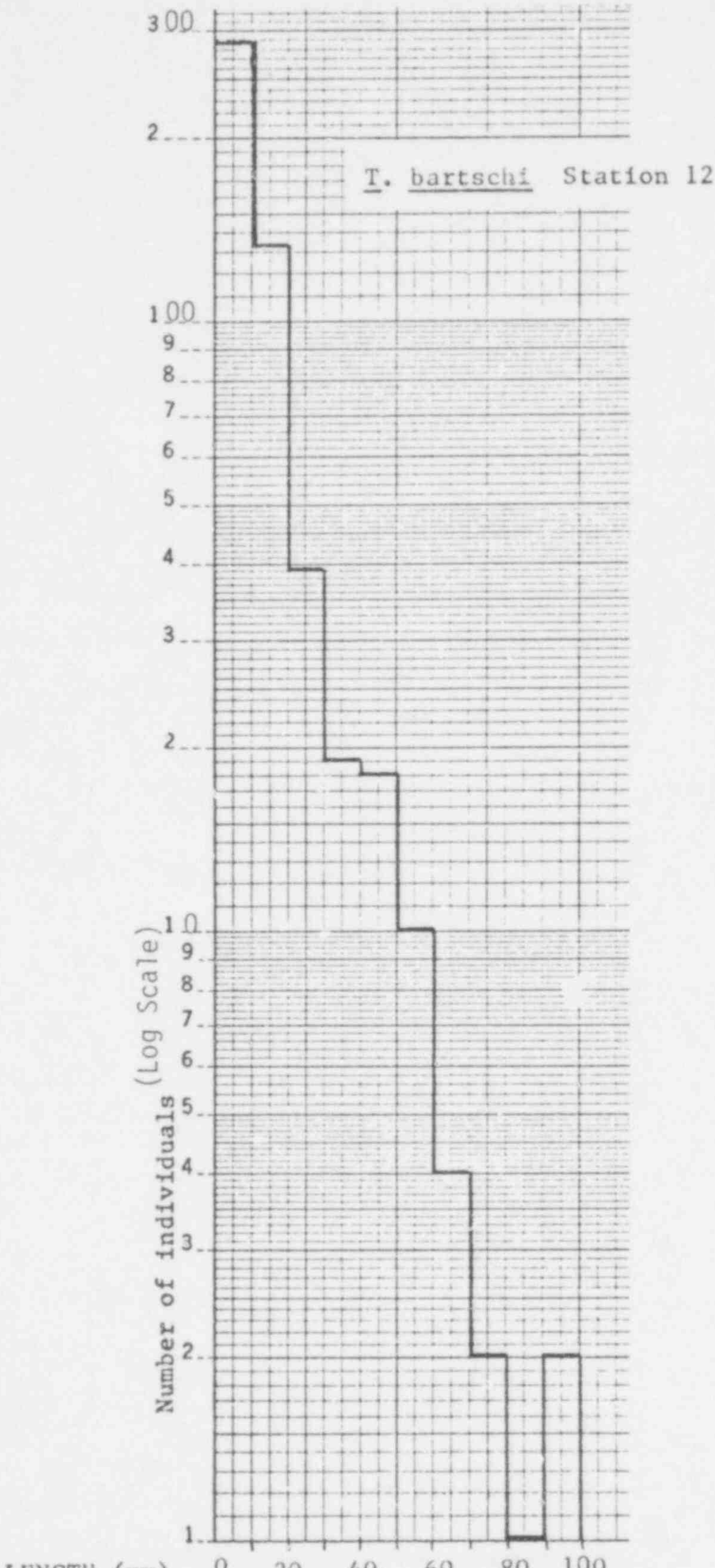


FIGURE 2A continued



305 247

FIGURE 2A continued



18

FIGURE 2 continued

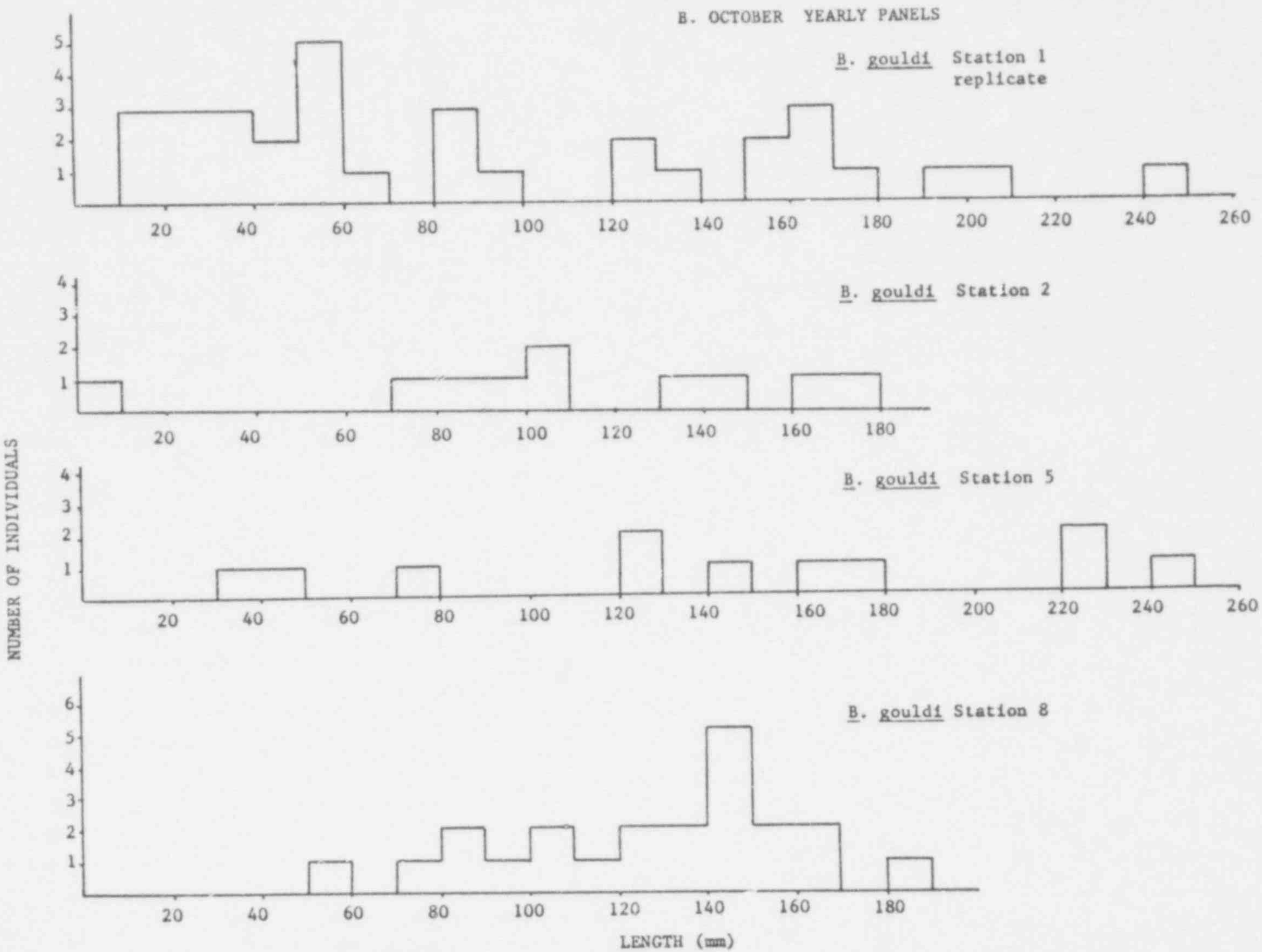
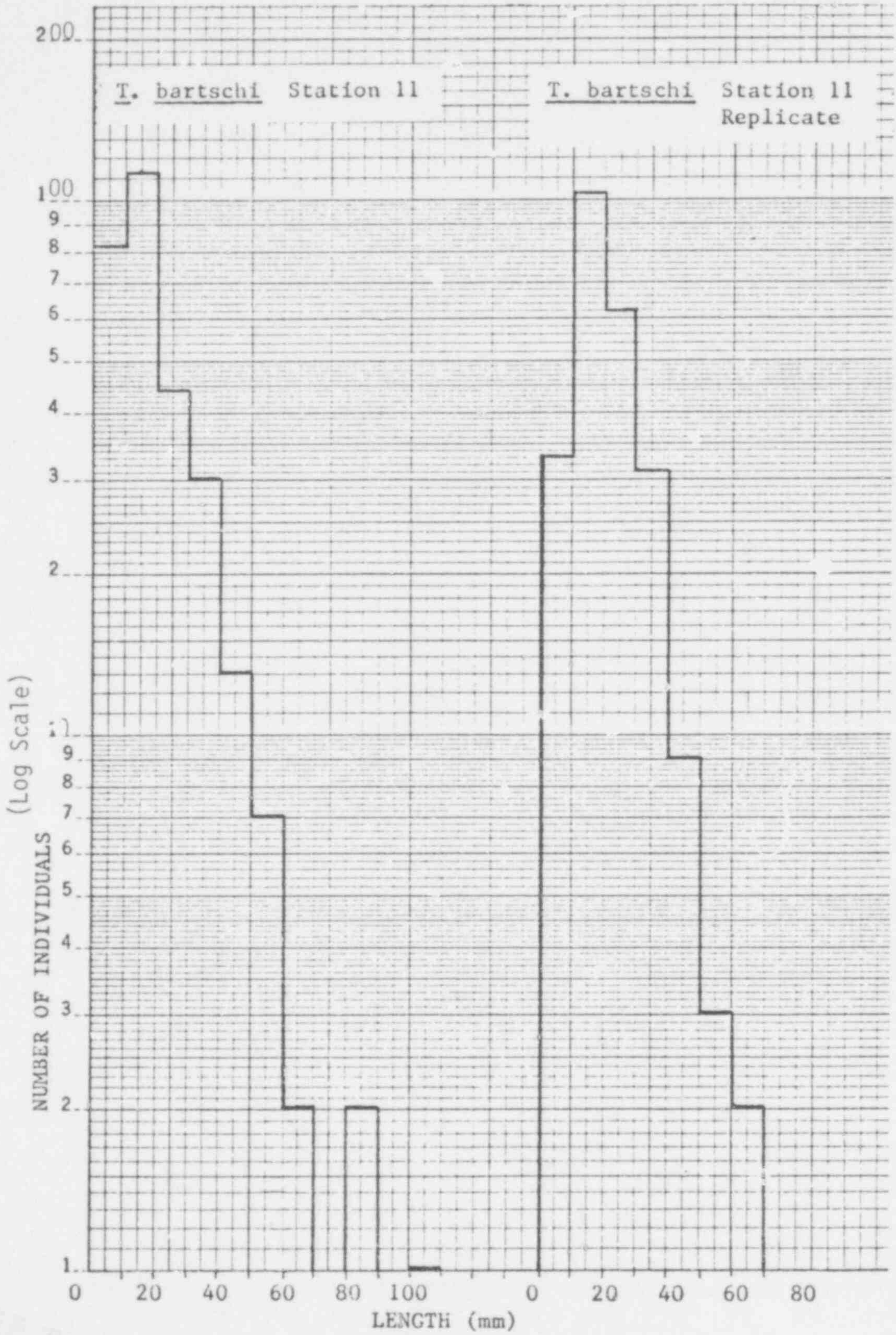


FIGURE 2B, continued



POOR ORIGINAL

305 250

FIGURE 2B, continued

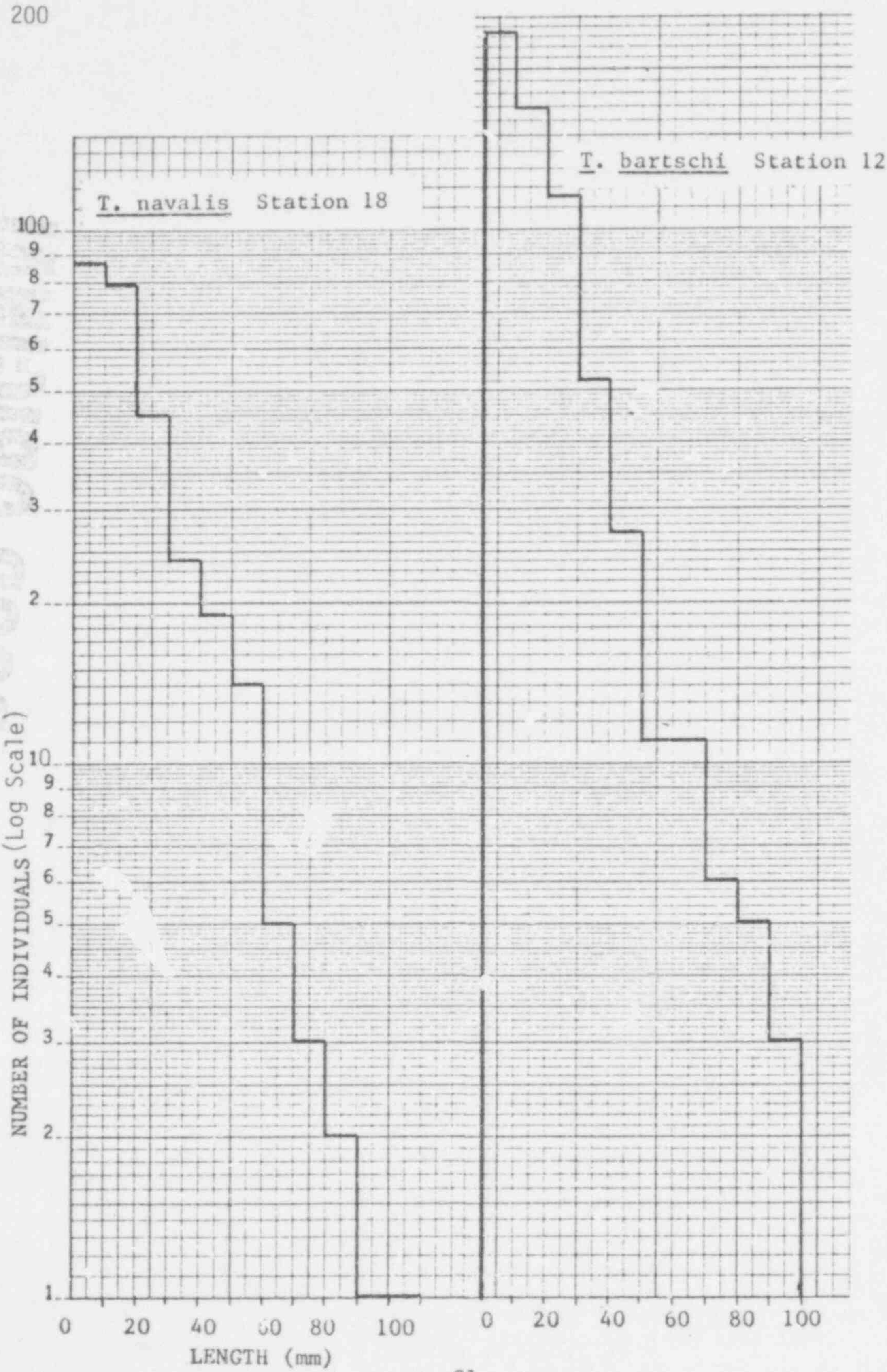


FIGURE 2, continued

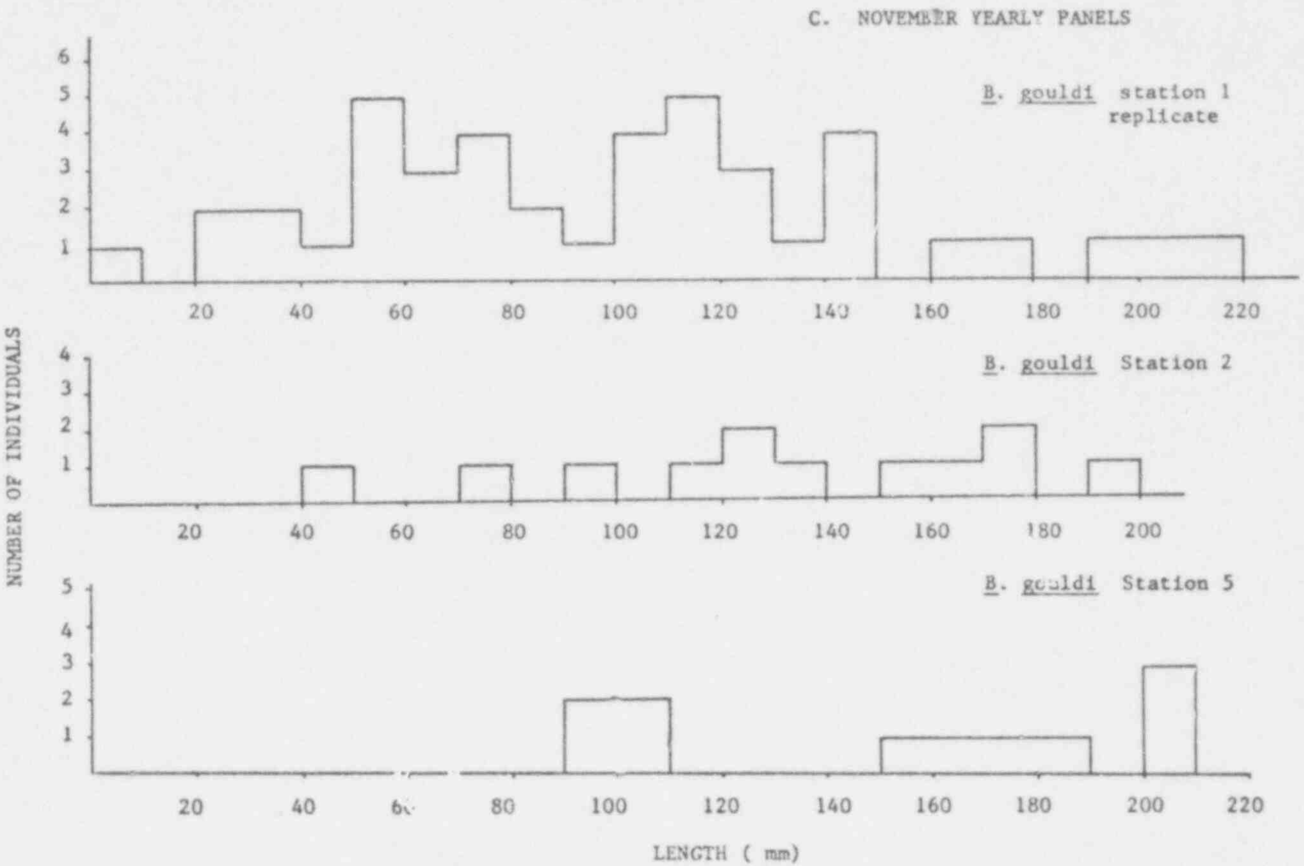


FIGURE 2C, continued

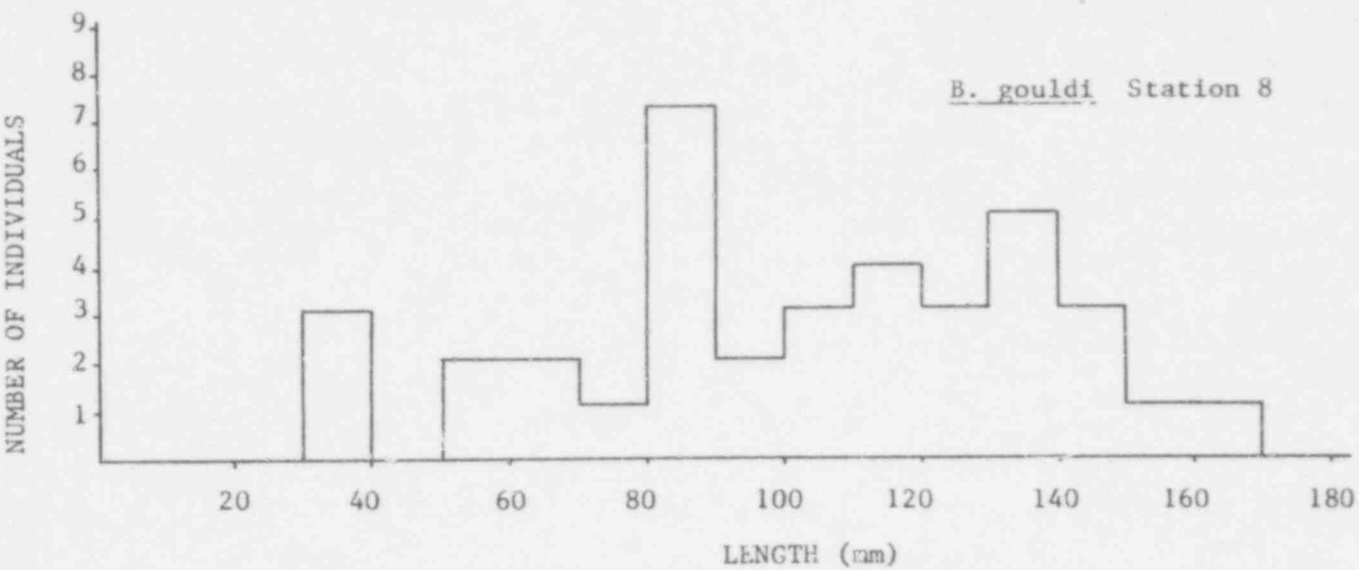


FIGURE 2C, continued

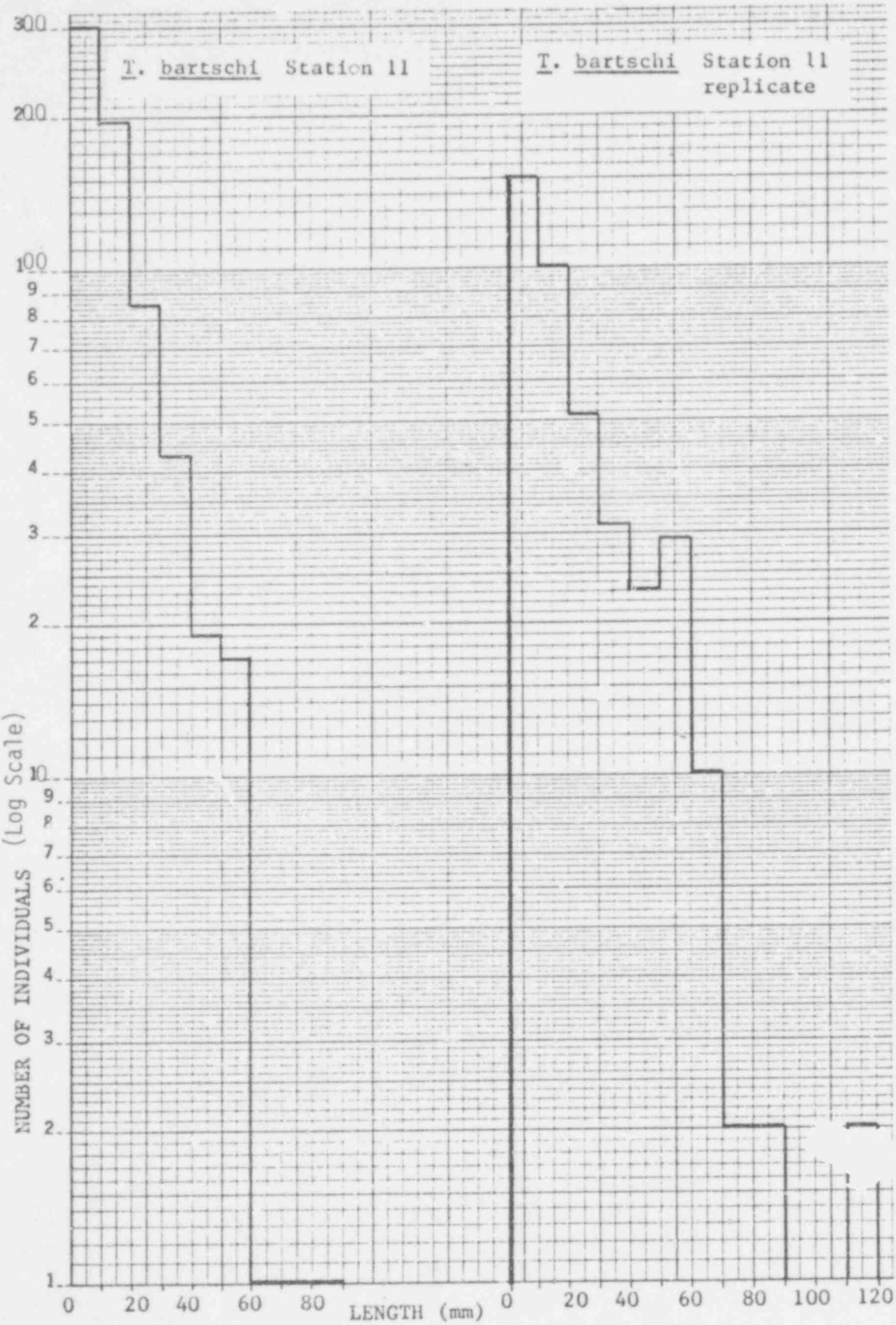


FIGURE 20, continued

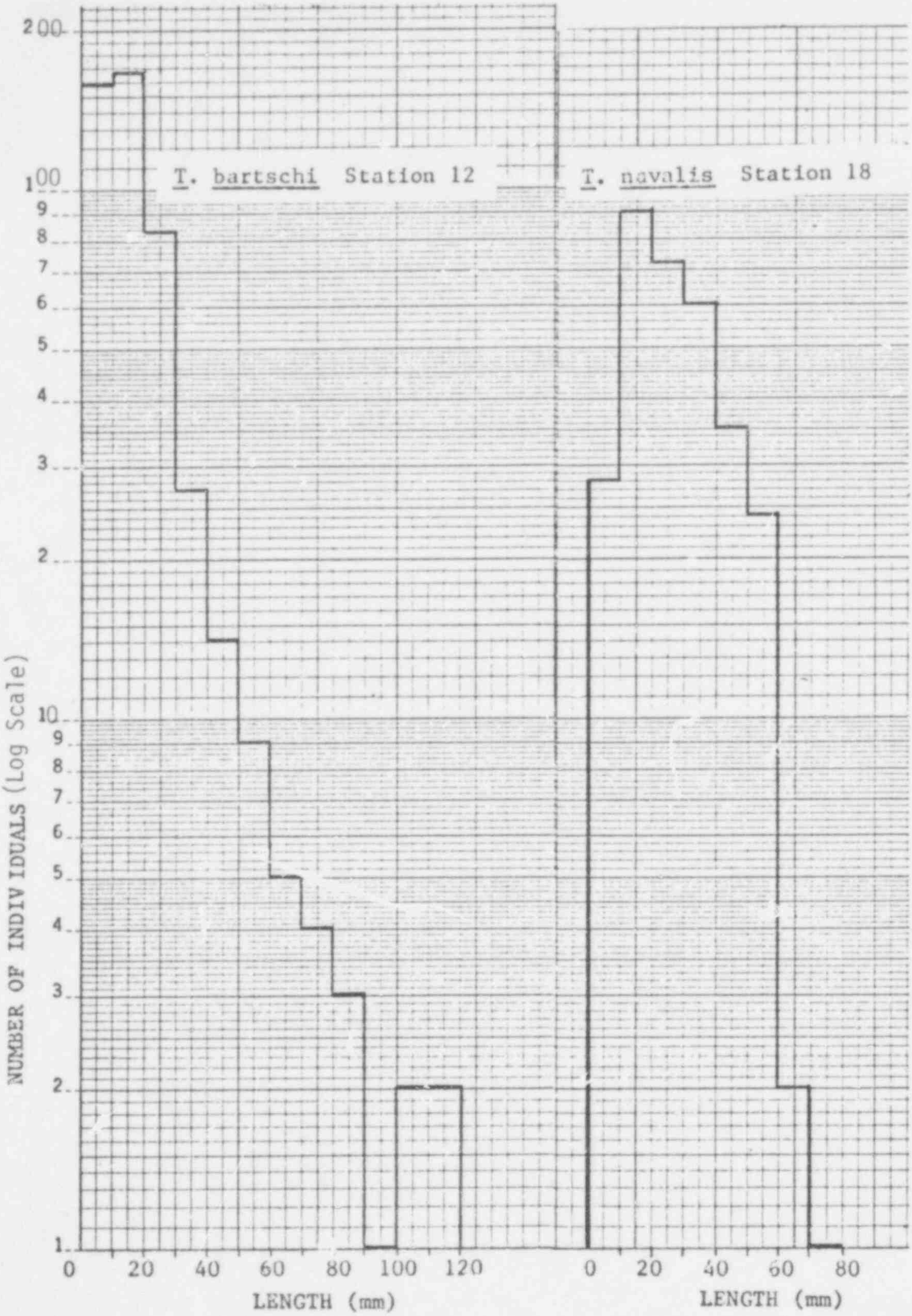


Table 10

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

Date Removed:	Sept 9, 1978					Oct 8, 1978				Nov 4, 1978			
Station	B.g.	T.b.	T.n.	T.sp.	Total	B.g.	T.b.	T.n.	Total	B.g.	T.b.	T.n.	Total
1	29	0	0	0	29	31	0	0	31	36	0	0	37
2	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	34	0	0	34
3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	5	0	0	0	5	3	0	0	3	3	0	0	3
5	4	0	0	0	4	5	0	0	5	4	0	2	6
6	1	0	0	0	1	0	0	0	0	1	0	0	1
7	0	0	0	0	0	0	0	0	0	0	0	0	0
8	6	3	0	0	9	10	2	1	13	6	2	1	9
9	0	0	0	0	0	0	0	0	0	1	0	0	1
10	2	373	0	0	375	1	247	0	248	2	189	0	191
11	2	970	0	0	972	2	522	0	524	0	765	0	765
12	0	526	0	0	526	0	668	0	668	1	300	0	301
13	0	0	8	0	8	2	0	0	2	0	0	0	0
14	5	0	0	0	5	10	0	0	10	7	0	1	8
17	1	0	18	0	19	0	0	23	23	0	0	14	14
18	1	0	564	0	565	3	0	1070	1073Δ			#	#
19	0	0	5	1	6	1	0	7	8	0	0	5	5
20	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	56	1872	595	1	2524	68	1439	1101	2608	95	1256	24	1375

⊛ Rack missing; recovered in November.

Δ Part of panel missing.

Panel riddled; 90% dead.

Table 11

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

Date Removed:	Sept 9, 1978					Oct 8, 1978				Nov 4, 1978			
Station	B.g.	T.b.	T.n.	Tsp.	Total	B.g.	T.b.	T.n.	Total	B.g.	T.b.	T.n.	Total
1	29	0	0	0	29	31	0	0	31	36	0	1	37
2	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	⊛	34	0	0	34
3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	5	0	0	0	5	3	0	0	3	3	0	0	3
5	4	0	0	0	4	5	0	0	5	4	0	2	6
6	1	0	0	0	1	0	0	0	0	1	0	0	1
7	0	0	0	0	0	0	0	0	0	0	0	0	0
8	6	3	0	0	9	10	2	1	13	6	2	1	9
9	0	0	0	0	0	0	0	0	0	1	0	0	1
10	2	373	0	0	375	1	249*	0	250*	2	193*	0	195*
11	2	970	0	0	972	2	522*	0	524*	0	765	0	765*
12	0	526	0	0	526	0	671*	0	671*	1	360*	0	361*
13	0	0	3	0	8	2	0	0	2	0	0	0	0
14	5	0	0	0	5	10	0	0	10	7	0	1	8
17	1	0	18	0	19	0	0	23	23	0	0	14	14
18	1	0	564	0	565	3	0	1070	1073+*Δ			*#	*#
19	0	0	5	1	6	1	0	7	8	0	0	7*	7*
20	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	56	1872	595	1	2524	68	1442*	1101	2611+*	95	1320*	26*	1441+*

* Mortality occurred. Compare numbers with Table 10.

⊛ Rack missing; Recovered in November.

Δ Part of panel missing; animals presumed dead.

\# Panel riddled; ~90% dead.

\+ Some dead specimens could not be counted.

Table 12
Length Ranges of Living Specimens, in mm, Cumulative Panels Submerged May 31, 1978

Date Removed:	Sept 9, 1978			Oct 8, 1978			Nov 4, 1978		
Station	B.g.	T.b.	T.n.	B.g.	T.b.	T.n.	B.g.	T.b.	T.n.
1	3-132			17-247			21-278		95
2							11-210		
3									
4	22-250*			156-310*			84-174		
5	8-105			30-200			15-195		15-205
6	70						104		
7									
8	14-160	2-15		83-300	18-51	170	95-214	15-42	92
9							307*		
10	87-128	2-53		200	2-132*		163-184	2-100*	
11	9-122	2-69		107-142	4-117			2-48	
12		1-90*			2-75		43	2-62	
13			8	8-188					
14	61-150			18-180			70-242		247*
17	60		7-172*			39-219*	200		86-197
18	53		1-73	9-45		2-103			
19			3-125	127		9-132			15-155
20									

* Largest specimen each month, each species.

FIGURE 3: HISTOGRAMS OF LENGTHS OF SHIPWORMS TAKEN FROM PANELS

A. SEPTEMBER CUMULATIVE PANELS

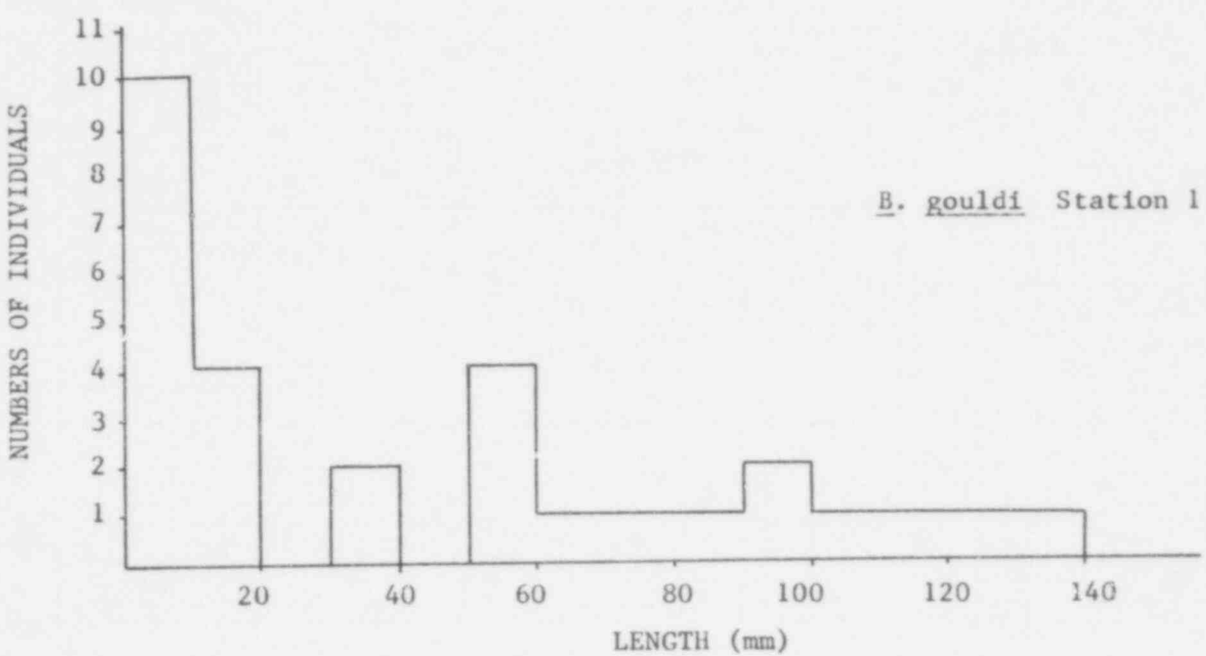
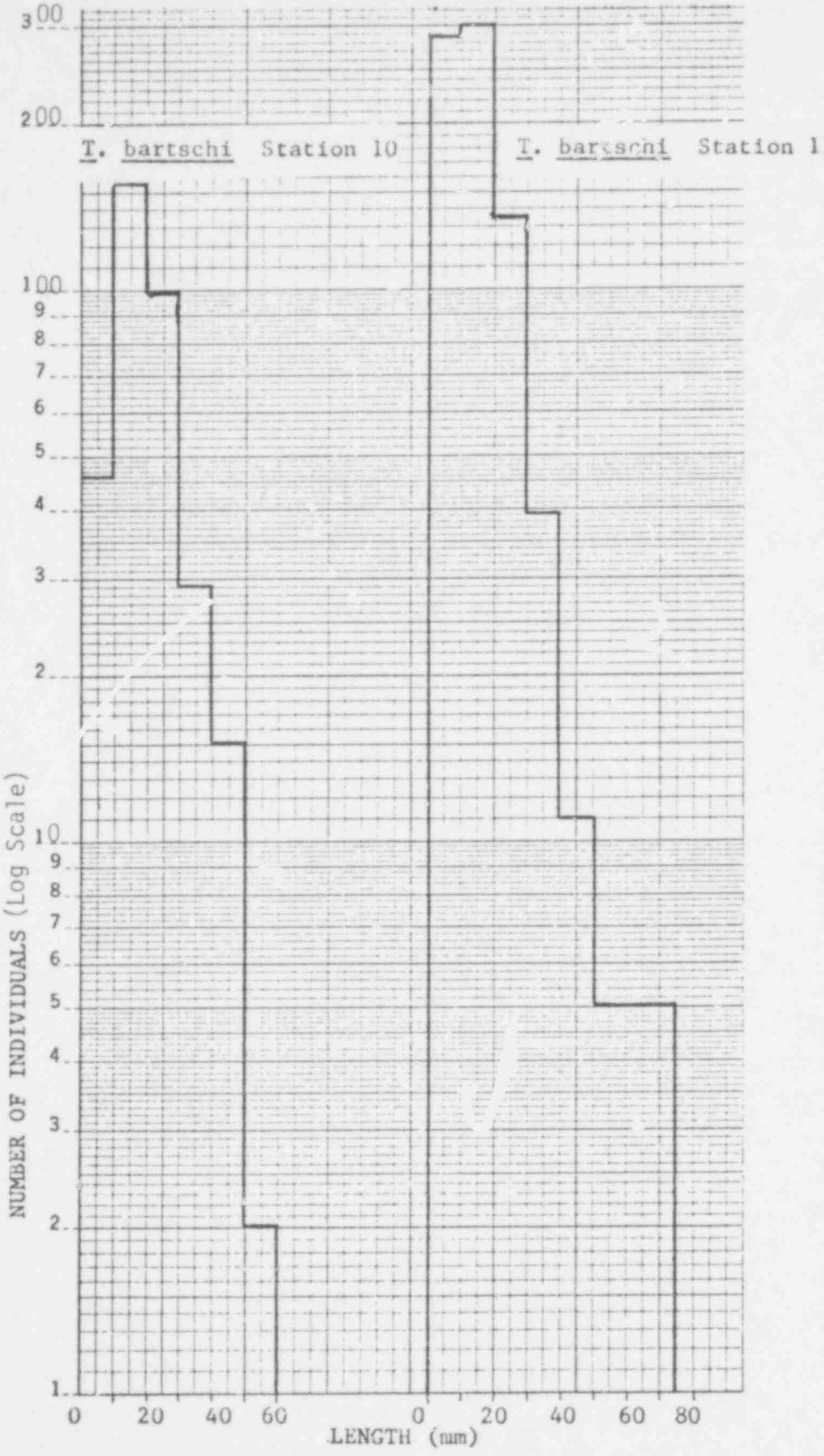
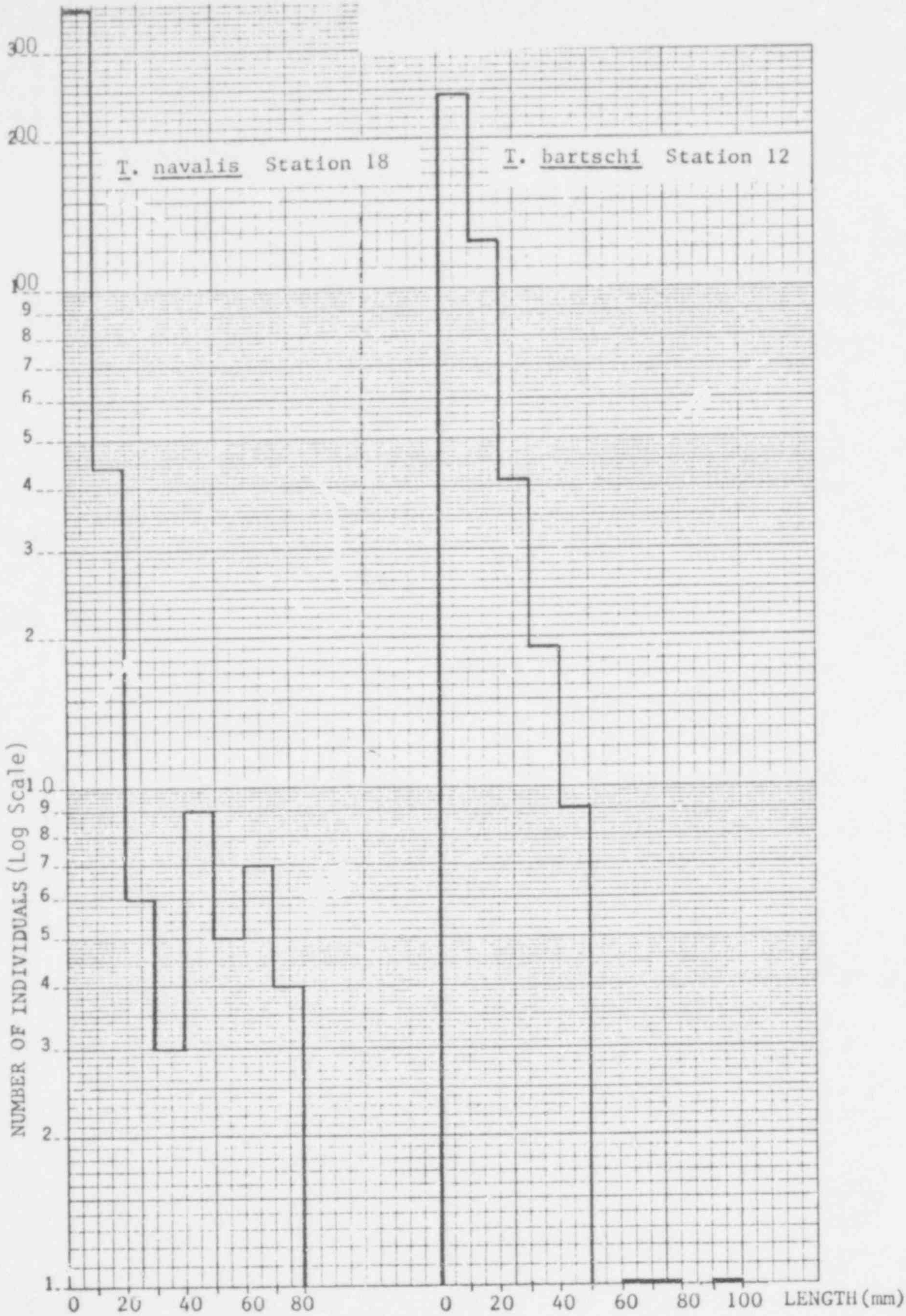


FIGURE 3A, continued



395 260

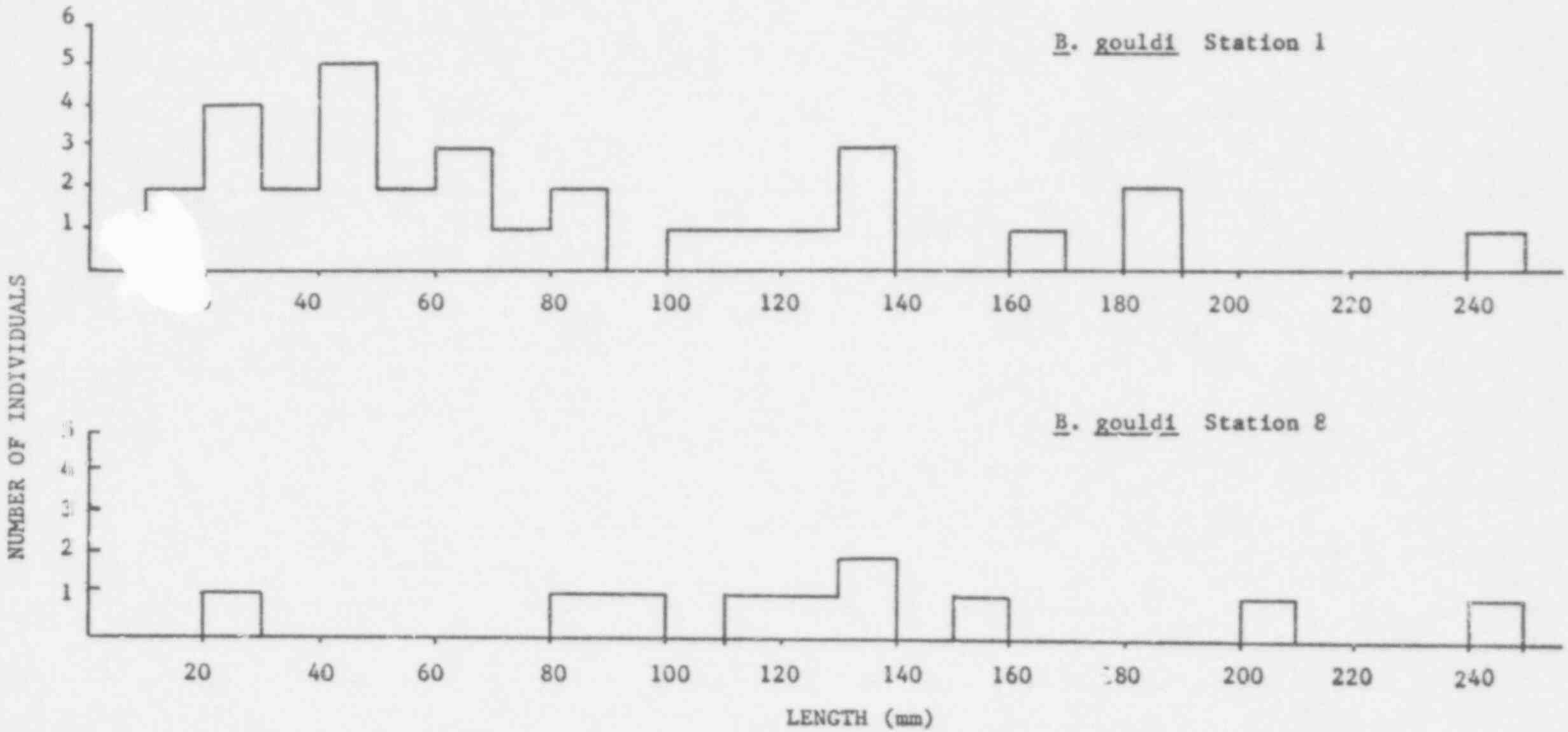
FIGURE 3A, continued



305 261

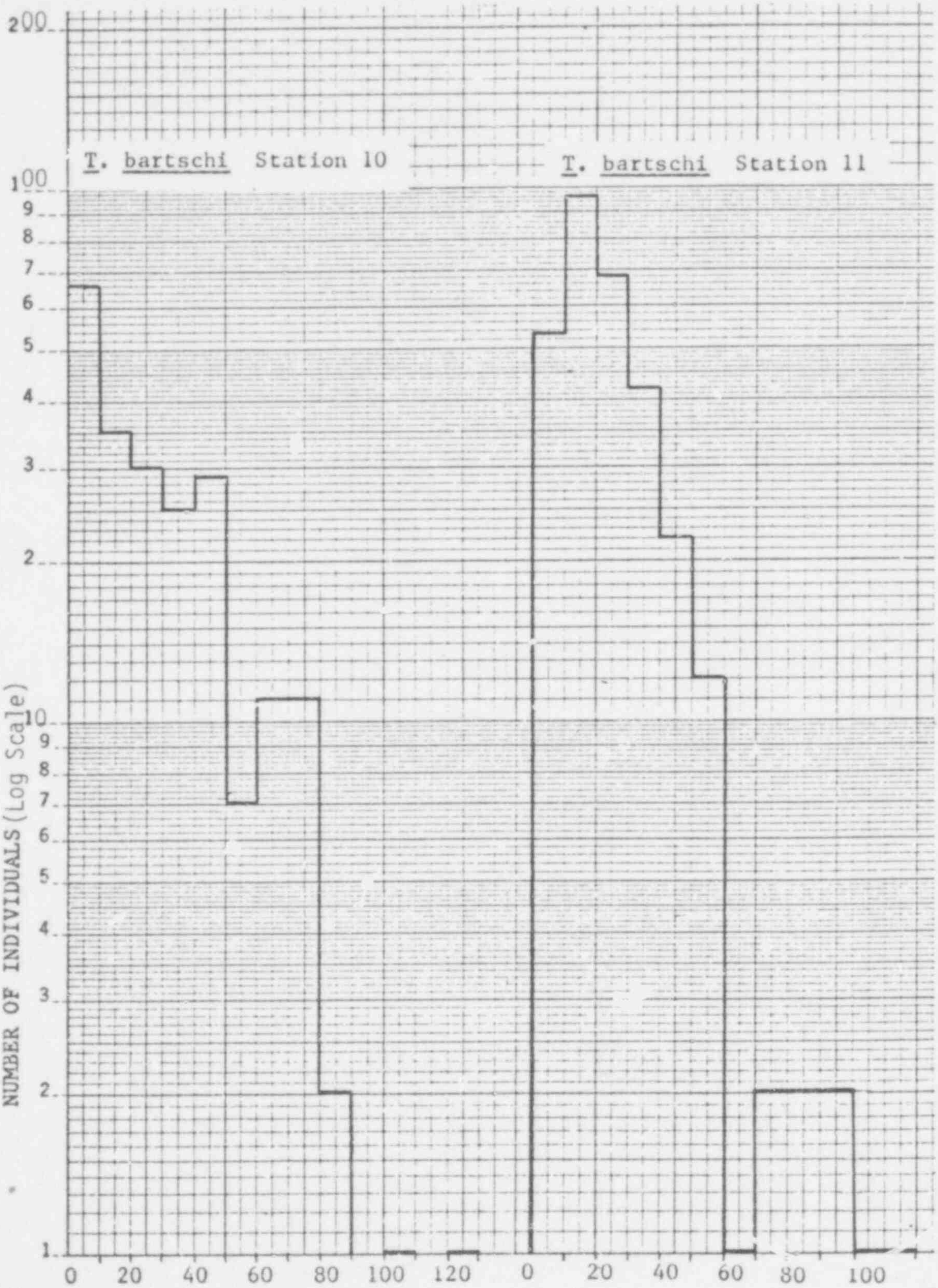
FIGURE 3, continued

B. OCTOBER CUMULATIVE PANELS



505 262

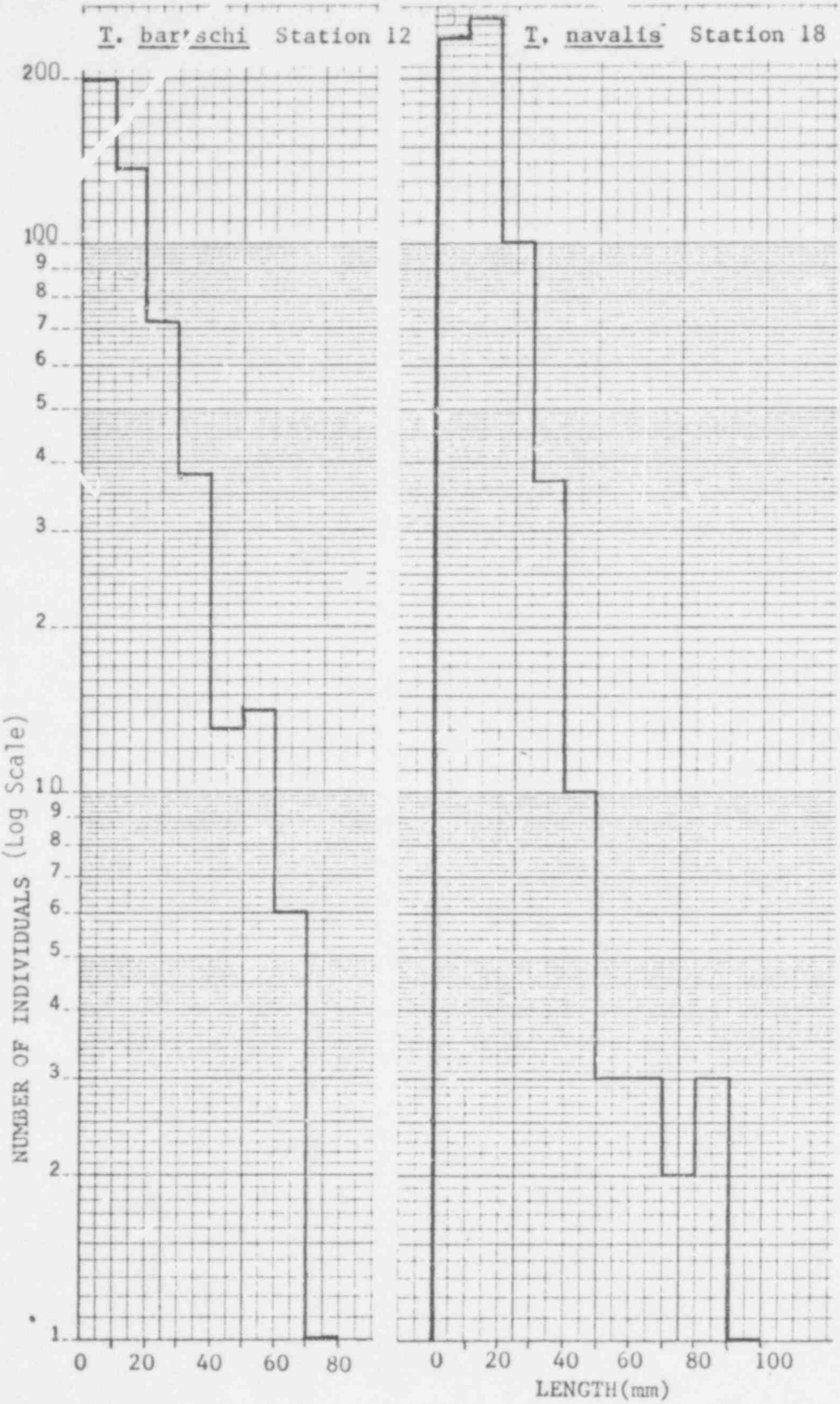
FIGURE 3B, continued



305 265

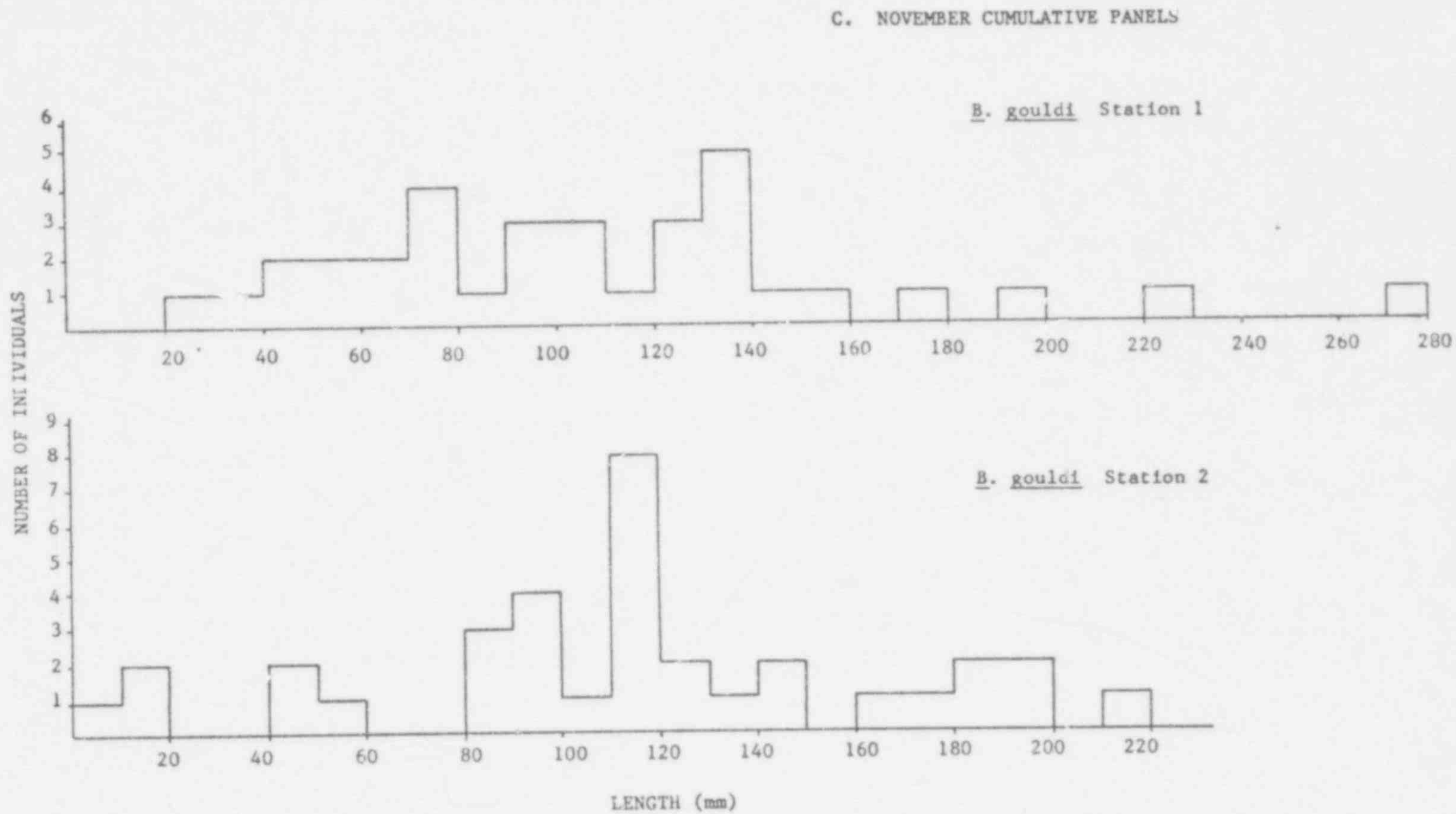
POOR ORIGINAL

FIGURE 3B, continued



305 264

FIGURE 3, continued



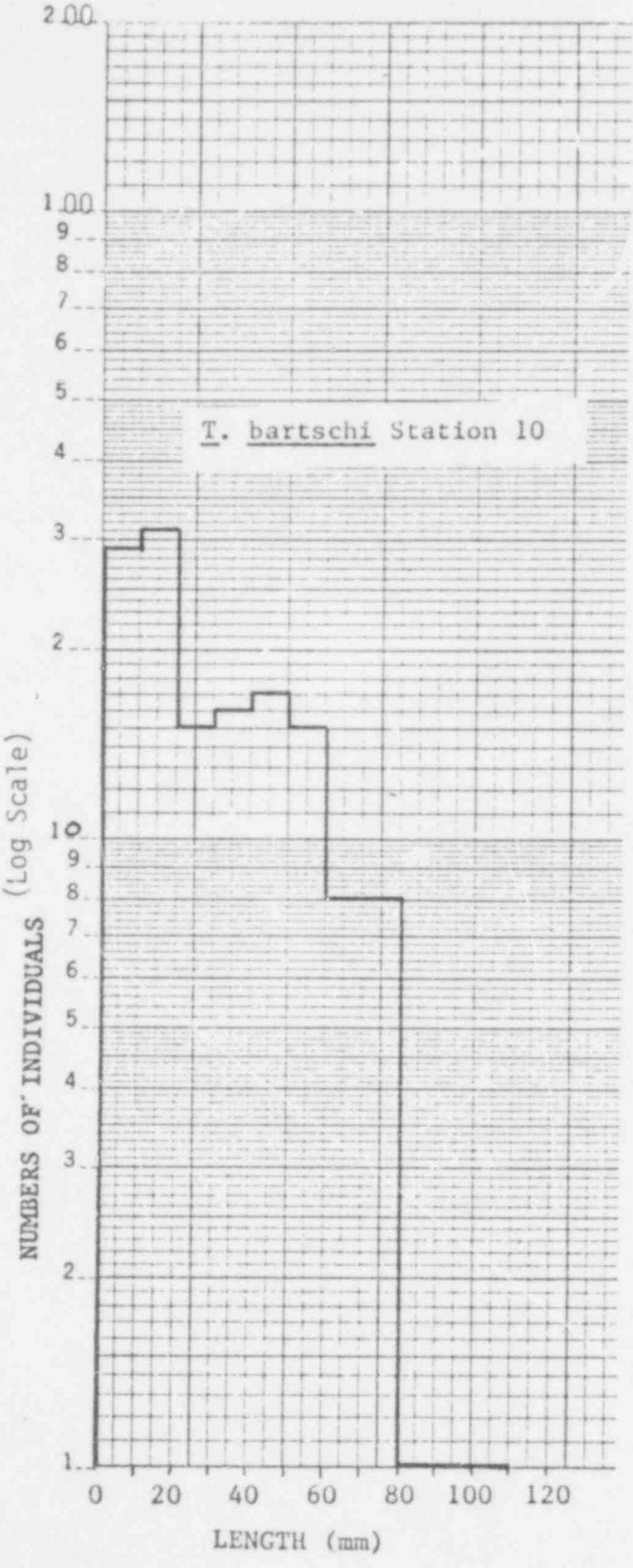


FIGURE 3C, continued

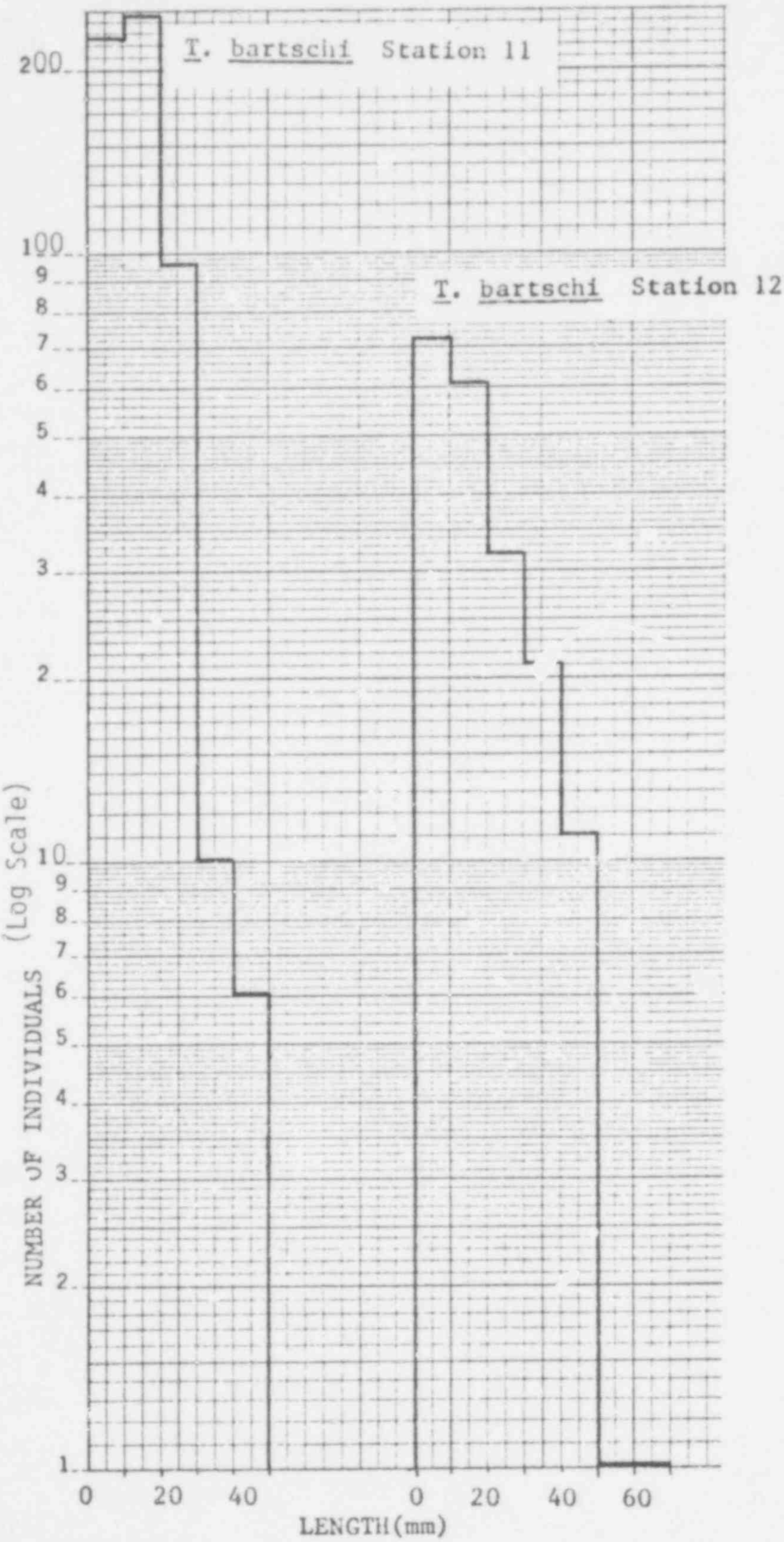


FIGURE 3C, continued

Table 13

Percentage Weight Loss by Cumulative Panels Submerged May 31, 1978

	Date Removed				
	July 7	Aug 8	Sept 9	Oct 7	Nov 5
Mo. Submerged:	1	2	3	4	5
Station					
1	0.0	0.0	5.0	17.1	42.8
2	0.0	lost	lost	lost	37.2
3	0.0	1.0	4.0	2.0	3.8
4	0.0	0.0	0.0	1.6	0.0
5	0.0	0.0	0.2	1.3	4.9
6	0.0	0.0	0.0	1.6	0.0
7	0.0	0.0	11.6	0.0	0.0
8	0.0	0.0	2.9	10.1	6.3
9	0.0	0.0	0.0	0.0	0.0
10	17.4	0.0	14.6	22.6	24.6
11	0.9	2.8	37.7	53.7	75.7
12	0.0	0.0	8.1	18.9	67.8
13	0.0	0.0	0.0	0.0	0.4
14	0.0	0.0	10.6	3.5	19.6
17	0.0	0.0	2.0	0.0	25.2
18	0.0	0.0	10.6	82.0	73.6
19	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0

Table 14

Percentage Weight Loss by Yearly Panels, Removed Sept-Nov,1978

Station	Month Removed		
	Sept 9	Oct 7	Nov 5
1	2.4	3.5	17.3
1 rep.	13.8	23.3	53.3
2	8.0	10.2	24.7
3	3.6	5.0	5.7
3 rep.	4.9	8.0	8.3
4	5.1	0	6.3
5	12.6	27.2	19.8
6	0	5.6	12.6
7	5.1	5.3	9.0
8	20.0	39.1	59.[illegible]
10	8.0	13.3	6.8
11	68.2	76.5	84.7
11 rep.	64.9	70.1	39.7
12	40.5	59.2	61.7
14	18.3	22.6	22.6
14 rep.	8.9	4.8	14.6
15	0	0	32.6
16	4.0	0	12.5
16 rep.	4.0	13.4*	10.3
17	26.7*	23.4*	36.8
18	lost	31.8	72.6
19	0	8.1	7.4

* <u>Limnoria</u> damage.

Reproduction

In Table 15 are ash-free dry weights of gonads and somatic tissues for some of the specimens of Bankia gouldi removed in September and October, 1978. By November, many specimens had gonads so small that they could not be dissected. Although the sample size at Oyster Creek stations was necessarily small, a trend toward both larger gonads on an absolute scale and proportionally larger gonads can be seen. The results are not statistically significant, due to small sample size and high variance. However, the trend is the same for all experimental panels except for the yearly panels removed in October, where the gonad/body ratio was highest at control stations. In all cases, the gonad/body ratio dropped between September and October.

Specimens of Teredo could be examined directly for larvae in the gills as an indicator of reproductive condition (Table 16). The percentage of Teredo carrying larvae did not change significantly over the months reported here. Over 1/3 of all T. bartschi carried larvae, while only about 1% of T. navalis did. All of the latter were at station 18. Larvae of T. bartschi did not appear outside of Oyster Creek (at stations 4 and 8) until November 4, 1978. The smallest shipworm found to have larvae in the gills was a T. bartschi 4 mm long from Oyster Creek.

Table 15

Gonad Ash-free Dry Weights
Bankia gouldi
Specimens Removed Sept-Oct, 1978

Monthly Panels, 8/8/78-9/9/78			
Mean Gonad Wt.±SD			.00211±.00119
Mean of (Gonad Wt/Total Body Wt)±SD			.15373±.07637
N	0	0	12
Cumulative Panels, 5/30/78-9/9/78			
Mean Gonad Wt ± SD	.00340±.00181	.00454*±.00160	.00356±.00240
Mean (G/B) ± SD	.07743±.07848	.13018*±.07943	.11812±.09505
N	11	3	19
Cumulative Panels, 5/30/78-10/7/78			
Mean Gonad Wt ± SD	.00421±.00401	.00427*±.00093	.00264±.00192
Mean (G/B) ± SD	.04830±.02345	.05772*±.01457	.04265±.03191
N	15	3	17
Yearly Panels, 9/7/77-9/9/78			
Mean Gonad Wt ± SD	0.00549±.00461	.00998*±.00829	.00551±.00496
Mean (G/B) ± SD	0.14438±.11707	.20116*±.11523	.15156±.10657
N	26	3	29
Yearly Panels, 10/6/77-10/7/78			
Mean Gonad Wt ± SD	.00325±.00244	.00543*	.00282±.00206
Mean (G/B) ± SD	.04080±.03353	.04774	.06023*±.03310
N	34	1	39

* Highest value

Table 16

The Percentage of <u>Teredo</u> Specimens Found with Larvae in the Gills#

Yearly Panels	*T. bartschi* Sept 9	*T. bartschi* Oct 8	*T. bartschi* Nov 4	*T. navalis* Sept 9	*T. navalis* Oct 8	*T. navalis* Nov 4
Sta.						
1	-	-	-	0(1)	-	-
4	-	-	100(1)	0(1)	0(1)	0(1)
5	-	-	-	-	0(2)	0(1)
8	0(8)	0(8)	78(9)	-	-	0(1)
10	50(16)	67(12)	26(19)	-	-	-
11	34(1261)	53(393)	25(1744)	-	-	-
11repl.	44(980)	34(459)	27(496)	-	0(1)	-
12	12(729)	33(884)	34(670)	0(1)	-	-
14	-	-	-	0(4)	0(1)	-
17	-	-	-	0(2)	0(14)	0(9)
18	-	-	-	*	.002(494)	.006(465)
19	-	-	-	0(2)	0(5)	0(7)
Cumulative Panels						
1	-	-	-	-	-	0(1)
5	-	-	-	-	-	0(2)
8	0(3)	0(2)	50(2)	-	0(1)	0(1)
10	64(373)	40(247)	31(189)	-	-	-
11	44(970)	34(522)	36(765)	-	-	-
12	49(526)	19(668)	26(300)	-	-	-
13	-	-	-	0(8)	-	-
14	-	-	-	-	-	0(1)
17	-	-	-	0(18)	0(23)	0(14)
18	-	-	-	.009(564)	.02(1070)	*
19	-	-	-	0(6)	0(7)	0(5)
Total %	39%	34%	26%	0.8%	1.5%	0.6%

\# The percentage is followed by the number of specimens examined.

* No Panel

FOULING ORGANISMS

Tables 17-23 give presence-absence data for some of the most common fouling organisms in Barnegat Bay. The format is the same as in our earlier reports.

Electra crustulenta (Table 17) settled widely and heavily in Barnegat Bay, except for the lowest salinity station, #3. The same occurred during September-November of 1977. E. crustulenta is found on yearly panels at station 3, so it does settle there but is seasonally restricted. E. crustulenta was most abundant in Forked River.

Hydroides dianthus (Table 18) settled only on Long Beach Island and at Waretown during fall, 1978. It is most abundant in Forked River and from Waretown south. It tends not to co-occur with Mercierella enigmatica, another calcareous tube-building polychaete. Compared with 1977, H. dianthus was not as abundant nor as frequent, especially on monthly panels. It is not abundant in Oyster Creek.

Botryllus schlosseri (Table 19) also was less frequent and abundant in fall of 1978 than in 1977 at the same time of year. It is most common at Waretown, Long Beach Island, and the main channel of Forked River. The biggest change since 1977 was its disappearance from stations 1 and 2. Although it is entirely absent from Oyster Creek, the Generating Station is not implicated, because it is also absent from Stout's and Cedar Creek, and the middle branch of Forked River. Its patchy distribution is unexplained. B. schlosseri actively starts new colonies in fall months.

Enteromorpha (Table 20) comprises two species, E. intestinalis at most inner bay stations and E. prolifera at Long Beach Island. The distribution pattern of E. intestinalis is spotty, and differs from 1977. All plants, except those of E. prolifera, were small in 1978. Enteromorpha did not colonize during September and October.

The barnacle Balanus eburneus (Table 21) stopped settling in October, as it did in 1977. During August and September, it settled most abundantly in Oyster Creek and the mouth of Forked River (station 4, 8, 10, and 11). Molgula manhattensis (Table 22) and campanulareid hydroids were both found on a few monthly panels; adults were more common at the southern stations (14-19).

The total number of fouling species (Tables 24-26) is greatest on Long Beach Island (stations 18-19), closely followed by Forked River (stations 4-6 and 8) and Waretown (station 14). The lowest number of species were at the northern and low-salinity stations (#1-3 and 7). Oyster Creek falls in between.

Table 17

Distribution of Some Common Fouling Organisms

Electra crustulenta

	Station 1	2	3	4	5	6	7	8	10	11	12	14	17	18	19
A. Monthly															
Sept		X		X	X			X		X	X	X	X	X	
Oct	X	X		X	X	X	X	X	X	X		X		X	
Nov	X					X	XR		X			X			X
B. Cumulative															
Sept	X	-		X	X			X		X		X	X	X	
Oct	X	-		X	X	X		X			X	X	X		
Nov	X	X		X	X	X	X	X	X			X	X	X	
C. Yearly															
Sept	X	X	X	X	X	X		X	X	X	X	X	X	X	X
Oct	X	X	X	X	X	X		X	X	X		X		X	X
Nov	X	X	X	X	X			X	X	X	X	X		X	

X : Present
XR : Present but Rare
\- : No panel

Table 18

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															
Sept												X		X	X
Oct														X	
Nov															
B. Cumulative															
Sept		-		X	X				X#			X	X	X	X
Oct		-		X	X			X				X	X	X	X
Nov		X	X#	X	X			X	X#			X	X	X	X
C. Yearly															
Sept				X	X	X		X				X	X	X	
Oct			X#	X	X	X		X	X#			X	X	X	X
Nov	X	X	X#	X	X	X		X	XR#	XR#		X	X	X	X
D. On Block or Rack Only															
Sept	X	X								X#	X				
Oct	X	X					X			X#					
Nov							X				X				

X : Present
XR : Present but Rare
: May have been confused with *Mercierella enigmatica*
- : No panel

Table 19

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															
Sept				X	X			X							X
Oct				X	X			X				X			X
Nov				X	X			X				X			X
B. Cumulative															
Sept		-		X	X			X				X			
Oct		-		X	X	X		X				X			X
Nov				X	X	X		X				X			X
C. Yearly															
Sept				X	X	X		X							
Oct				X	X			X				X			X
Nov				X	X	X		X				X			X
D. On Block or Rack Only															
Sept													X		
Oct													X		
Nov															

X : Present
XR : Present but Rare
\- : No panel

Table 20

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															
Sept				X											X
Oct															
Nov															
B. Cumulative															
Sept		-		X										X	X
Oct		-		X										X	X
Nov		X			X									X	
C. Yearly															
Sept				X										X	
Oct				X				X							X
Nov														X	X
D. On Block or Rack Only															
Sept	X				X			X		X					
Oct	X	X										X			
Nov															

X : Present
XR : Present but Rare
\- : No panel

Table 21

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															
Sept		X		X	X	X		X	X	X		X		X	
Oct				X				X	X			X			
Nov															
B. Cumulative															
Sept	X	-	X	X		X		X	X	X		X	X	X	X
Oct	X	-	X	X	X	X		X	X	X	X	X	X	X	X
Nov	X		X			X	XR		X	X	X	X	X		X
C. Yearly															
Sept	X	X	X	X					X	X		X		X	X
Oct	X	X	X	X	X	X		X	X	X		X	X	X	X
Nov	X	X	X	X	X	X		X	X	X	X	X		X	X
D. On Rack or Block Only															
Sept							X				X				
Oct															
Nov															

X : Present
XR : Present but Rare
\- : No panel

Table 22

Distribution of Some Common Fouling Organisms

<u>Mogula manhattensis</u>

	Station 1	2	3	4	5	6	7	8	10	11	12	14	17	18	19
A. Monthly															
Sept					X				X			X			X
Oct				X					X			X			X
Nov												X			
B. Cumulative															
Sept	X	-			X							X	X		X
Oct		-			X			X	X			X	X	X	X
Nov		X			X			X	X			X	X		X
C. Yearly															
Sept					X	X		X	X			X	X	X	
Oct				X	X	X		X		X	X	X	X	X	X
Nov					X	X		XR	XR	X		X	X		X
D. On Block or Rack Only															
Sept				X						X	X				
Oct															
Nov															

X : Present
XR : Present but Rare
\- : No panel

Table 23

Distribution of Some Common Fouling Organisms

<u>Campanulareid</u> spp.

	Station 1	2	3	4	5	6	7	8	10	11	12	14	17	18	19
A. Monthly															
Sept					X							X			
Oct												X		X	
Nov															
B. Cumulative															
Sept		-					X					X	X	X	
Oct		-												X	
Nov															
C. Yearly															
Sept				X				X				X			
Oct								X				X		X	X
Nov	X			X	X								X	X	
D. On Rack or Block Only															
Sept															
Oct															
Nov								X				X			

X : Present
XR : Present but Rare
\- : No panel

Table 24

Sedentary Species Richness, September 1978

Station	Panels Monthly	Panels Cum.	Panels Yrly	Racks	Block	4 x 4	Total
1	0	6	4	10	3	-	10
2	4	-	4	5	6	4	9
3	4	3	4	5	3	3	10
4	8	11	12	11	6	-	17
5	8	11	10	13	9	11	17
6	7	11	10	10	5	8	17
7	7	1	3	4	3	2	9
8	4	5	11	12	7	8	16
10	6	8	9	11	3	4	13
11	7	8	5	3	-	-	17
12	5	4	5	10	1	3	12
14	8	13	11	11	6	7	17
17	5	9	8	9	2	6	16
18	8	12	16	9	4	-	22
19	9	11	5	10	5	9	17

- : No substrate

Table 25

Sedentary Species Richness, October 1978

Station	Panels Monthly	Panels Cum.	Panels Yrly	Racks	Block	4 x 4	Total
1	2	4	3	8	5	-	9
2	5	-	6	7	7	5	13
3	3	5	8	7	4	5	10
4	7	12	11	12	7	-	17
5	5	10	11	8	6	9	15
6	2	9	9	11	5	8	15
7	3	3	4	5	2	3	8
8	7	11	12	12	7	9	17
10	6	5	9	9	4	4	12
11	4	6	8	10	5	3	13
12	2	3	5	9	3	3	14
14	8	11	12	10	4	5	16
17	1	8	7	10	3	7	12
18	9	14	14	10	5	-	19
19	8	10	16	12	8	7	22

- : No substrate

Table 26

Sedentary Species Richness, November 1978

Station	Panels Monthly	Cum.	Yrly	Racks	Block	4 x 4	Total
1	2	6	5	6	4	-	9
2	0	6	6	8	4	4	13
3	4	5	6	8	6	4	11
4	5	8	13	5	2	-	14
5	5	17	12	15	5	8	21
6	4	11	14	10	5	8	19
7	2	7	3	5	3	-	10
8	3	10	14	9	6	5	19
10	2	7	9	10	3	5	14
11	2	6	9	12	5	8	15
12	1	6	5	4	2	2	10
14	5	13	11	9	5	6	18
17	1	10	10	9	4	7	17
18	1	9	17	13	4	-	20
19	7	12	10	16	7	12	22

- : No substrate

305 285

DISCUSSION

Despite the shutdown for refueling, Teredo bartschi continued to thrive in Oyster Creek. The most significant finding of the quarter was the discovery in Forked River of T. bartschi containing larvae. From the low numbers of T. bartschi in Forked River and the presence of larvae only in November, it appeared that T. bartschi was a summer invader and was not reproductively active there until the end of the summer of 1978. It will be of great importance if T. bartschi undergo an outbreak in Forked River next spring. The larvae in the gills of T. bartschi appear to remain alive and healthy through November, at least. T. navalis, on the other hand, appears not to keep larvae in the gills through the fall months. This is a major species difference. T. bartschi may require only a few warm days for release of larvae and settling, since its free-swimming period can be less than 72 hours (1).

Monthly shipworm settlements were comparable to those in the fall of 1977, except that there were more T. bartschi, and T. bartschi replaced T. navalis and T. furcifera on the monthly panels in Oyster Creek. T. navalis continued to settle heavily at Long Beach Island. Each year, B. gouldi stops settling before Teredo species in the fall.

Species composition was mixed, but there was primarily one species at each locality where the attack was intense. The greatest damage occurred in Oyster Creek, both in terms of number of individuals and amount of wood destroyed. Compared with 1976 and 1977, attack of T. navalis at station 17 increased, while attack of B. gouldi at station 2 was lower. Surprisingly, there was no attack at station 20 in Cedar Creek, despite evidence of former attack. But the salinity was too low. In years prior to 1978, the salinity must have been higher, allowing shipworms to invade. The attack of T. bartschi in Oyster Creek was more widespread than in 1977 (2).

Because the generating station was not operating during most of the period reported here, high growth rates were not correlated with Oyster Creek. Growth rate is related to the species, degree of crowding, and temperature (3, 4); growth declined in September. Mortality was also related to crowding, and was significant only at a few stations (#12, 18). Exact quantitative estimates of mortality are difficult in badly damaged panels because the valves and pallets of the shipworms fall out of the wood. For this reason, mortality is underestimated at stations 10-12 and 18. Likewise, mortality of newly-settled juveniles goes unrecorded because they fail to leave impressions in the wood.

The gonad size and gonad:body weight ratio indicate that there is a greater reproductive potential in Oyster Creek. The contradictory fact that the gonad:body weight ratio was higher at control stations in October may mean that the Oyster Creek specimens spawned out earlier, or it may be an artifact of small sample size.

The only major fouling organism which had a distribution related to the operation of the power plant in this quarter was Electra crustulenta. Without increased salinity, it would be absent or rare in Oyster Creek and Forked River. In general, fouling was less abundant in the fall of 1978 than in the fall of 1977, except at station 14 where little change was noted. The reason for the difference is not known.

The total number of fouling species in Oyster Creek declined in fall, due to high August temperatures and heavy siltation. The silt affected Enteromorpha intestinalis and other algae as well as Electra crustulenta; barnacles were not affected.

We have reported the finding of Mercierell igmatica, an introduced polychaete, in Oyster Creek and Fork ver (5). We have no evidence that it is related to the therm lume; it is not a warm-water species.

The slightly lower salinity in Oyster Creek compared with Forked River is due to an influx of fresh water from both Oyster Creek . d the upper parts of Forked River. Low salinities at stations 6 and 9 compared with 5 during the summer and in November were due to dewatering activities for installation of sewer pipes. These activities had no noticeable impact on the marine fauna, except at the point of entry, where fouling was scarce and turbidity was high.

The negative effect of the Generating Station on wooden structures via shipworm attack is not the only biological problem to have arisen from the operation of the Station. Increase in biochemical oxygen demand due to entrainment of organisms in the cooling water system has been reported (6). The thermal plume has affected fish distributions (7), caused fish kills (8), altered growth patterns (3), and extended the breeding season of invertebrates (9).

Still unresolved are the impact of these changes on the entire Barnegat Bay ecosystem, and the possible future spread of Teredo bartschi in Forked River.

REFERENCES

1. C. E. Lane, J. Q. Tierney, and R. E. Hennacy, "The respiration of normal larvae of Teredo bartschi Clapp," Biological Bulletin 106, 323-327 (1954). Available in public science libraries.

2. B. R. Richards, A. E. Helm, C. I. Belmore, and R. E. Hillman, "Annual Report for the Period June 1, 1976 to November 30, 1977 on Woodborer Study Associated with the Oyster Creek Generating Station," prepared for the Jersey Central Power and Light Co., February 1, 1978. Available in Energy Spectrum library, Oyster Creek Generating Station.

3. M. J. Kennish and R. K. Olsson, "Effects of thermal discharge on the microstructural growth of Mercenaria mercenaria," Environmental Geology 1, 41-64 (1975). Available in public science libraries.

4. J. W. Gibbons, "Thermal additions and the enhancement of species populations," in Thermal Ecology II, U.S.E.R.D.A. Symposium Series (CONF-750425), 1976. Available for purchase from National Technical Information Service, Springfield, Virginia 22161.

5. K. E. Hoagland and R. D. Turner, "Introduced species found in the vicinity of a temperate-zone nuclear generating station." Ms submitted to Marine Biology (1979). Available from the senior author.

6. C. O'Neill, D. Doyle, O. Donovan, and E. Kearns, "Biochemical oxygen demand as a measure of entrainment loss at a nuclear power station," Underwater Naturalist 10(3), 19-20 (1977). Available for purchase from the American Littoral Society.

7. O. Donovan, D. Doyle, C. O-Neill, and E. Kearns, "Thermal plume impact on fish distributions in Barnegat Bay," Underwater Naturalist 10(3), 14-18 (1977). Available for purchase from the American Littoral Society.

8. Jersey Central Power and Light Co., "Oyster Creek and Forked River Nuclear Generating Stations 316(a) and (b) Demonstration." Vol. 1: Text; Vol. 2: Appendices A1-C1; Vol 3: Appendices C2-C6; Vol. 4: Appendices C7-D1; Vol. 5: Appendices E1-F1 (1978). Available in Energy Spectrum library, Oyster Creek Nuclear Generating Station.

9. J. S. Young and A. B. Frame, "Some effects of a power plant effluent on estuarine epibenthic organisms," Int. Revue ges. Hydrobiol. 61 (1), 37-61 (1976). Available in public science libraries.

APPENDIX: STATION LOCALITIES

STATION NUMBER	NAME	DESCRIPTION	COORDINATES	
1	Holly Park	Dick's Landing Island Drive Bayville, N.J. Bay contrcl	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 Rale h Drive Gustav Walt..s' residence Estuarine control	39° 50.7' 74° 9'	N W
4	Mouth of Forked River	South Shore Developed property Possible temperature increase increased oceanic influence due to reverse flow	39° 49.4' 74° 9.8'	N W
5	Leilani Drive	At branch point of Forked River	39° 49.5' 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, Fork.d River just S. of State M	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

305 287

STATION NUMBER	NAME	DESCRIPTION	COORDINATES
** 9	Intake Canal	House closest to intake canal Salinity effect; strong current upstream	39° 49.2' N 74° 12.2' 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
**13	Rte 9 Bridge	Oyster Creek just below discharge canal. Temperature, salinity increase	39° 48.7' N 74° 12' 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' N 74° 10.9' 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' N 74° 11' W
+16	Iggie's Marina	East Bay Ave, Barnegat, N.J. Same purpose as Loc. 15	39° 44.8' N 74° 11.6' W
17	Manahawkin Bay	At bridge to Long Beach Island Same purpose as Loc. 15	39° 40' N 74° 13' W

305 288

STATION NUMBER	NAME	DESCRIPTION	COORDINATES
**18	Barnegat Light	Marina adjacent to Coast Guard Station	39^{o} 45.8' N 74^{o} 6.5' W
**19	Long Beach Island	Bayview Marina	39^{o} 45.2' N 74^{o} 6.9' W
# 20	Cedar Creek	Opposite home of Mr. and Mrs. Sokolich 415 Terry Ave. (Not on map) Inland from Station 2, at point where stream narrows.	39^{o} 52.1' N 74^{o} 9.5' W

** Stations new as of May 27, 1977

\# Stations new as of May 31, 1978

\+ Stations discontinued as of June 1, 1978

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.I.
Waretown, New Jersey 08758

Mr. Sam Grant
Grant's Boat Works
Lakeside Drive
Forked River, New Jersey 08731

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

Mr. Charles Kochman
Compass Road
Waretown, New Jersey 08758

Mr. Jerry Savaris
Margo's Marina
Manahawkin, New Jersey 08050

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

Mr. and Mrs. Sokolich
415 Terry Avenue
Cedar Creek
Bayville, New Jersey 08721

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

Part B

Bea R. Richards, Director
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

NRC FORM 335 (7-77)

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

1. REPORT NUMBER (Assigned by DDC)
NUREG/CR-0812

4. TITLE AND SUBTITLE (Add Volume No., if appropriate)
Analysis of Populations of Boring and Fouling Organisms in the Vicinity of the Oyster Creek Nuclear Generating Station

2. (Leave blank)

3. RECIPIENT'S ACCESSION NO.

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

5. DATE REPORT COMPLETED

MONTH	YEAR
March	1979

9. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)
Wetlands Institute (Lehigh University)
Stone Harbor, New Jersey 08247

DATE REPORT ISSUED

MONTH	YEAR

6. (Leave blank)

8. (Leave blank)

12. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)
Environmental Effects Branch
Division of Safeguards, Fuel Cycle and Environmental Res.
Office of Nuclear Regulatory Research
Nuclear Regulatory Commission, Washington, D. C. 20555

10. PROJECT/TASK/WORK UNIT NO.

11. CONTRACT NO.
AT(49-24)-0347

13. TYPE OF REPORT
Quarterly Report

PERIOD COVERED (Inclusive dates)
September 1, 1978-November 30, 1978

15. SUPPLEMENTARY NOTES

14. (Leave blank)

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. Out most recent findings covering September-November, 1978, are that at least one subtropical species of the borer family Teredinidae continues to live in Oyster Creek; it now breeds at the mouth of Forked River. The subtropical _Teredo bartschi_ living in Oyster Creek retained well-developed larvae in the gills through November, while the native species _B. gouldi_ spawned out. The gonads of _B. gouldi_ were vanishingly small in November. Larvae of _T. bartschi_ settled in Oyster Creek and larvae of the native _T. navalis_ settled on _Long Beach_ Island in September, but no later. The last _B. gouldi_ of the season settled in August. The greatest wood damage occurred at station 12 in Oyster Creek. Increased siltation on rocks in Oyster Creek decreased both the abundance and the diversity of fouling organisms. The introduced polychaete _Mercierella enigmatica_ has been found in Oyster Creek as well as stations to the north.

17. KEY WORDS AND DOCUMENT ANALYSIS — **17a. DESCRIPTORS**

marine borers	Teredinidae	_T. bartschi_
shipworms	Forked River	_T. navalis_
Oyster Creek	_Teredo bartschi_	_Long Beach_ Island
Barnegat Bay	_B. gouldi_	polychaete _Mercierella enigmatica_

17b. IDENTIFIERS/OPEN-ENDED TERMS

18. AVAILABILITY STATEMENT

19. SECURITY CLASS (This report)

21. NO. OF PAGES

20. SECURITY CLASS (This page)

22. PRICE
$

NRC FORM 335 (7-77)

305 292

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

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
U.S. NUCLEAR REGULATORY
COMMISSION

U.S. MAIL

305 293