NON-RADIOLOGICAL ENVIRONMENTAL MONITORING REPORT

Calvert Cliffs Nuclear Power Plant

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BALTIMORE GAS & ELECTRIC COMPANY

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TABLE OF CONTENTS

Section	Section Number
Introduction	1
Summary	2
Treatment Chemical Usage	3
Copper and Nickel at Plant Intake & Discharge	4
Fish Bottom Trawling	5
Blue Crab Studies	6
Oyster Tray Studies	7.1
Heavy Metal Analyses of Oysters	7.2
Impingement Counts	8.1
Survival Estimates of Impinged Fish	8.2
Zooplankton Entrainment	9

INTRODUCTION

Amendment numbers 23 and 7 of the USNRC facility operating licenses for Calvert Cliffs Nuclear Power Plant, Unit Nos. 1 and 2, respectively, require the submission of an annual report analyzing the data collected to satisfy the requirements of the Non-radiological Environmental Technical Specifications for these facilities. This report presents and analyzes the data collected for this purpose between January 1, 1981 and December 31, 1981. For ease of reference, it has been formatted in accordance with the appropriate non-radiological environmental technical specifications.

This report has been prepared by a cooperative effort between The Academy of Natural Sciences of Philadelphia, it's field laboratory at Benedict, Maryland, and the Baltimore Gas and Electric Company. The authors and affiliation of each section are identified.

SUMMARY

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The 1981 program of studies at the Calvert Cliffs Nuclear Power Plant included monitoring studies of biological populations and certain associated physico-chemical variables in the vicinity of the plant, as well as special studies on the effects of impingement and entrainment. During 1981 both generating units at Calvert Cliffs were in commercial operation. The following passages summarize the major results of the individual study elements.

Monthly monitoring of physico-chemical variables revealed the expected slight temperature elevations in the vicinity of the plant and higher salinities than had been observed in recent years.

The dominant fish species collected by bottom trawl during 1981 were bay anchovy, spot, winter flounder, and Atlantic menhaden. Winter flounder were rarely caught in 1980; and croaker and blueback herring, dominant species in 1980, were much less abundant during 1981. Total number of fish caught was greater at Kenwood Beach than at Plant Site or Rocky Point, although the number of species at Kenwood Beach was lower than elsewhere. The largest catches came from the 6-m depth, the 12-m depth was intermediate, and the 9-m depth had the smallest catches. There was no significant difference between the numbers of anchovy or menhaden caught at the three stations, but spot were more abundant at Plant Site than at Kenwood Beach or Rocky Point. Five times the number of blue crabs were caught in 1981 compared with 1980. Plant Site produced the largest catches and Kenwood Beach produced the smallest catches of blue crabs.

Average blue crab catches (taken by pots) increased 315% from 1980 levels, and were 2.6 times the previous high set in 1979. There were no significant station differences in abundance or size, but the percent males at Kenwood Beach was greater than at Rocky Point. There has been a significant decrease in the percent males caught at each station since 1968, but this decrease has been equal among stations.

Oyster growth was greater at the Plant Site than at reference stations, probably because of stimulation by warm water

discharges from the plant. Oyster mortality rates were low and similar at plant and reference stations. Analyses of oyster tissue revealed higher copper concentrations at the Plant Site than at reference stations. Copper concentrations were inversely related to distance from the plant discharge, but nickel concentrations did not show a recognizable pattern. Concentrations of both metals were also higher at the Plant Site during the 1973-75 preoperational period, and it is not evident that the observed metal concentrations have produced any harmful effects on oysters near the plant.

The estimated total number of fish and crabs impinged during 1981 (3,274,180) was twice that of 1980 (1,605,754). Much of this increase was due to increased numbers of crabs impinged. There were more large impingement episodes during 1981 than in 1980, although seasonal patterns of impingement were similar to prior years. More fish were impinged at Unit 2 than at Unit 1, and more fish and crabs were collected from the Royce screens at Unit 2 than from the standard screens. The survival rates of fishes impinged were similar at Units 1 and 2, but overall survival rates were lower in 1981 than in 1980. There was a trend toward smaller individuals on the smaller-mesh Royce screens than on the standard screens, but survival of spot, oyster toadfish, and winter flounder were similar on both mesh sizes. Blueback herring showed higher survival on the Royce screens, whereas bay anchovy showed lower survival.

Zooplankton entrainment studies during summer 1981 showed that, as in previous years, nauplii and juvenile copepods sustained the greatest losses during plant transit. Mechanical stress appears to be the most likely cause of zooplankton losses, but this has not been confirmed. Although decreased survival was correlated with maximum zooplankton densities and high ambient temperatures, there is little evidence that zooplankton mortality was directly attributable to thermal stress. Survival estimates were lower in 1981 than in 1980, but the reasons for this are unclear.

Other than the mortalities of zooplankton and fish associated with entrainment and impingement, respectively, there is no evidence that the operation of the Calvert Cliffs Nuclear Power Plant has had any adverse effect on oyster, crab, or fish populations in Chesapeake Bay.

TREATMENT CHEMICAL USAGE

The following quantities of treatment chemicals were used in the plant during 1981.

	Chemical	Amount
1.	Trisodium phosphate	- 0 -
2.	Boric Acid	91,830
3.	Hydrazine	5,255
4.	Sodium hypochlorite	27,470

COPPER AND NICKEL AT PLANT INTAKE AND DISCHARGE

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Copper and nickel concentrations were determined in samples of water collected once each calendar month at the intake curtain wall (30-foot depth) and from the discharge plume (surface) of the Calvert Cliffs Nuclear Power Plant. All samples were collected and acidified by personnel of Benedict Estuarine Research Laboratory and were delivered to the Electric Test Department, Baltimore Gas and Electric Company, for analysis.

All water samples were passed through a 0.45 micrometer membrane filter to remove suspended solids. The filtered samples were analyzed on a Perkin-Elmer Model 460 atomic absorption spectrophotometer with an HGA 2200 Graphite Furnace installed in the burner compartment. Analyses were performed by the method of additions using background correction and matrix modification in the furnace. Selected samples were analyzed by flameless atomic absorption after a chelation and extraction procedure in order to verify initial results.

Nickel values in 1981 discharge samples did not differ significantly from those in corresponding intake samples either on a monthly basis or on a mean annual basis. The range of values in intake samples was <0.001 mg/l to 0.006 mg/l and the range of discharge values was <0.001 mg/l to 0.006 mg/l. For the intake samples the mean annual value was 0.002 mg/l and, for discharge samples, 0.002 mg/l.

The range of copper concentrations in intake samples was 0.001 mg/l to 0.010 mg/l and in discharge samples, <0.001 mg/l to 0.010 mg/l. The mean annual values were 0.005 mg/l for the intake and 0.006 mg/l for the discharge. With the exception of the March and July results, intake and discharge values did not differ significantly. The March and July values were included in all calculations although it may not be truly representative.

A comparison of both copper and nickel values in 1981 with values for the period 1975-1980 shows that the 1981 values fall within the range of concentrations previously observed. No statistical difference was found between 1981 mean values and 1975-1980 mean values at either the intake or discharge.

Monthly values for copper and nickel concentrations are shown in Table 4.2-1.

References

American Public Health Association, et. al., Standard Methods for the Examination of Water and Wastewater, Washington, D. C., Fourteenth Edition, 1975.

Goldberg, Edward D., Strategies for Marine Pollution Monitoring, John Wiley & Sons, New York, N. Y. 1976.

Harris, Thomas E., "Copper and Nickel at Plant Intake and Discharge," Non-Radiological Environmental Monitoring Report, Baltimore Gas and Electric Company, 1976, 1977, 1978, 1979, 1980, 1981.

Perkin-Elmer Corporation, Analytical Methods for Atomic Absorption Spectrophotometry, 1975.

Perkin-Elmer Corporation, Analytical Methods for Atomic Absorption Spectroscopy Using the HGA Graphite Furnace, 1981.

U. S. Environmental Protection Agency, Methods for Chemical Analysis of Water and Wastes, 1978.

Table 4.2-1 Copper and Nickel Concentrations in Water Samples from Plant Intake and Discharge January through December, 1981 (mg/l)

	Copper		Nickel	
	Intake	Discharge	Intake	Discharge
January	0.004	0.005	0.006	0.006
February	0.004	0.004	0.003	0.003
March	0.005	0.010	0.001	0.001
April	0.004	0.006	<0.001	<0.001
May	0.005	0.005	<0.001	0.001
June	0.001	0.003	<0.001	0.001
July	0.010	<0.001	<0.001	<0.001
August	0.002	0.007	0.003	0.004
September	0.001	0.003	0.002	0.003
October	0.001	0.003	0.003	0.003
November	0.002	0.003	0.003	0.003
December	0.002	0.003	0.003	0.003

FISH BOTTOM TRAWLING

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Introduction

Bottom trawling studies of finfish populations have been conducted in the vicinity of the Calvert Cliffs Nuclear Power Plant (CCNPP) on the Chesapeake Bay since 1968. These studies have been undertaken to determine seasonal cycles in abundance, diversity and occurrence of fish species in the vicinity of the power plant and to document any plant-induced changes in the community structure of benthic fish populations (ANSP, 1969, 1970, 1971a, 1971b, 1973, 1974; Moore, 1975, 1976; Hixson, 1977; Naiman, Hixson and Capizzi, 1978; Hixson and Capizzi, 1979; Hixson and Hirshfield, 1980; Hirshfield and Hixson, 1981). Data from the most recent study, conducted from January through December 1981, are presented in this report.

Materials and Methods

Samples were collected monthly during 1981 at three stations: Kenwood Beach (KB), Plant Site (PS), and Rocky Point (RP) (Fig. 5-1). Sampling consisted of duplicate 15-min bottom trawls at all stations at 6-, 9- and 12-m depths. After each trawl up to 50 individuals of each species were measured for total length (TL). If more than 1,000 individuals of any species were captured, the total number was estimated volumetrically. Carapace widths of up to 25 blue crabs (*Callinectes sapidus*) collected while trawling were recorded after each trawl.

The total number of fish and crabs, number of species and the measurements of representative individuals of each species for each trawl depth are kept on file at the Benedict Estuarine Research Laboratory.

Samples were collected with a 7.62-m semi-balloon trawl, modified as an otter trawl. The net had a body and cod-end of 3.17-cm stretch mesh. The cod-end inner liner was made of 1.27-cm stretch mesh. Tow speed was approximately 4 knots. Benthic trawls do not effectively sample non-benthic species, e.g., Atlantic menhaden (*Brevoortia tyrannus*), bay anchovy (*Anchoa mitchilli*), or larger individuals of other species that can outswim the net. Date, time, depth, weather conditions, tidal stage and trawling direction (with or against tidal flow) were recorded during each trawl.

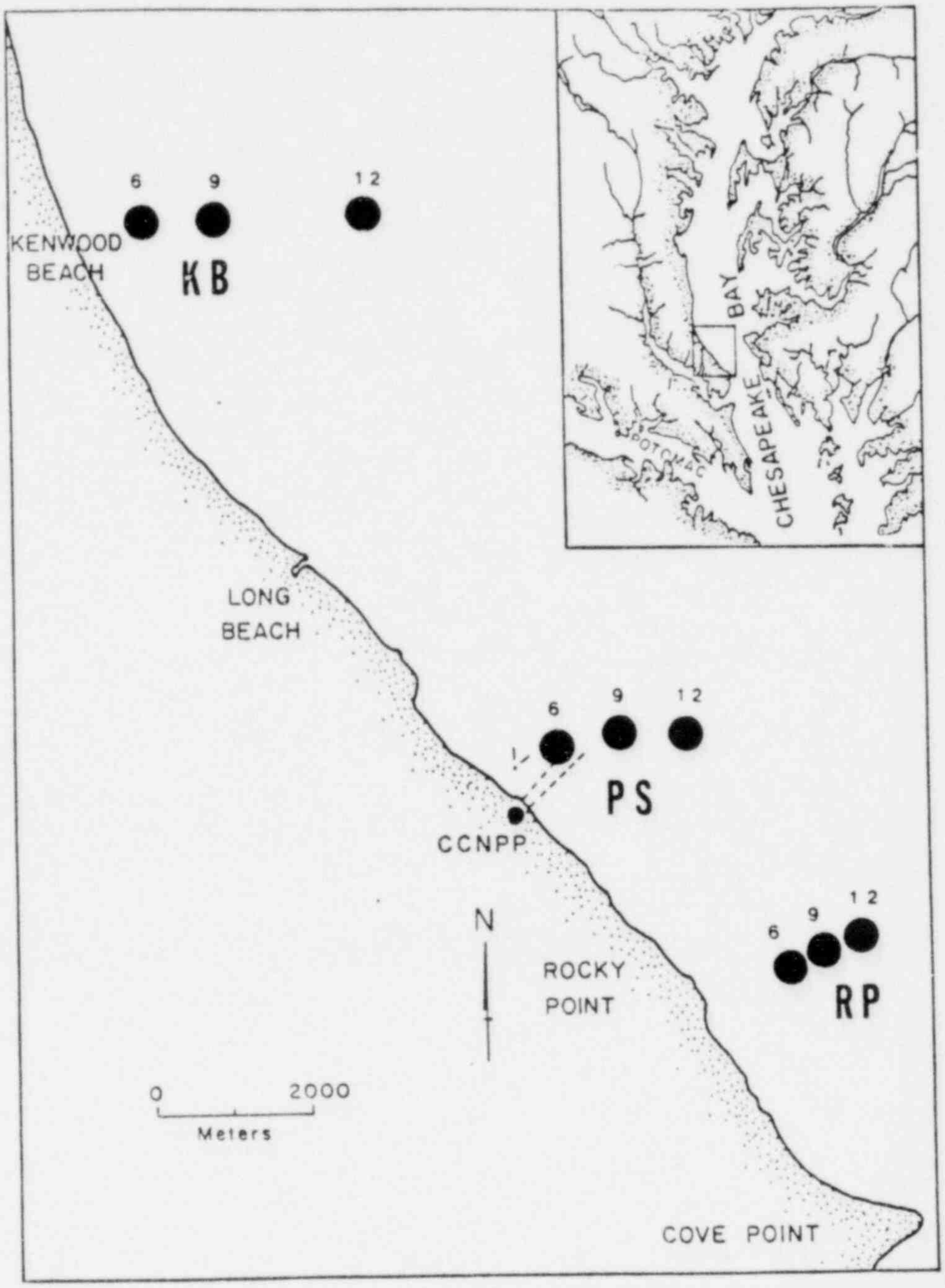

Figure 5-1. Fish bottom-trawling stations, showing sampling sites at 6-, 9- and 12-m depths, at Kenwood Beach (KB), Plant Site (PS) and Rocky Point (RP) on the Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant (CCNPP), 1981.

During each sampling period, surface and bottom temperature (°C), salinity (ppt) and dissolved oxygen (mg/l) measurements were made at each depth at each station. Temperature and salinity were measured with a Beckman RS5-3 salinometer; dissolved oxygen (DO) with a YSI (Yellow Springs Instrument) dissolved oxygen meter.

Statistical Analyis

Environmental Data

Bottom temperature, bottom salinity and bottom DO values were analyzed using a three-way analysis of variance (ANOVA) (Sokal and Rohlf, 1969) having month (January-December), depth (6 m, 9 m, 12 m), and station (KB, PS, RP) as main effects. The three-way interaction was used as the error term since environmental data were measured only once for each combination of main effects.

Major Fish Species

Representatives of bay anchovy (*Anchoa mitchilli*), spot (*Leiostomus xanthurus*), winter flounder (*Pseudopleuronectes americanus*), and Atlantic menhaden (*Brevoortia tyrannus*) comprised 98.5% of all fish collected in 1981 bottom trawl samples and were considered to be major species. The abundances of these species and blue crabs (*Callinectes sapidus*) were analyzed using two statistical methods. However, winter flounder were collected infrequently and therefore were not included in statistical analyses.

A three-way ANOVA (month, depth, and station as main effects for the environmental variables) was used to analyze the spatial and temporal distribution of the major species. Duplicate trawls at each station-depth combination permitted evaluation of the three-way interaction. In addition, Duncan's multiple range test (Steel and Torrie, 1960) was used to describe overall differences among months, stations and depths.

The second method ignored the spatial relationship of the stations, but rather, characterized each trawl by a measurement of depth, bottom temperature, bottom salinity, and bottom DO. The abundances of the major species were treated as a function of these four variables. Since collections were made over a 12-month period, an analysis of covariance (ANCOVA) was appropriate, treating months as a class variable and the four environmental parameters as independent regressor variables (covariates). This approach allowed several questions to be addressed:

1) Was there an overall effect of bottom temperatures on the abundance of each species in our trawl samples?

2) If so, was the effect positive or negative?

3) Was there a significant variation over months in the direction of the temperature effect?

4) If so, in what months was the effect strongly positive or negative?

The ANCOVA included both temperature and temperature X month terms to test for significant heterogeneity in the slope of temperature over months. If significant heterogeneity did exist, the temperature term was deleted and the model was analyzed using temperature X month alone, which determined the magnitude of the temperature effect for each month. If no heterogeneity was indicated, then the model was analyzed using only the temperature term, and not the temperature X month term, to determine whether there was a significant overall temperature effect.

The number of individuals was transformed using ln (N+1) to normalize the values. In addition, analyses included only those months when at least 20 individuals of the fish species under analysis were collected. Blue crab abundances were analyzed for the period from May through November.

Results and Discussion

Physico-chemical Variables

Tables 5-1, 5-2, and 5-3 present surface and bottom values for temperature (°C), salinity (ppt) and DO (ppm) by depth at Kenwood Beach, Plant Site and Rocky Point, respectively.

The ANOVA of bottom temperature indicated significant variation due to month, station and depth (Table 5-4). Bottom temperatures were significantly higher in August than any other month (Table 5-5). Bottom water at the Plant Site station was significantly warmer than bottom water at Kenwood Beach (Table 5-6). However, neither of those stations was significantly different from Rocky Point. The somewhat intermediate temperatures observed at Rocky Point occurred primarily during the colder months of January and February (Tables 5-1 through 5-3) and would explain the marginal significance of the overall station effect. On the average, temperatures at 6 m were significantly higher than those at either 9 or 12 m (Table 5-7).

The ANOVA of bottom salinity (Table 5-4) indicated significant or highly significant variation due to month, station, depth and a month X depth interaction. Salinity tended to be higher at Rocky Point than at either Plant Site or Kenwood Beach, which were similar to each other (Table 5-6). Furthermore, salinity was usually highest at 12 m and lowest at 6 m

Table 5-1. Surface and bottom temperature (°C), salinity (ppt), and dissolved oxygen (mg/l) recorded during trawling studies at Kenwood Beach in the vicinity of the Calvert Cliffs Nuclear Power Plant by depth, January through December 1981.

Depth	Month	Temperature (°C) S	Temperature (°C) B	Salinity (ppt) S	Salinity (ppt) B	Dissolved Oxygen (mg/l) S	Dissolved Oxygen (mg/l) B
6 m	January	-0.5	-0.2	18.8	19.2	11.5	11.4
	February	0.7	0.4	19.1	19.9	11.4	11.3
	March	3.8	3.7	13.1	13.2	12.0	11.4
	April	9.2	8.9	17.2	17.3	10.4	10.3
	May	15.8	15.7	12.9	13.5	8.9	8.4
	June	23.8	23.2	12.5	13.0	9.7	8.3
	July	25.9	25.3	13.6	14.1	7.2	5.4
	August	27.2	26.6	16.6	17.0	6.0	3.2
	September	25.6	24.6	18.8	18.6	7.5	3.6
	October	19.0	18.1	19.9	19.8	8.6	8.5
	November	13.9	13.4	17.5	17.9	11.3	10.5
	December	7.0	7.1	19.4	19.2	13.0	13.1
9 m	January	-0.8	-0.8	18.8	19.4	11.3	11.3
	February	0.6	0.2	19.0	20.1	11.9	11.8
	March	3.9	3.7	13.1	14.2	11.9	11.4
	April	8.8	8.6	17.4	17.4	10.6	10.2
	May	15.7	16.0	13.0	14.1	9.1	8.6
	June	23.2	17.2	12.7	20.2	8.7	1.3
	July	25.5	23.9	13.8	15.6	6.6	2.9
	August	26.7	25.6	16.8	18.5	5.8	0.7
	September	25.7	24.6	19.1	18.8	4.8	2.8
	October	8.2	8.1	20.0	20.5	18.9	19.0
	November	13.6	13.5	17.7	18.6	11.2	10.4
	December	7.7	7.5	19.6	19.5	13.0	14.4
12 m	January	-1.0	-1.0	15.5	15.3	11.7	11.7
	February	0.4	0.2	19.8	20.1	11.4	11.5
	March	3.6	4.1	14.2	23.[illegible]	11.8	9.5
	April	8.4	8.2	17.4	17.5	10.5	10.4
	May	15.6	14.5	13.5	22.5	9.6	2.1
	June	22.5	16.9	13.0	21.5	8.4	0.7
	July	25.5	23.3	14.4	17.2	7.9	3.6
	August	26.6	25.6	17.0	19.2	6.2	1.5
	September	24.5	24.4	18.7	19.3	6.9	2.7
	October	19.0	20.2	20.5	21.7	8.9	7.8
	November	13.4	13.8	17.5	20.1	10.8	9.8
	December	7.4	7.4	19.8	19.9	14.6	14.6

Table 5-2. Surface and bottom temperature (°C), salinity (ppt), and dissolved oxygen (mg/l) recorded during trawling studies at the Plant Site Station in the vicinity of the Calvert Cliffs Nuclear Power Plant by depth January through December 1981.

Depth	Month	Temperature (°C) S	Temperature (°C) B	Salinity (ppt) S	Salinity (ppt) B	Dissolved Oxygen (mg/l) S	Dissolved Oxygen (mg/l) B
	January	0.3	0.4	19.5	19.6	11.4	11.0
	February	1.8	1.7	19.4	19.5	11.8	11.4
	March	4.3	4.7	13.2	14.5	12.2	11.7
	April	9.2	9.0	17.3	17.4	10.5	10.5
	May	17.8	17.3	13.0	12.8	8.4	8.5
6 m	June	23.2	19.8	14.2	16.5	9.2	5.2
	July	26.6	25.9	14.9	15.3	4.8	4.0
	August	27.8	27.8	17.3	17.3	*	*
	September	26.2	24.7	19.1	19.2	5.5	4.0
	October	20.0	19.8	20.0	20.0	9.2	8.0
	November	16.1	14.5	17.1	17.3	12.0	11.6
	December	7.6	7.6	19.8	19.8	11.2	11.0
	January	-0.1	-0.2	19.1	20.7	11.4	11.4
	February	0.9	1.0	20.3	20.4	11.1	11.1
	March	3.9	4.1	13.1	13.3	12.2	11.6
	April	8.9	9.3	17.3	17.3	10.4	10.4
	May	15.9	15.8	13.3	14.3	9.0	8.7
9 m	June	24.3	23.1	13.2	13.6	10.5	9.2
	July	25.7	25.2	14.1	14.8	7.0	4.8
	August	27.6	26.5	16.6	17.6	*	*
	September	26.9	24.7	18.2	19.0	4.9	3.4
	October	20.1	19.4	20.0	20.0	9.0	7.8
	November	14.5	13.7	17.5	18.5	12.0	10.4
	December	8.5	7.5	19.6	18.9	12.4	12.2
	January	-0.3	-0.4	18.9	19.9	11.4	11.6
	February	0.2	0.4	20.1	20.1	11.2	11.2
	March	3.8	3.8	13.3	21.3	11.7	9.4
	April	9.2	8.7	17.3	17.4	10.5	10.2
	May	15.9	15.0	13.6	19.4	9.1	3.0
12 m	June	22.5	16.2	12.2	20.7	9.0	0.6
	July	25.8	23.7	14.2	16.6	7.8	2.5
	August	27.1	25.6	17.0	19.5	6.4	0.7
	September	26.6	24.7	19.2	19.0	6.9	3.9
	October	19.9	19.7	20.0	20.5	9.1	7.1
	November	14.4	13.6	17.1	18.8	10.9	9.8
	December	7.3	9.1	20.0	19.6	11.5	11.3

*Dissolved oxygen meter inoperable.

Table 5-3. Surface and bottom temperature (°C), salinity (ppt), and dissolved oxygen (mg/l) recorded during trawling studies at Rocky Point in the vicinity of the Calvert Cliffs Nuclear Power Plant by depth, January through December 1981.

Depth	Month	Temperature (°C)		Salinity (ppt)		Dissolved Oxygen (mg/l)	
		S	B	S	B	S	B
	January	-0.1	-0.1	19.8	19.8	11.4	11.3
	February	1.8	1.6	19.6	19.9	11.8	11.9
	March	4.1	4.1	13.2	13.5	12.1	11.9
	April	8.8	8.9	18.2	18.2	10.1	10.0
	May	16.2	15.8	13.2	13.4	9.0	8.7
6 m	June	22.4	20.7	15.3	16.3	8.2	5.4
	July	25.2	24.8	15.2	15.3	5.6	5.3
	August	26.9	26.0	17.2	17.2	*	*
	September	24.9	24.9	19.0	18.8	6.8	5.5
	October	19.3	19.5	20.3	20.1	8.3	8.2
	November	14.1	13.9	17.5	17.5	12.0	11.7
	December	8.0	8.0	19.8	19.7	12.6	12.6
	January	-0.6	-0.2	19.4	19.5	11.4	11.2
	February	1.6	0.8	19.7	20.5	12.2	12.3
	March	4.0	4.1	13.5	21.1	11.9	9.6
	April	9.0	6.4	18.1	20.8	10.2	8.9
	May	15.8	15.9	13.3	13.9	9.2	8.8
9 m	June	22.5	18.4	15.2	19.9	8.2	1.3
	July	25.3	22.6	15.0	19.1	5.5	1.2
	August	27.0	26.4	17.1	17.4	*	1.5
	September	24.7	24.4	18.8	20.1	6.4	3.2
	October	19.4	19.4	20.2	20.3	8.6	8.2
	November	13.9	14.0	17.7	17.9	11.8	11.2
	December	7.9	8.1	19.7	20.3	12.4	12.0
	January	-0.2	-0.5	19.4	19.6	11.4	11.4
	February	1.6	0.3	20.0	20.5	11.4	12.1
	March	3.7	4.1	13.7	22.2	12.3	10.0
	April	8.6	6.1	17.9	21.4	10.4	9.2
	May	15.9	15.6	14.0	15.6	9.3	8.6
12 m	June	22.3	17.6	14.8	21.1	8.2	0.6
	July	25.2	22.4	15.1	19.9	6.1	0.4
	August	27.0	25.5	17.2	21.4	7.2	0.4
	September	24.5	23.9	18.6	21.6	6.4	2.5
	October	20.3	19.3	20.2	20.3	7.1	8.1
	November	13.4	14.1	17.6	20.4	11.2	10.0
	December	7.7	7.7	19.8	20.5	12.4	12.4

*Dissolved oxygen meter inoperable.

Table 5-4. Results of 3-way ANOVA of bottom temperature, bottom salinity, and bottom dissolved oxygen levels recorded during trawl studies in the vicinity of Calvert Cliffs Nuclear Power Plant, 1981. ($\alpha = 0.05$)

Effect	DF	Bottom Temperature SS	Bottom Temperature P	Bottom Salinity SS	Bottom Salinity P	Bottom Dissolved Oxygen SS	Bottom Dissolved Oxygen P
Month	11	8618.3	0.0001	212.2	0.0001	1596.7	0.0001
Station	2	13.7	0.0317	18.5	0.0134	5.8	0.3373
Depth	2	18.8	0.0100	123.9	0.0001	42.4	0.0010
M X S	22	35.6	0.6152	48.8	0.3467	68.1	0.3109
M X D	22	56.8	0.1651	148.5	0.0002	93.0	0.0874
S X D	4	8.9	0.3167	10.9	0.2506	9.1	0.4889
Corrected Total	107	8832.8		648.7		1930.5	

Table 5-5. Duncan's multiple range test comparisons among months of bottom temperature, bottom salinity, and bottom dissolved oxygen levels during trawl studies in the vicinity of Calvert Cliffs Nuclear Power Plant, 1981. Means with the same letter were not significantly different.

Month	Bottom Temperature		Bottom Salinity		Bottom Dissolved Oxygen	
	$\bar{x}$	Group	$\bar{x}$	Group	$\bar{x}$	Group
JAN	-0.22	H	19.22	ABC	11.37	AB
FEB	0.69	H	20.13	A	11.62	AB
MAR	4.04	G	17.39	ED	10.72	BC
APR	8.23	F	18.30	BCD	10.01	BC
MAY	15.73	D	15.50	F	7.27	D
JUN	19.23	C	18.09	CD	3.62	E
JUL	24.12	B	16.43	EF	3.34	E
AUG	26.18	A	18.34	BCD	0.89*	F
SEP	24.54	B	19.38	ABC	3.51	E
OCT	18.17	C	20.36	A	9.19	C
NOV	13.83	E	18.56	BCD	10.60	BC
DEC	7.78	F	19.71	AB	12.62	A

*12-m depth only

Table 5-6. Duncan's multiple range test comparisons among stations of bottom temperature, bottom salinity, and bottom dissolved oxygen levels during trawl studies in the vicinity of Calvert Cliffs Nuclear Power Plant, 1981. Means with the same letter were not significantly different.

Station	Bottom Temperature		Bottom Salinity		Bottom Dissolved Oxygen	
	$\bar{x}$	Group	$\bar{x}$	Group	$\bar{x}$	Group
Kenwood Beach	13.1	B	18.3	B	8.2	A
Plant Site	14.0	A	18.1	B	7.8	A
Rocky Point	13.5	AB	19.0	A	7.7	A

Table 5-7. Duncan's multiple range test comparisons among depths of bottom temperature, bottom salinity, and bottom dissolved oxygen levels during trawl studies in the vicinity of Calvert Cliffs Nuclear Power Plant, 1981. Means with the same letter were not significantly different.

Depth	Bottom Temperature		Bottom Salinity		Bottom Dissolved Oxygen	
	$\bar{x}$	Group	$\bar{x}$	Group	$\bar{x}$	Group
6 m	14.1	A	17.3	C	8.5	A
9 m	13.3	B	18.2	B	8.2	A
12 m	13.2	B	19.9	A	7.0	B

although the highly significant month X depth interaction demonstrates that variation with depth was not consistent over months (Tables 5-5 and 5-7).

Bottom DO concentrations varied significantly over months and depths (Table 5-4). While DO levels were similar at the 6 and 9 m depths, they were much lower at 12 m (Table 5-7).

Community Composition

Dominant species at each station were bay anchovy (*Anchoa mitchilli*), spot (*Leiostomus xanthurus*), winter flounder (*Pseudopleuronectes americanus*), Atlantic menhaden (*Brevoortia tyrannus*), Atlantic croaker (*Micropogonias undulatus*) and weakfish (*Cynoscion regalis*) (Table 5-8). These species made up at least 98.9% of the total catch at each station and 99.4% of the total catch at all stations combined.

Station Abundance

Total numbers of fish collected during the year by depth and station are presented in Table 5-9. Total numbers at all depths combined at the Plant Site were similar to those at Rocky Point and both were lower than Kenwood Beach. At the 6-m depth, totals were lowest at the Plant Site; totals at Kenwood Beach and Rocky Point were similar. At the 9- and 12-m depths, totals were lowest at Rocky Point.

Total numbers of finfish collected at each depth are presented by station and month in Tables 5-10 through 5-12. At the 6-m depth the majority of fish were collected from May through November (Table 5-10). Few fish were collected from January through April and in December. This pattern is consistent with previous studies. Largest numbers at the 9-m depth (Table 5-11) occurred from May through November, except June when totals at all stations were low. Totals at the 9-m depth at Rocky Point were also low during August and September. At the 12-m depth (Table 5-12) at all stations, the majority of fish were collected from September through December. During 1981, the 6-m depth generally yielded the highest totals and the 9-m depth the lowest (Plant Site had lowest totals at 6 m depth).

The total number of each species collected during the year is presented by station and depth in Table 5-13. At the 6-m depth, the largest number of species (Table 5-14) was collected at the Rocky Point station. Species collected only at Rocky Point at the 6-m depth were: blueback herring (*Alosa aestivalis*), striped anchovy (*Anchoa hepsetus*), lizardfish (*Synodus foetens*), threespine stickleback (*Gasterosteus aculeatus*), northern pipefish (*Syngnathus fuscus*), sand lance (*Ammodytes americanus*) and windowpane (*Scophthalmus aquosus*).

Table 5-8. Abundance and percent of total catch represented by each of the six most abundant species collected, by station, during trawling studies in the vicinity of the Calvert Cliffs Nuclear Power Plant, 1981.

Species		Kenwood Beach	Plant Site	Rocky Point	Total
Anchoa mitchilli	#	48,948	31,628	32,494	113,070
	%	92.1	77.4	80.0	84.0
Leiostomus xanthurus	#	2,899	7,560	5,203	15,662
	%	5.5	18.5	12.8	11.6
Pseudopleuronectes americanus	#	163	616	1,624	2,403
	%	0.3	1.5	4.0	1.8
Brevoortia tyrannus	#	909	81	431	1,421
	%	1.7	0.2	1.1	1.1
Micropogonias undulatus	#	46	611	101	758
	%	<0.1	1.5	0.2	0.6
Cynoscion regalis	#	51	112	325	488
	%	<0.1	0.3	0.8	0.4
Remaining species	#	133	230	438	801
	%	0.3	0.6	1.1	0.6

Table 5-9. Total number of fish collected, by station and depth, during trawling studies at the Calvert Cliffs Nuclear Power Plant, 1981.

Station	Depth			Total
	6 m	9 m	12 m	
Kenwood Beach	25,266	13,340	14,543	53,149
Plant Site	8,901	12,104	19,833	40,838
Rocky Point	21,341	8,276	10,999	40,616
Total	55,508	33,720	45,375	134,603

Table 5-10. Total numbers of fish collected at the 6 m depth, by station and month, during trawling studies in the vicinity of the Calvert Cliffs Nuclear Power Plant, 1981.

Month	Depth	Stations		
		Kenwood Beach	Plant Site	Rocky Point
Jan	6 m	0	1	3
Feb	6 m	0	3	3
Mar	6 m	2	3	0
Apr	6 m	1	0	299
May	6 m	1710	613	5573
Jun	6 m	1174	190	1427
Jul	6 m	2886	3587	3635
Aug	6 m	11,859	883	407
Sep	6 m	4158	3236	5857
Oct	6 m	2100	358	4087
Nov	6 m	1376	22	50
Dec	6 m	0	5	0
Total		25,266	8901	21,341

Table 5-11. Total numbers of fish collected at the 9 m depth, by station and month, during trawling studies in the vicinity of the Calvert Cliffs Nuclear Power Plant, 1981.

Month	Depth	Stations		
		Kenwood Beach	Plant Site	Rocky Point
Jan	9 m	9	6	5
Feb	9 m	0	0	3
Mar	9 m	12	5	11
Apr	9 m	0	98	114
May	9 m	2676	2220	925
Jun	9 m	72	19	197
Jul	9 m	1326	4053	106
Aug	9 m	653	569	1
Sep	9 m	6344	4747	3
Oct	9 m	607	204	1668
Nov	9 m	1507	182	4692
Dec	9 m	134	1	551
Total		13,340	12,104	8276

Table 5-12. Total numbers of fish collected at the 12 m depth, by station and month, during trawling studies in the vicinity of the Calvert Cliffs Nuclear Power Plant, 1981.

Month	Depth	Stations		
		Kenwood Beach	Plant Site	Rocky Point
Jan	12 m	21	12	10
Feb	12 m	2	2	1
Mar	12 m	4	5	27
Apr	12 m	0	213	424
May	12 m	9	107	12
Jun	12 m	26	226	34
Jul	12 m	63	194	2
Aug	12 m	0	1	0
Sep	12 m	17	5533	109
Oct	12 m	3174	5773	732
Nov	12 m	10,724	5080	8990
Dec	12 m	503	2687	658
Total		14,543	19,833	10,999

Table 5-13. Total number of each species collected, by depth and station, during trawling studies in the vicinity of the Calvert Cliffs Nuclear Power Plant, 1981.

Species	Stations: Kenwood Beach			Plant Site			Rocky Point			Total
	6 m	9 m	12 m	6 m	9 m	12 m	6 m	9 m	12 m	
Rhinoptera bonasus	0	0	0	1	0	0	0	0	0	1
Anguilla rostrata	0	0	0	1	0	0	1	0	0	2
Alosa aestivalis	0	5	9	0	2	5	179	4	13	217
Alosa pseudoharengus	0	2	9	1	2	10	2	4	2	32
Alosa sapidissima	0	0	0	0	0	0	0	1	1	2
Brevoortia tyrannus	693	213	3	43	4	34	368	8	55	1,421
Dorosoma cepedianum	0	0	1	0	0	1	0	0	1	3
Anchoa hepsetus	0	0	0	0	2	0	2	1	101	106
Anchoa mitchilli	23,108	11,965	13,875	4,630	9,142	17,856	14,331	8,058	10,105	113,070
Synodus foetens	0	0	0	0	0	0	2	0	0	2
Opsanus tau	0	0	1	32	4	8	10	3	3	61
Gobiesox strumosus	0	1	0	1	1	0	0	0	0	3
Urophycis regius	0	0	0	0	0	5	0	1	4	10
Menidia beryllina	0	0	1	0	0	0	0	0	0	1
Menidia menidia	2	2	0	2	1	2	0	2	2	13
Gasterosteus aculeatus	0	0	0	0	0	0	1	0	0	1
Syngnathus fuscus	0	0	1	0	1	1	1	3	1	8
Prionotus carolinus	0	0	0	1	0	1	1	0	0	3
Morone americana	0	9	3	0	4	2	0	1	1	20
Morone saxatilis	0	1	0	0	0	0	0	1	0	2
Pomatomus saltatrix	0	0	0	0	0	3	0	0	0	3
Cynoscion regalis	0	12	39	0	28	84	0	34	291	488
Leiostomus xanthurus	1,315	1,036	548	3,534	2,841	1,185	4,787	107	309	15,662
Micropogonias undulatus	0	8	38	1	1	609	0	23	78	758
Hypsoblennius hentzi	0	1	2	1	0	0	0	0	0	4
Chasmodes bosquianus	1	0	0	0	0	0	0	0	0	1
Ammodytes americanus	0	0	0	0	0	0	1	0	0	1
Gobiosoma bosci	0	0	0	0	0	1	0	0	0	1
Peprilus alepidotus	16	18	4	0	7	9	2	6	5	67
Paralichthys dentatus	7	12	9	7	8	12	23	12	13	103
Scophthalmus aquosus	0	0	0	0	0	0	1	0	0	1
Pseudopleuronectes americanus	116	47	0	565	47	4	1,616	3	5	2,403
Trinectes maculatus	8	8	0	81	9	1	13	4	9	133
Total # Fish Collected	25,266	13,340	14,543	8,901	12,104	19,833	21,341	8,276	10,999	134,603
Total for Station		53,149			40,838			40,614		
Callinectes sapidus	139	231	57	1,100	366	102	252	214	161	2,622

Table 5-14. Total number of species collected, by depth and station, during trawling studies in the vicinity of the Calvert Cliffs Nuclear Power Plant, 1981.

Depth	Stations		
	Kenwood Beach	Plant Site	Rocky Point
6 m	9	15	18
9 m	16	17	19
12 m	15	20	19
Total	21	25	26

Species collected solely at the 6-m depth at the Plant Site were the cow-nose ray (*Rhinoptera bonasus*), skilletfish (*Gobiesox strumosus*), Atlantic croaker (*Micropogonias undulatus*) and feather blenny (*Hypsoblennius hentzi*). Striped blenny (*Chasmodes bosquianus*) was the only species collected solely at the 6-m depth at Kenwood Beach.

At the 9-m depth, the largest number of species was collected at Rocky Point (19), the lowest at Kenwood Beach (16). Species collected solely at the 9-m depth at Rocky Point were American shad (*Alosa sapidissima*) and spotted hake (*Urophycis regius*). No species were collected only at the Plant Site at the 9-m depth. Feather blenny (*Hypsoblennius hentzi*) was the only species collected at the 9-m depth solely at Kenwood Beach.

The Plant Site station yielded the largest number of species collected at the 12-m depth (20), Kenwood Beach the lowest (15) (Table 5-14). Species collected at the 12-m depth only at the Plant Site were northern searobin (*Prionotus carolinus*), bluefish (*Pomatomus saltatrix*), and naked goby (*Gobiosoma bosci*). Species collected at the 12-m depth only at Rocky Point were American shad (*Alosa sapidissima*) and striped anchovy (*Anchoa hepsetus*). Tidewater silverside (*Menidia beryllina*) and feather blenny (*Hypsoblennius hentzi*) were the only species collected at the 12-m depth solely at Kenwood Beach.

Analyses of blue crab (*Callinectes sapidus*) catch data (Tables 5-15, 5-16, and 5-17) indicated significantly higher numbers of blue crabs were collected at the 6-m depth ($p<0.0001$). Furthermore, significantly more individuals were collected at the Plant Site station, but this trend was not consistent at all depths. Approximately five times as many blue crabs were collected in 1981 (2622) as compared to 1980 (446) (Hirshfield and Hixson, 1981).

ANCOVA of blue crabs indicated no significant overall effects of environmental variables. However, in the months of August and November the effect of temperature was marginally significant and positive ($p<0.04$ and $p<0.05$, respectively).

Major Finfish Species

Anchoa mitchilli - Bay anchovy

The ANOVA of bay anchovy abundances indicated that month and depth and all of their interactions were highly significant (p at least <0.005) but station and the three-way interaction were not significant (Table 5-18). Significantly fewer anchovies were collected at 12 m than at 6 or 9 m (Table 5-19); however, these differences were not consistent over months. Greatest numbers of anchovies were collected from September

Table 5-15. Numbers of blue crab (*Callinectes sapidus*) collected, by sex, depth and station, during bottom trawling studies in the vicinity of the Calvert Cliffs Nuclear Power Plant, 1981.

Depth	Sex	Kenwood Beach	Plant Site	Rocky Point
6 m	♂	59	378	107
	♀	80	722	145
9 m	♂	97	147	73
	♀	134	219	141
12 m	♂	31	50	48
	♀	26	52	113
Total		427	1568	627

Table 5-16. Three-way ANOVA of abundance of blue crabs collected during trawling studies in the vicinity of Calvert Cliffs Nuclear Power Plant, 1981. ($\alpha = 0.05$)

Effect	df	SS	P
Month	6	46.7	0.0001
Station	2	21.3	0.0001
Depth	2	22.5	0.0001
M X S	12	24.9	0.0062
M X D	12	53.3	0.0001
S X D	4	16.3	0.0011
M X S X D	24	36.0	0.0209
Corrected Total	125	270.2	

Table 5-17. Duncan's multiple range test comparisons among months, stations and depths of blue crab abundances during trawling studies in the vicinity of Calvert Cliffs Nuclear Power Plant, 1981. Means were calculated using log-transformed data: ln (N + 1). Means with the same letter were not significantly different.

Months	$\bar{x}$	Group	Stations	$\bar{x}$	Group	Depth	$\bar{x}$	Group
MAY	2.93	A	Kenwood Beach	1.52	C	6 m	2.47	A
JUN	1.07	D						
JUL	1.36	D	Plant Site	2.52	A	9 m	2.06	B
AUG	2.43	AB						
SEP	1.65	CD	Rocky Point	1.93	B	12 m	1.44	C
OCT	2.33	AB						
NOV	2.18	C						

Table 5-18. Three-way ANOVA of major fish species collected during trawling studies in the vicinity of Calvert Cliffs Nuclear Power Plant, 1981. (α = 0.05)

Effect	Bay Anchovy			Spot			Atlantic Menhaden		
	DF	SS	P	DF	SS	P	DF	SS	P
Month	8	255.6	0.0001	5	106.7	0.0001	3	21.7	0.0017
Station	2	2.7	0.6268	2	43.9	0.0001	2	3.5	0.2365
Depth	2	32.7	0.0053	2	5.1	0.1939	2	33.8	0.0001
M X S	16	205.3	0.0001	10	49.1	0.0023	6	12.7	0.1245
M X D	16	443.3	0.0001	10	224.4	0.0001	6	28.4	0.0034
S X D	4	104.2	0.0001	4	27.1	0.0032	4	14.7	0.0264
M X S X D	32	133.3	0.1022	20	64.4	0.0136	12	28.3	0.0527
Corrected Total	161	1413.6		107	601.6		71	185.2	

Table 5-19. Duncan's multiple range test comparisons among depths of major fish species collected during trawling studies in the vicinity of Calvert Cliffs Nuclear Power Plant, 1981. Means were calculated using log-transformed data: ln (N + 1). Means with the same letter were not significantly different.

Depth	Bay Anchovy		Spot		Atlantic Menhaden	
	$\bar{x}$	Group	$\bar{x}$	Group	$\bar{x}$	Group
6 m	4.25	A	2.54	A	1.96	A
9 m	4.18	A	2.94	A	0.45	B
12 m	3.27	B	2.44	A	0.56	B

through November (Table 5-20) and no specimens were collected January through March.

ANCOVA of bay anchovies determined significant heterogeneity in the effects of temperature over months. The final model included month, dissolved oxygen concentration, salinity, depth and temperature within months and explained 78.4% of the variation in anchovy abundances. The overall effect of temperature within months was highly significant ($p<0.0001$). In September and December the effect was significant and positive (September: $p<0.0002$; December: $p<0.005$). April was the only month that showed a significant negative effect ($p<0.02$).

Leiostomus xanthurus - spot

The ANOVA of spot abundances (Table 5-18) showed all main effects (except depth) and their interactions were significant (p at least <0.02). Spot tended to be most abundant at the Plant Site station ($\bar{x}$ = 3.49); abundances at Kenwood Beach and Rocky Point ($\bar{x}$ = 2.46 and 1.96, respectively) were lower and similar to each other (Table 5-21). However, in three of the six months for which spot abundances were analyzed, more specimens were collected at Rocky Point (May and October) or Kenwood Beach (November). The significant station X depth interaction resulted because the lowest number of fish at Rocky Point were collected at 9 m, whereas the fewest fish at Kenwood Beach and Plant Site were collected at 12 m.

ANCOVA of spot abundances showed significant heterogeneity in the effects of temperature over months. The final model included month, depth, bottom dissolved oxygen, bottom salinity, and bottom temperature within months. This model explained 74.5% of the variation in spot abundance. Only in July was there a significant temperature effect, and it was positive ($p<0.0007$). In addition, the effect of depth was significant and positive ($p<0.001$). The effect of salinity was significant but negative, indicating that more spot were collected in lower salinity waters. Finally, the effect of DO was weakly significant ($p<0.05$) and negative.

Brevoortia tyrannus - Atlantic menhaden

ANOVA of menhaden abundances (Table 5-18) indicated a significant or highly significant effect of month, depth, month X depth, and station X depth ($p<0.002$; $p<0.0001$; $p<0.004$; $p<0.03$, respectively). More menhaden were collected at 6 m ($\bar{x}$ = 1.96) than at 9 or 12 m ($\bar{x}$ = 0.45 and 0.56, respectively) (Table 5-19). Although menhaden were more or less uniformly distributed over stations (Table 5-21), the weakly significant station x depth effect was caused by high abundances at 12 m at Rocky Point in April.

ANCOVA of menhaden abundances indicated significant heterogeneity in temperature effects over months. The final

Table 5-20. Duncan's multiple range test comparisons among months of major fish species collected during trawling studies in the vicinity of Calvert Cliffs Nuclear Power Plant, 1981. Means were calculated using log-transformed data: ln (N + 1). Means with the same letter were not significantly different.

Month	Bay Anchovy		Spot		Atlantic Menhaden	
	$\bar{x}$	Group	$\bar{x}$	Group	$\bar{x}$	Group
JAN	*		*		*	
FEB	*		*		*	
MAR	*		*		*	
APR	2.13	E	*		0.42	B
MAY	3.21	CDE	4.28	A	1.26	A
JUN	3.65	CD	*		*	
JUL	4.07	C	3.65	A	1.76	A
AUG	2.98	CDE	2.07	BC	0.52	B
SEP	5.09	AB	1.56	C	*	
OCT	5.51	A	1.83	BC	*	
NOV	5.88	A	2.48	B	*	
DEC	2.59	DE	*		*	

* Insufficient numbers collected to warrant statistical analysis.

Table 5-21. Duncan's multiple range test comparisons among stations of major fish species collected during trawling studies in the vicinity of Calvert Cliffs Nuclear Power Plant, 1981. Means were calculated using log-transformed data: ln (N + 1). Means with the same letter were not significantly different.

Station	Bay Anchovy		Spot		Atlantic Menhaden	
	$\bar{x}$	Group	$\bar{x}$	Group	$\bar{x}$	Group
Kenwood Beach	4.08	A	2.46	B	1.12	A
Plant Site	3.85	A	3.49	A	0.68	A
Rocky Point	3.77	A	1.96	B	1.18	A

model included month, depth, bottom dissolved oxygen, bottom salinity, and bottom temperature within months. This model explained 54.6% of the variation in menhaden abundances. The effect of temperature was significant and negative in April and August, but was not significant in any other month. The effect of depth was significant ($p<0.02$) and negative.

Conclusions

During 1981, the Plant Site station had significantly higher bottom temperatures than Kenwood Beach. Mean temperatures at Rocky Point were intermediate in value and were not significantly different from the other stations. Salinity was significantly higher at Rocky Point than at either Kenwood Beach or the Plant Site. However, salinity was somewhat lower at the Plant Site than at Kenwood Beach but that difference was not statistically significant. Dissolved oxygen was similar among all stations. Crabs were most abundant at 6 m at the Plant Site station. Approximately five times as many crabs were collected during 1981 trawling studies as were collected in 1980. The distribution of crabs was independent of the selected environmental variables. Spot were significantly more abundant at the Plant Site station, anchovies were intermediate and menhaden least abundant. However, difference in distributions among stations was not significantly different for anchovy or menhaden. There is no evidence to suggest that plant operation had a consistent effect on fish distributions in the vicinity of Calvert Cliffs.

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BLUE CRAB STUDIES

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Introduction

For nearly a century the blue crab, *Callinectes sapidus*, has been the basis of an important commercial fishery in the Chesapeake Bay and its tributaries. During the past 40 years the annual catch has averaged nearly 60 million pounds valued at more than 3 million dollars. From 1965 to 1975 the average annual catch increased to almost 72 million pounds valued at 7.5 million dollars, but reduced catches in the late 1970s decreased the average annual catch from 1968 to 1978 to 60.4 million pounds (U. S. Fish and Wildlife Service, 1970*a*, *b*; National Marine Fisheries Service, 1972-1979*a*, *b*). Dockside value, however, continued to increase and catches averaged 8.7 million dollars annually for this period. Reported landings for 1979 totaled 59.5 million pounds valued at 13 million dollars (National Marine Fisheries Service, 1980 and 1981), and increased to 64.5 million pounds worth 14.8 million dollars in 1980 (from unpublished monthly landings issued by the Resource Statistics Division of the National Marine Fisheries Service).

The size of the 1981 crab population in Chesapeake Bay was predicted by W. Van Engel of the Virginia Institute of Marine Science to be the lowest in 20 years (Hirzel, 1980). Van Engel based this prediction on heavy rainfall and subsequent runoff in late 1979 which he believed eliminated many larvae and juveniles from the lower Bay. His sampling in the lower Bay in late 1979 indicated only about one-tenth the number of juveniles seen the year before. It was these crabs which would make up much of the commercial catch in late 1980 and early 1981 according to Van Engel. However, recent investigations (Sulkin, 1981) indicate that most crab larvae normally move out of the lower Bay, where they are spawned, into a nursery area in the Atlantic. Therefore, sampling only the lower Bay to estimate the next year's population would not provide data representative of distributions throughout the entire area inhabited by larval and post-larval blue crabs; thus, estimates of abundance for the following year could be quite low.

In addition to being one of the most abundant commercial species of the Chesapeake Bay, the blue crab is also one of the most tolerant of a wide range of salinities and temperatures. Tagatz (1969) has shown that at salinities slightly lower than those at Calvert Cliffs, 50% of the crabs acclimated to 22°C will survive 48 h at a temperature of 36.9°C. Burton (1978)

has also demonstrated high thermal tolerance in blue crabs. Since maximum temperatures near the discharge of the Calvert Cliffs Nuclear Power Plant (CCNPP) are several degrees below this (Naiman, Hixson, and Capizzi, 1978), it seems reasonable to assume that crabs would not be killed by heated effluents discharged from the plant. However, sublethal temperatures may affect distribution of the population, so that numbers of crabs, or their sizes or sex ratios may be changed from normal distribution patterns. Because fluctuations in the annual abundance of blue crabs are common (Pearson, 1948; Van Engel, 1958; Tagatz, 1965; Abbe, 1973), this study was designed to examine the abundance, seasonality, sex ratios, and size-frequency distribution of the crab population in the vicinity of the CCNPP over several years, and to ascertain whether any significant changes in these factors might result from the plant's operation.

Materials and Methods

Program Design

Commercial techniques (Van Engel, 1962) and crab pots of 25-mm (1-in) mesh were used to sample the crab population at Kenwood Beach (KB), the Plant Site (PS), and Rocky Point (RP) (Fig. 6-1) from early May until late fall, when cold temperatures reduced crab activity so that they could no longer be caught with pots. In 1981 crabbing continued through the first week of December. Most commercial pots have 38-mm (1½-in) mesh and will generally not hold crabs smaller than 76 mm (3 in) in width. However, the smaller mesh used in this study allowed some crabs less than 51 mm (2 in) wide to be caught.

Pots were fished every other week throughout the season. During those weeks, five pots were fished for four days at each station (weather permitting). Pots were set in 2-4 m of water and baited daily with menhaden.

Bottom temperature, salinity and dissolved oxygen (DO) concentrations were measured daily at each station during the weeks fished. Temperature and salinity were determined with a Beckman RS5-3 portable salinometer, and DO concentrations were measured with a YSI Model 57 dissolved oxygen meter.

The following information was derived from the catch:

1. Total number of crabs
2. Number of pots fished
3. Mean number of crabs per pot
4. Percent of total caught at each station
5. Total weight (kg)
6. Mean weight per crab (g)
7. Number of legal-size crabs (≧127 mm)

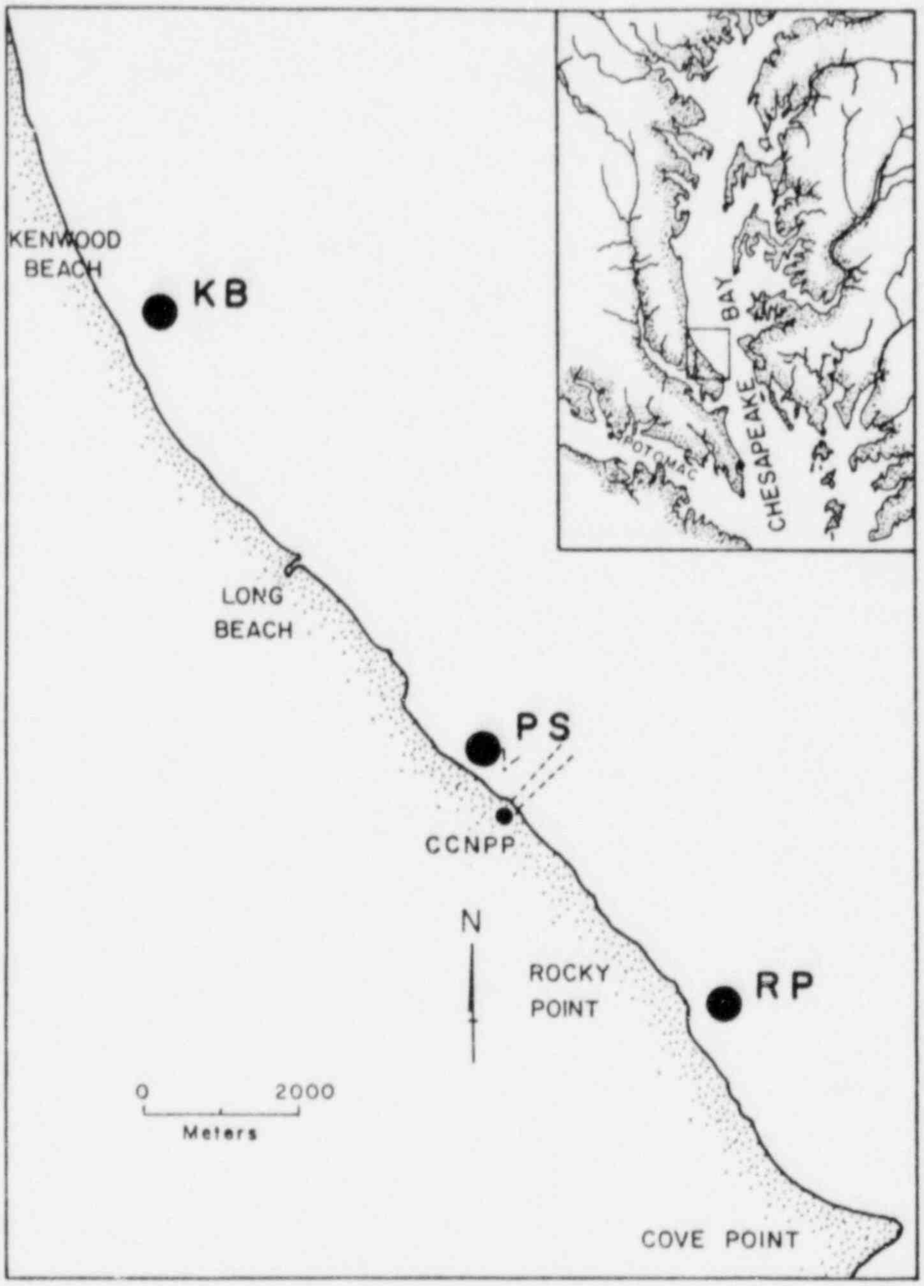

Figure 6-1. Locations of crab pots at Kenwood Beach (KB), Plant Site (PS), and Rocky Point (RP) in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant from 1968 to 1981.

8. Number of non legals (<127 mm)
9. Percent legal-size crabs
10. Mean number of legal-size crabs per pot
11. Mean width across lateral spines (mm)
12. Number of male crabs
13. Number of female crabs
14. Percent male crabs

Statistical Analysis

Some of the variables of this study were analyzed using a blocked analysis of variance design with the following model:

$$y = \mu + \alpha + \beta + \varepsilon$$

where y = response variable
μ = overall mean
α = station effect
β = date effect
and ε = random error.

The responses analyzed by this procedure were:

1. log (number of crabs + 1/number of pots)
2. log (number of males + 1/number of pots)
3. log (number of females + 1/number of pots)
4. log (number of legal crabs + 1/number of pots)
5. Total weight of males/number of pots
6. Total weight of females/number of pots
7. Total weight of crabs/number of pots
8. Arcsin ($\sqrt{\text{percent males}}$)
9. Mean width of males
10. Mean width of females
11. Mean width of total crabs

Results and Discussion

1981

Although a small commercial catch had been predicted, 1981 turned out to be a year of huge catches. Van Engel predicted that commercial crab landings from Maryland and Virginia would total only about 40 million pounds from September 1980 to August 1981 (Hirzel, 1980), and based on the number of sub-legal crabs observed in the Calvert Cliffs area from September to November 1979 (114 of 1578 or 7.2%), a poor year in 1981 appeared likely.

There was, however, a tremendous 1980 year class which was first indicated to us by thousands of dead crabs (20-30 mm carapace width) on the beach at Dares Beach, Maryland, during the winter of 1981. At that time the size of this population

Bay-wide was unknown, and also, whether the small crabs would grow enough during the season to be of commercial significance.

The 1981 study at CCNPP resulted in the largest number of crabs caught during the 14 years that these studies have been conducted. The total for 1981 was 15,106 crabs (Table 6-1), more than 2.6 times the highest yearly catch made from 1968 to 1980 (Table 6-2). The season began with small catches (Fig. 6-2), and through early June, the prediction of a poor year appeared correct. These early-season crabs were from the 1979 year class and about 60% of them were legal size in May (Fig. 6-3). But as the 1979 year class ran its course and was replaced by the 1980 year class, the percentage of legal-size crabs decreased to less than 20% in mid-June. As the low point for legal-size percentage was reached, the number of crabs caught per pot began to increase rapidly, from more than 10 in mid-June, to near 20 in mid-July to over 30 in mid-August (Fig. 6-2). The number of legal-size crabs climbed much more slowly than total crabs as it depended on the growth of individuals. As shown in Fig. 6-4 the number of legal-size crabs per pot (averaged across three stations) did not reach 10 until late July, 20 was reached in October, and 30 was approached in November.

The rapid increase in numbers of crabs by mid-June may have been enhanced by rapidly rising water temperatures from mid-May to mid-June (Fig. 6-5). Warmer temperatures would have resulted in greater metabolic activity and faster growth of crabs. Thus very small crabs would become available to the pot fishery earlier than they would have under cooler conditions. After June, temperatures were almost stable until August when they began a gradual 4-mo decline. This temperature pattern was in sharp contrast to that observed in 1980 (Abbe, 1981), when the temperature rose gradually until August and then fell fairly rapidly.

Tables 6-3 through 6-6 list the number and weight by sex of crabs caught each week in 1981. Weekly station means (crabs per pot) showed a rapid rise during June, July and August to a peak of about 31, followed by a decline and a second period of increases during August, September and October until a second peak in early November reached a level slightly above the August peak. During November, as temperatures fell, the catch per pot dropped sharply (Figs. 6-2 and 6-5).

The total number of crabs caught each month was near 2,000 during June, July and September, about 2,500 in November, and 3,000 in October (Table 6-6). Only about 200 crabs were caught in May, but nearly 3,400 were taken during August. More crabs were caught in one month (August 1981) than during all of 7 of the previous 13 years (Table 6-2). By the end of the 1981 season, the total of 15,106 crabs was a 332% increase above the 3,494 caught in 1980. A total of 896 pots were fished, yielding 16.86 crabs per pot (Table 6-1), a 315% increase above the

Table 6-1. Number of blue crabs caught, their carapace width, weight and sex, and the number of pots fished at three stations near the Calvert Cliffs Nuclear Power Plant in Chesapeake Bay during 1981.

	Kenwood Beach	Plant Site	Rocky Point	Total	Grand Mean
Total number of crabs	5,180	5,308	4,618	15,106	
Number of pots fished	293	300	303	896	
Crabs per pot	17.68	17.69	15.24		16.86
Percent at each station	34.9	35.0	30.1	100.0	
Total weight (kg)	680	684	608	1,972	
Weight per crab (g)	131	129	132		131
Legal-size crabs (≥127 mm)	3,476	3,461	3,274	10,211	
Sub legal (<127 mm)	1,704	1,847	1,344	4,895	
Percent legal-size crabs	67.1	65.2	70.9		67.6
Legal-size crabs per pot	11.86	11.54	10.81		11.40
Mean width (mm)	129.6	130.5	130.4		130.2
Number of males	2,618	2,495	1,740	6,853	
Number of females	2,562	2,813	2,878	8,253	
Percent males	50.5	47.0	37.7		45.4

Table 6-2. Summary of abundance, size and sex composition of crab catches near the Calvert Cliffs Nuclear Power Plant in Chesapeake Bay from 1968 through 1981.

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Total number	239	2,833	1,557	4,784	3,046	3,059	3,970	4,902	2,845	2,092	3,476	5,741	3,494	15,106
Total weight (kg)	48	367	240	711	449	480	632	778	392	378	552	864	638	1,972
Weight per crab (g)	200	132	154	150	145	159	159	159	138	181	159	150	183	131
Number ≥ 127 mm (legal size)	206	2,006	1,191	3,620	2,202	2,388	2,942	4,009	1,922	1,739	2,601	4,450	2,879	10,211
Number < 127 mm (sub legal)	33	827	366	1,164	844	671	1,028	893	923	353	875	1,291	615	4,895
Percent ≥ 127 mm	86.2	70.8	76.5	75.7	72.3	78.1	74.1	81.8	67.6	83.1	74.8	77.5	82.4	67.6
Number males	158	1,995	962	2,660	1,800	1,753	2,366	2,381	1,245	1,082	1,707	3,034	1,464	6,853
Number females	81	838	595	2,124	1,246	1,306	1,604	2,521	1,600	1,010	1,769	2,707	2,030	8,253
Percent males	66.1	70.4	61.8	55.6	59.1	57.3	59.6	48.6	43.8	51.7	49.1	52.8	41.9	45.4
Total pots fished	281	470	616	730	754	855	817	923	840	750	880	879	861	896
Number of crabs per pot	0.85	6.03	2.52	6.55	4.04	3.58	4.86	5.31	3.39	2.79	3.95	6.53	4.06	16.86
Legal-size crabs per pot	0.73	4.27	1.93	4.96	2.92	2.79	3.60	4.34	2.29	2.32	2.96	5.06	3.34	11.40

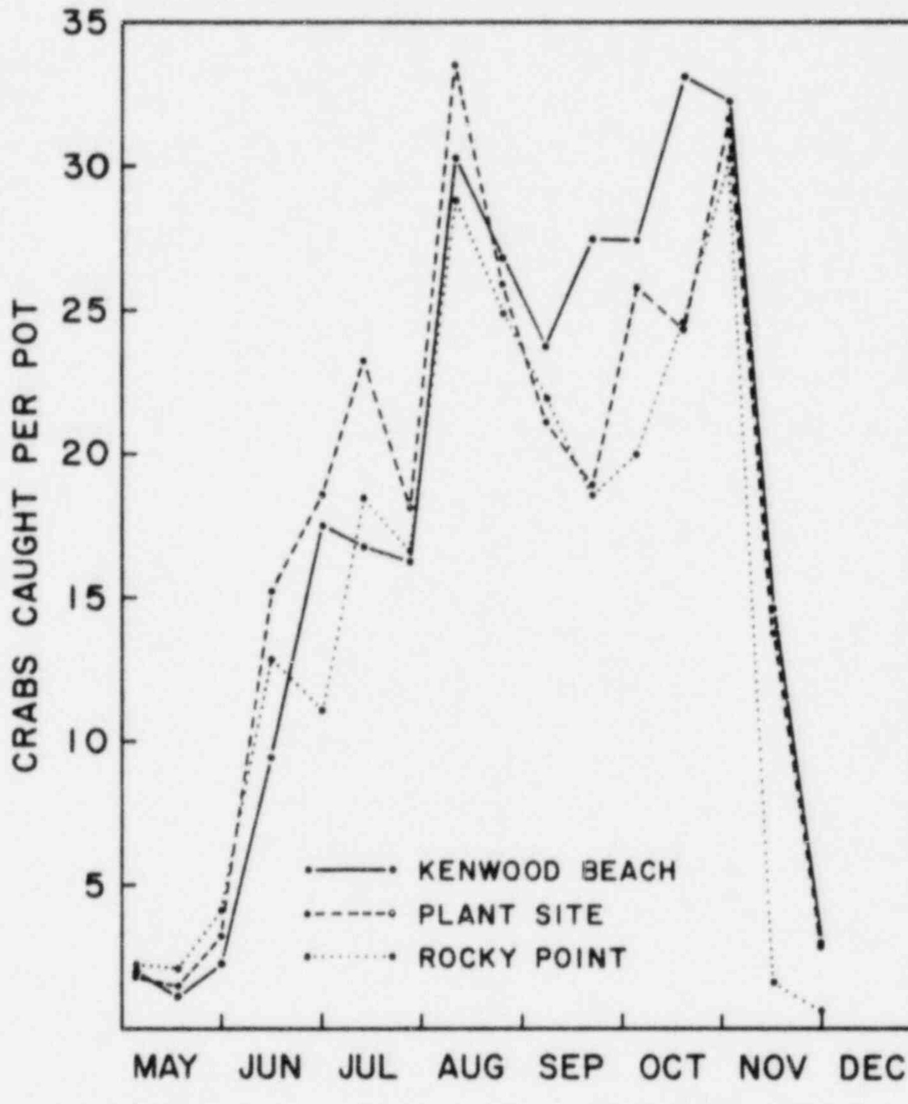

Figure 6-2. Mean number of crabs caught per pot during each sampling week at three stations in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant in 1981.

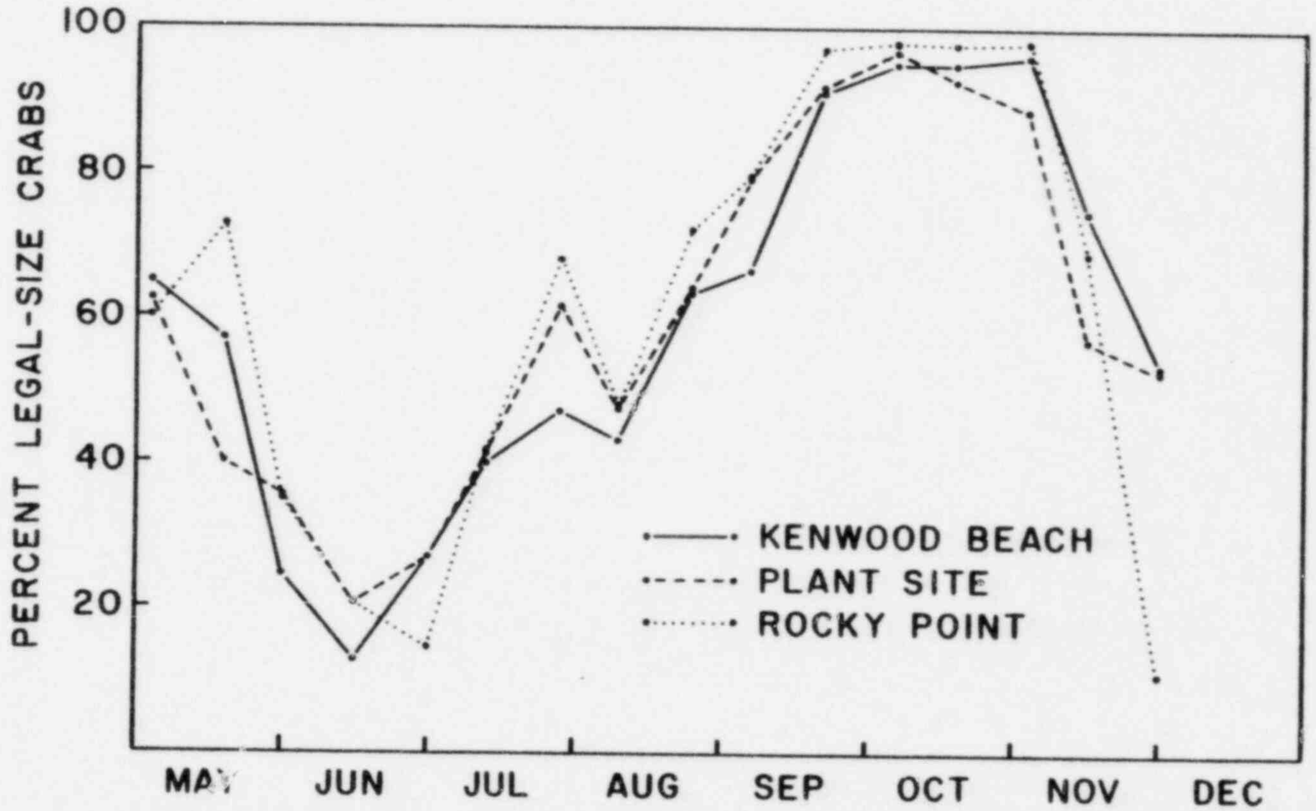

Figure 6-3. Percent of catch made up of legal-size crabs (≥127 mm) during each sampling week at three stations in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant in 1981.

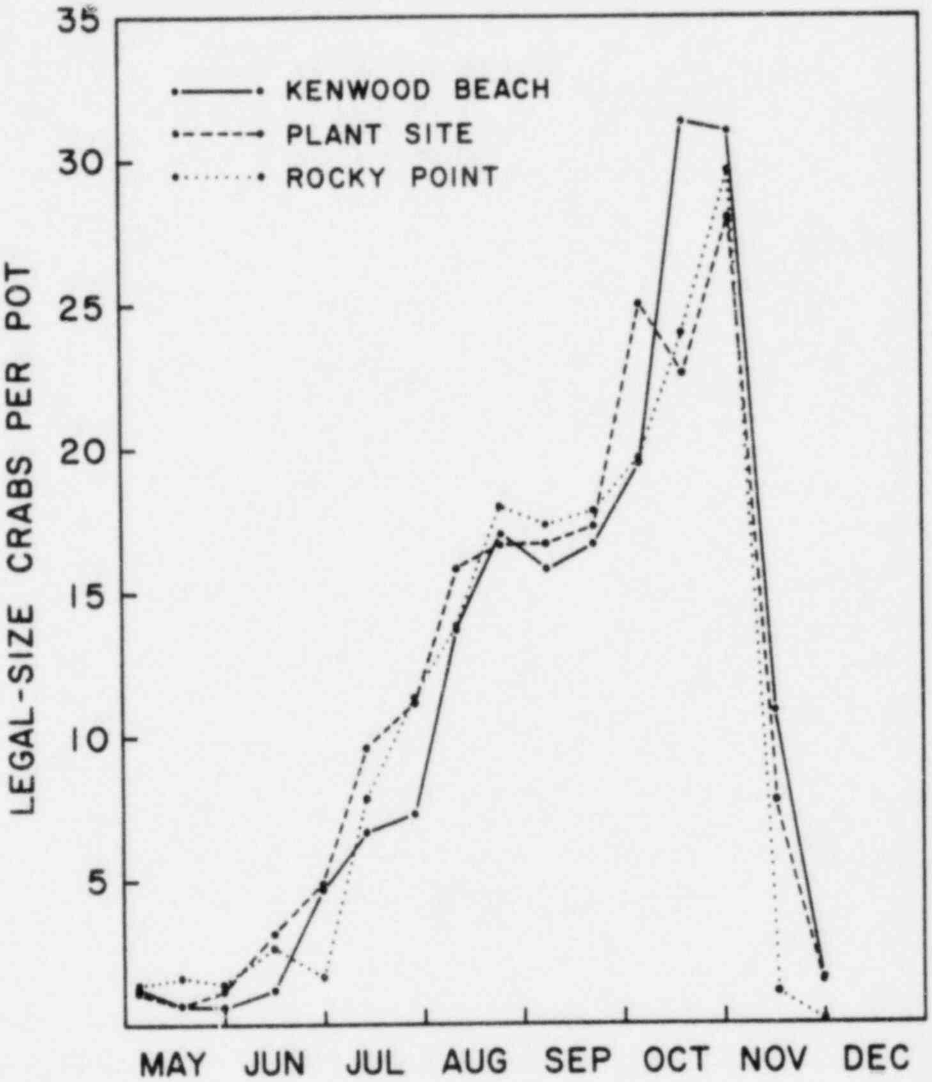

Figure 6-4. Mean number of legal-size crabs caught per pot during each sampling week at three stations in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant in 1981.

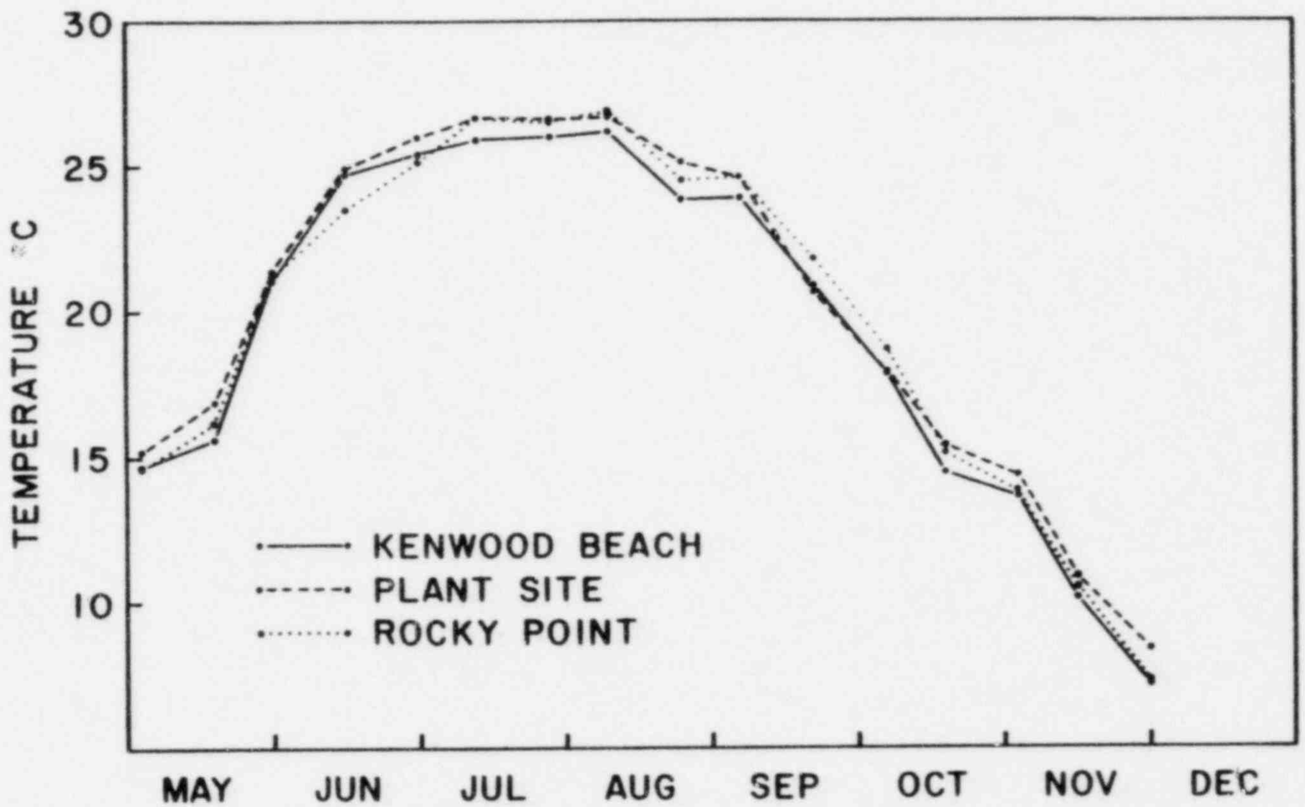

Figure 6-5. Weekly mean bottom water temperature (based on daily readings taken up to five days) during weeks fished at three stations in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant during 1981.

Table 6-3. Numbers and weights (kg) of male and female blue crabs, number of pots, and average number of crabs caught per pot during weeks fished in 1981 at Kenwood Beach in Chesapeake Bay in the area of the Calvert Cliffs Nuclear Power Plant.

	Males		Females			
Week of:	No.	Wt.	No.	Wt.	No. Pots	Crabs/pot
4 May 81	23	3.68	11	1.08	17	2.00
18 May 81	11	1.58	10	1.18	20	1.05
1 Jun 81	26	1.98	19	1.39	20	2.25
15 Jun 81	121	9.05	68	4.22	20	9.45
29 Jun 81	161	15.70	136	13.00	17	17.47
13 Jul 81	229	25.95	107	10.22	20	16.80
27 Jul 81	169	19.90	140	15.60	19	16.26
10 Aug 81	413	48.90	193	16.90	20	30.30
24 Aug 81	444	57.60	92	11.80	20	26.80
7 Sep 81	395	52.80	80	8.80	20	23.75
21 Sep 81	58	6.70	217	31.80	10	27.50
5 Oct 81	69	10.80	343	56.50	15	27.47
19 Oct 81	208	36.20	454	70.50	20	33.10
2 Nov 81	149	28.80	497	72.80	20	32.30
16 Nov 81	121	17.10	171	21.40	20	14.60
30 Nov 81	21	2.42	24	3.45	15	3.00
Total	2618	339.16	2562	340.64	293	
Mean	163.6	21.20	160.1	21.29	18.3	17.68

Table 6-4. Numbers and weights (kg) of male and female blue crabs, number of pots, and average number of crabs caught per pot during weeks fished in 1981 at the Plant Site in Chesapeake Bay in the area of the Calvert Cliffs Nuclear Power Plant.

Week of:	Males		Females		No. Pots	Crabs/pot
	No.	Wt.	No.	Wt.		
4 May 81	17	2.14	15	2.00	17	1.88
18 May 81	17	1.78	13	1.50	20	1.50
1 Jun 81	27	2.22	38	3.34	20	3.25
15 Jun 81	126	9.30	179	17.00	20	15.25
29 Jun 81	148	13.50	149	15.85	16	18.56
13 Jul 81	330	37.00	135	13.20	20	23.25
27 Jul 81	216	29.70	146	17.70	20	18.10
10 Aug 81	410	50.40	260	27.00	20	33.50
24 Aug 81	309	37.80	209	28.00	20	25.90
7 Sep 81	207	26.60	214	29.30	20	21.05
21 Sep 81	55	6.00	228	33.00	15	18.87
5 Oct 81	59	8.60	458	73.90	20	25.85
19 Oct 81	170	29.60	318	49.90	20	24.40
2 Nov 81	251	40.10	287	42.70	17	31.65
16 Nov 81	131	13.90	144	16.90	20	13.75
30 Nov 81	22	2.64	20	1.80	15	2.80
Total	2495	311.28	2813	373.09	300	
Mean	155.9	19.46	175.8	23.32	18.8	17.69

Table 6-5. Numbers and weights (kg) of male and female blue crabs, number of pots, and average number of crabs caught per pot during weeks fished in 1981 at Rocky Point in Cheaspeake Bay in the area of the Calvert Cliffs Nuclear Power Plant.

	Males		Females			
Week of:	No.	Wt.	No.	Wt.	No. Pots	Crabs/pot
4 May 81	27	3.04	13	2.16	17	2.35
18 May 81	19	2.65	25	3.12	20	2.20
1 Jun 81	42	3.56	41	3.78	20	4.15
15 Jun 81	167	13.00	91	6.75	20	12.90
29 Jun 81	124	8.97	64	5.60	17	11.06
13 Jul 81	244	27.30	126	13.10	20	18.50
27 Jul 81	139	17.00	195	24.90	20	16.70
10 Aug 81	288	33.40	260	26.80	19	28.84
24 Aug 81	198	23.30	301	41.00	20	24.95
7 Sep 81	169	19.60	270	36.10	20	21.95
21 Sep 81	16	1.80	262	39.10	15	18.53
5 Oct 81	35	6.30	365	63.10	20	20.00
19 Oct 81	165	34.40	326	52.80	20	24.55
2 Nov 81	94	17.20	511	74.20	20	30.25
16 Nov 81	8	0.45	24	3.15	20	1.60
30 Nov 81	5	0.20	4	0.26	15	0.60
Total	1740	212.17	2878	395.92	303	
Mean	108.8	13.26	179.9	24.74	18.9	15.24

Table 6-6. Total numbers and weights (kg) of male and female blue crabs, number of pots, and average number of crabs caught per pot during weeks fished in 1981 at all three stations in Chesapeake Bay in the area of the Calvert Cliffs Nuclear Power Plant.

Week of:	Males No.	Males Wt.	Females No.	Females Wt.	No. Pots	Crabs/pot
4 May 81	67	8.86	39	5.24	51	2.08
18 May 81	47	6.01	48	5.80	60	1.58
1 Jun 81	95	7.76	98	8.51	60	3.22
15 Jun 81	414	31.35	338	27.97	60	12.53
29 Jun 81	433	38.17	349	34.[illegible]5	50	15.64
13 Jul 81	803	90.25	368	36.52	60	19.52
27 Jul 81	524	66.60	481	58.20	59	17.03
10 Aug 81	1111	132.70	713	70.70	59	30.92
24 Aug 81	951	118.70	602	80.80	60	25.88
7 Sep 81	771	99.00	564	74.20	60	22.25
21 Sep 81	129	14.50	707	103.90	40	20.90
5 Oct 81	163	25.70	1166	193.50	55	24.16
19 Oct 81	543	100.20	1098	173.20	60	27.35
2 Nov 81	494	86.10	1295	189.70	57	31.39
16 Nov 81	260	31.45	339	41.45	60	9.98
30 Nov 81	48	5.26	48	5.51	45	2.13
Total	6853	862.61	8253	1109.65	896	
Mean	428.3	53.91	515.8	69.35	56.0	16.86

4.06 crabs per pot in 1980. Mean width and weight were 130 mm and 131 g, respectively (Table 6-1). Legal-size crabs (≧127 mm) made up 67.6% of the total and males accounted for 45.4%. This legal-size percentage tied the previous low of 1976, and resulted from the huge 1980 year class which took much of the season to attain legal size.

Station KB produced 34.9% of the total (17.68 crabs/pot), PS produced 35.0% (17.69 crabs/pot) and RP produced 30.1% (15.24 crabs/pot). The weekly mean catch at each station (Fig. 6-2) was analyzed using a blocked ANOVA to test the numbers of crabs caught per pot, but no significant station differences were detected; the same result was found for females analyzed separately. There was, however, a significant station difference for number of males per pot ($p=0.01$). Duncan's multiple range test (Walpole and Myers, 1972) showed the geometric mean at RP (3.37) was less than at PS(5.44) and KB (5.64) ($p<0.05$).

The mean size of crabs was 129.6 mm at KB, 130.5 mm at PS, and 130.4 mm at RP (Table 6-1). Males at KB, PS, and RP were 126.6, 124.2 and 122.8 mm, respectively; females at the same stations averaged 131.6, 135.5 and 135.4 mm, respectively. The difference between the mean sizes of males and females was much greater at RP than at KB, but no statistically significant differences were detected among stations for size of either sex (all $p>0.10$).

Male crabs were heaviest at KB (130 g), followed by PS (125 g) and RP (122 g). Weights of females showed the opposite pattern with heaviest females at RP (138 g) followed by PS and KB (133 g for each). This is the same pattern that was observed for widths since width and weight are naturally correlated. The weights of males and females caught per pot were analyzed separately. Males showed a significant difference among stations with 1,160, 1,040 and 700 g per pot caught at KB, PS, and RP, respectively, ($p=0.006$). Duncan's multiple range test determined that RP was less than PS and KB ($p<0.05$), with no difference between PS and KB. This difference directly correlated with the lower number of males caught per pot at RP. Weights of females per pot, however, were 1,160, 1,240, and 1,310 g at KB, PS, and RP and were not significantly different. Total weights per pot also differed significantly ($p=0.027$) in the same pattern as male weights per pot and again were correlated with lack of males at RP.

Males made up 50.5% of the catch at KB and 47.0% at PS, but only 37.7% at RP (Table 6-1). Analysis of these data revealed a significant station effect ($p=0.03$). Duncan's multiple range test showed no difference between RP and PS and no difference between PS and KB, but RP was less than KB ($p<0.05$). KB generally had a higher percentage of males than the other stations. During 11 of the 14 years since 1968, KB had the highest percentage of male crabs (Fig. 6-6). However, in 1981, as in 1980, the overall low percentage of males was

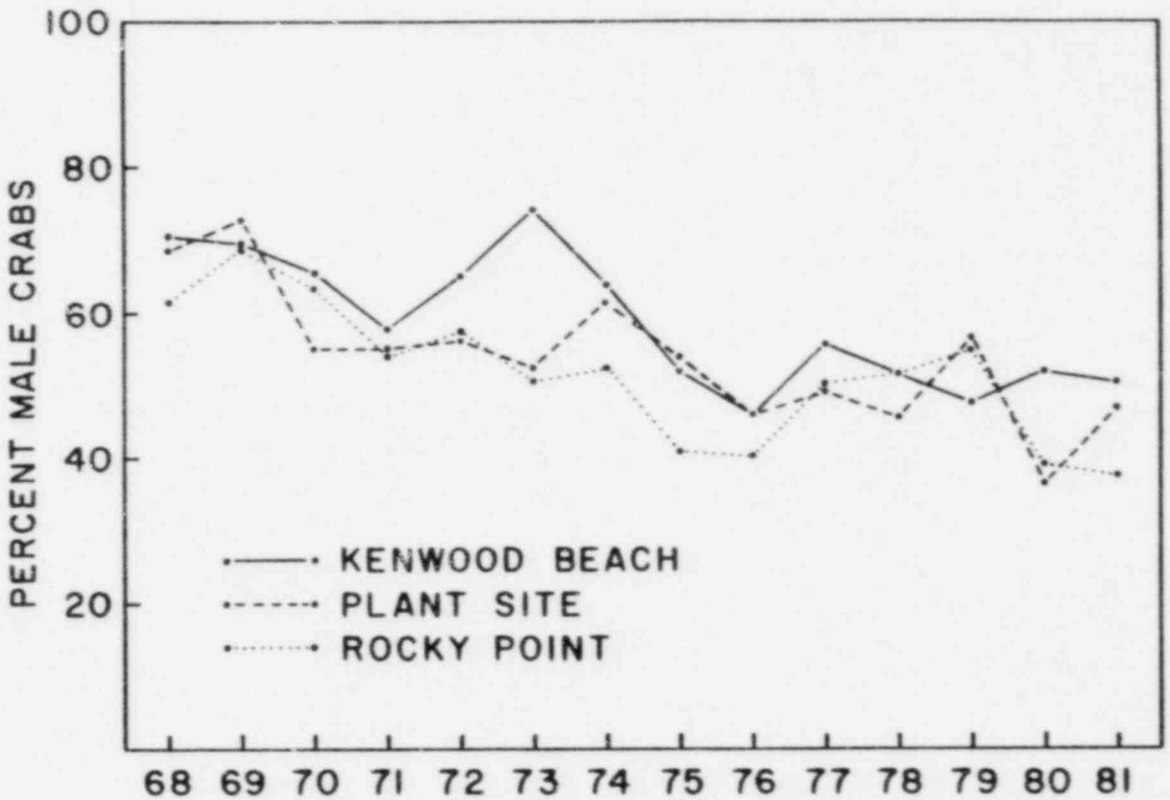

Figure 6-6. Percent of annual catch made up of male crabs at three stations in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant from 1968 through 1981.

probably related to the above-average salinity. From 1968 to 1979, salinity at Calvert Cliffs averaged about 12°/oo, but during much of the July-November 1980 period it was above 15°/oo and approached 18°/oo (Abbe, 1981). In 1981, salinity continued to rise and averaged 18°/oo for the season and reached 22°/oo at two stations in October (Fig. 6-7). The ratio of females to males in the population of an area increases with increasing salinity (Lippson, 1973). Souza et al. (1980) stated that in salinities above 10-12°/oo, males and females occur in approximately equal numbers. At lower salinities males are generally more abundant. The higher salinities at Calvert Cliffs during 1980 and 1981 were undoubtedly the main factor responsible for the low male percentages (Table 6-2). Early and mid-season catches were predominantly male (females accounted for only 41% of the catch through early September), but from mid-September until the end of the season, females made up 74% of the total (Table 6-6; Fig. 6-8).

The percentage of legal-size crabs followed the same pattern at all stations throughout the 1981 season (Fig. 6-3), and overall percentages were similar with 67.1% at KB, 65.2% at PS and 70.9% at RP (Table 6-1). The 67.6% for all stations was well below the 82.4% of 1980 (Abbe, 1981). This difference between years was due to the poor recruitment in 1980 and the excellent recruitment in 1981. No significant station differences were detected in 1981.

From 1968 through 1979 a total of 59 adult females bearing eggs (sponge crabs) was caught among 17,401 females (Abbe, 1980). During the 1978 and 1979 seasons only one sponge crab was seen although 4,476 females were collected. Truitt (1939) stated that sponge crabs are seldom seen north of the Rappahannock River in Virginia (about 50 mi down-bay from the CCNPP) except during dry years. During 1980, 32 sponge crabs were among the 2,030 females collected. Distribution for the season was two at KB, 18 at PS and 12 at RP. In 1981, 32 sponge crabs were caught among a total of 8,253 females, but the distribution and seasonality were quite different than in 1980. Twenty-five were caught in June, three in July, and two, one and one in September, October and November, respectively, compared with 18 in July, 9 in August, 4 in September, and 1 in October in 1980. Of the 25 caught in June 1981, 23 were from PS and 2 were from RP. When these values were adjusted for the number of females caught at each station during June and tested for station differences using a chi-square test for comparison of proportions (Fleiss, 1981), it was evident that sponge crabs at PS were significantly more abundant than at KB or RP ($p<0.005$). It is unusual for sponge crabs to be in the area as early as June, but these were 1980 adults which had apparently never migrated to the lower Bay. The reason that 92% of them were at PS is unclear. Perhaps some females overwintered near CCNPP because of elevated salinity and warmer temperatures during late 1980 and simply stayed in the area until they spawned in 1981. Only one sponge crab was collected at KB all

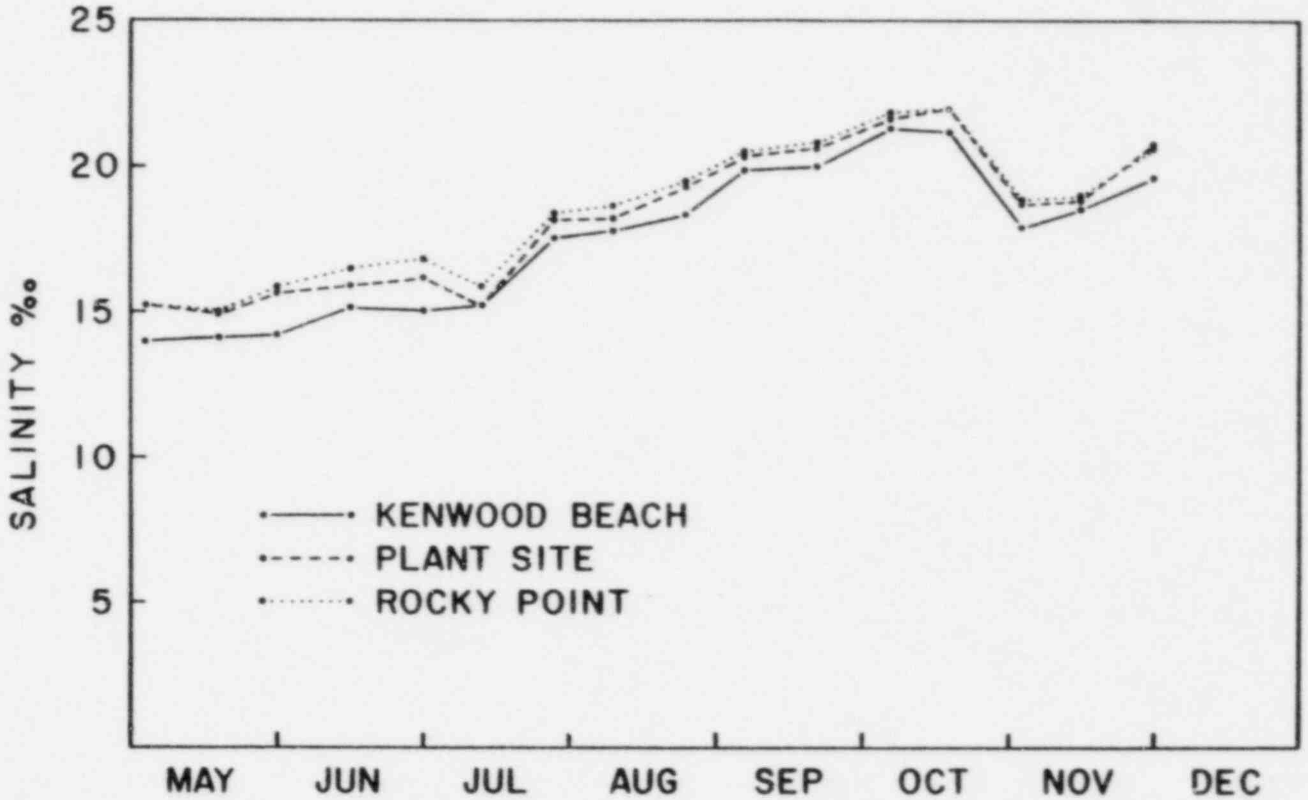

Figure 6-7. Weekly mean bottom water salinity (based on daily readings taken up to five days) during weeks fished at three stations in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant during 1981.

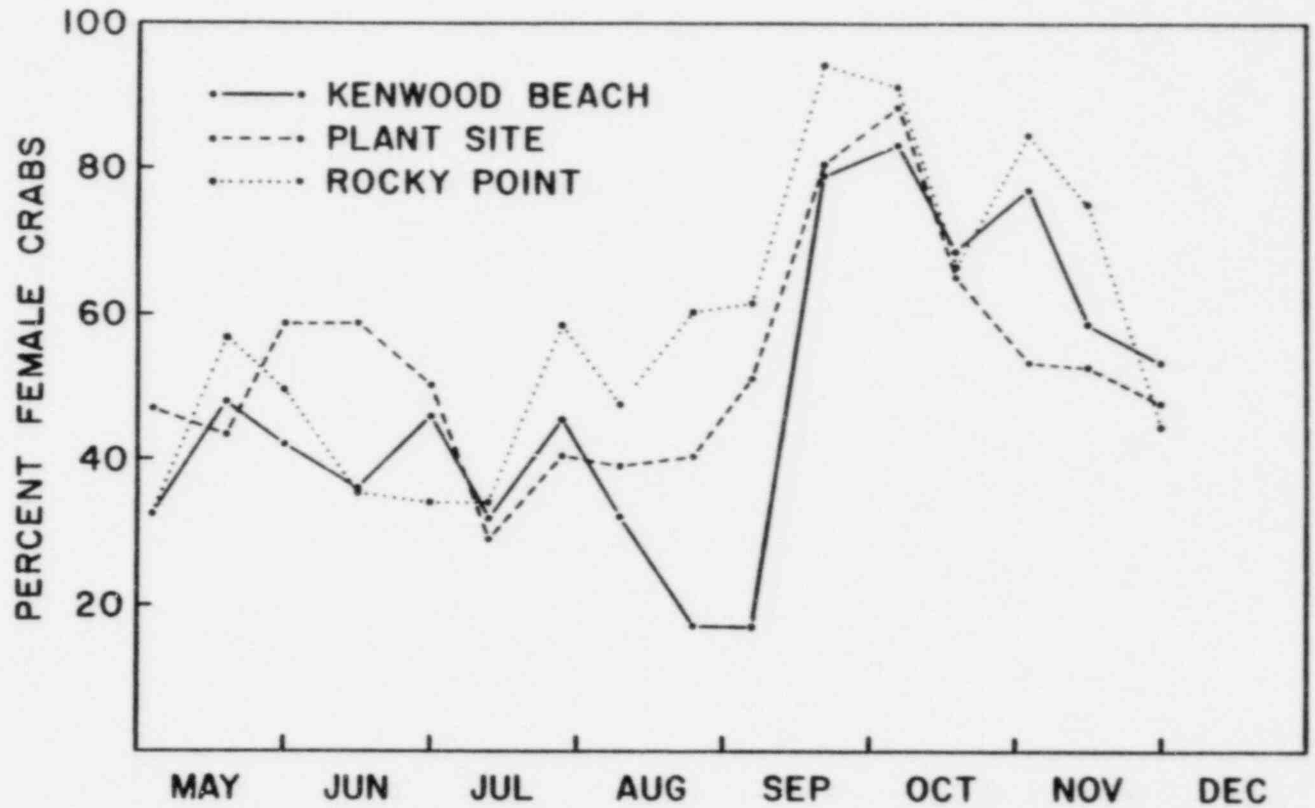

Figure 6-8. Percent of catch made up of female crabs during each sampling week at three stations in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant in 1981.

year, while 25 were taken at PS and six came from RP. However, after June, sponges at KB, PS, and RP numbered 1, 2, and 4, respectively.

Dead crabs were found in pots on several occasions in 1981, but none was associated with low dissolved oxygen (DO) concentrations. There were 3 days when DO concentrations were less than 3.0 mg/l (Table 6-7), but dead crabs were not observed. Since pots were crowded (often containing 30-50 crabs), and since bait was often eaten before pots were refished, cannibalism was sometimes observed. This was the chief cause of crab deaths during 1981. Isolated cases of cannibalism have been observed in the past, but it has never been a major cause of mortality before. Crab densities, however, were never before as high.

1968-1981

Table 6-2 summarizes the blue crab catches made in the Calvert Cliffs area of Chesapeake Bay from 1968 through 1981. Table 6-8 lists numbers of males and females, their weights, and the mean number caught per pot at each station during this period. In 14 years, 10,552 pots produced 57,144 crabs (5.42 crabs per pot), of which 51.6% were male and 74.1% were legal-size. Considerable variation in annual catch size, individual size, and sex ratio is evident from Tables 6-2 and 6-8. These fluctuations are due to natural changes in population structure and are probably unaffected by the power plant.

Mean numbers of crabs per pot by station by year are illustrated in Figure 6-9. Station values were generally similar, although KB in 1972-74 and RP in 1981 varied from the mean more than during other years. In 14 years, pots at KB produced an average 5.38 crabs per pot (33.1% of the total), while PS produced an average 5.45 crabs per pot (33.5%), and RP produced 5.42 crabs per pot (33.4%) (Table 6-8). It is apparent that these percentages are almost the same and no statistically significant difference exists between them ($p>0.05$).

The average number of crabs caught per pot by station has shown no meaningful change between preoperational (1968-74) and operational (1975-81) periods. The overall preoperational mean for all stations combined was 4.06 crabs per pot, whereas the operational mean was 6.25 crabs per pot (4.34 if 1981 data are excluded). During the preoperational period the average catch per pot at KB was 4.06 (33.3%), at PS 3.94 (32.3%), and at RP 4.18 (34.3%). Since commercial operation began in 1975 KB has averaged 6.24 crabs per pot (33.3%), while PS and RP have averaged 6.37 (34.0%), and 6.13 (32.7%), respectively.

The mean total weight per pot of males and females caught at each station each year are presented in Table 6-9. When these data were analyzed using the nonparametric Friedman rank

Table 6-7. Dissolved oxygen concentrations (mg/l) in bottom water at each of three stations in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant on days pots were fished, May-December 1981.

May

	4	5	6	8	18	19	20	21	22
Kenwood Beach	8.9	9.1	9.1	8.9	9.0	9.1	9.0	9.4	8.9
Plant Site	9.0	8.7	9.0	8.3	8.7	8.9	8.6	8.9	9.0
Rocky Point	9.0	9.1	8.7	8.7	8.8	9.4	9.1	9.0	9.1

June

	1	2	3	4	5	15	16	17	18	19	29	30
Kenwood Beach	10.1	9.7	10.0	9.0	10.6	8.3	8.4	8.2	8.8	6.8	7.8	8.4
Plant Site	11.2	10.3	10.5	10.2	10.3	6.5	6.1	5.8	6.9	6.6	8.4	5.7
Rocky Point	12.0	9.6	9.6	9.5	11.6	3.7	4.1	5.7	7.0	4.9	7.2	6.7

July

	2	3	13	14	15	16	17	27	28	29	30	31
Kenwood Beach	7.1	4.5	1.1	4.9	7.5	6.1	4.7	6.2	7.2	3.6	7.5	8.1
Plant Site	7.3	5.5	5.0	6.3	7.1	5.7	6.9	5.6	7.6	2.3	8.0	7.6
Rocky Point	6.4	5.6	5.8	5.9	6.9	5.4	4.9	5.2	6.7	3.6	7.5	8.4

August

	10	11	12	13	14	24	25	26	27	28
Kenwood Beach	7.1	3.1	2.4	5.4	3.9	7.5	9.9	8.9	6.6	3.9
Plant Site	7.4	3.5	2.9	4.2	4.2	5.0	9.7	7.0	5.1	4.3
Rocky Point	7.4	5.9	4.1	4.7	5.6	6.0	8.2	7.7	6.4	4.8

September

	7	8	9	10	11	21	22	24	25
Kenwood Beach	6.3	5.6	5.3	7.0	6.0	7.6	6.9	-	7.7
Plant Site	5.1	5.7	5.3	5.7	5.7	6.9	6.1	7.9	3.8
Rocky Point	6.0	5.9	5.6	6.2	5.5	7.1	6.7	6.6	7.6

October

	5	6	7	8	9	19	20	21	22	23
Kenwood Beach	8.0	7.6	7.6	-	7.9	7.7	7.8	7.5	8.0	8.3
Plant Site	7.0	6.9	7.4	7.2	7.7	7.5	7.8	7.5	7.8	7.7
Rocky Point	7.6	8.1	6.9	-	7.3	7.6	7.5	7.4	8.0	8.1

November

	2	3	4	5	6	16	17	18	19	20	30
Kenwood Beach	9.0	9.2	10.0	10.8	9.6	9.2	9.3	9.2	9.2	8.4	9.4
Plant Site	8.7	9.9	10.2	11.0	10.2	9.0	9.7	9.0	9.0	8.7	9.5
Rocky Point	8.1	9.4	10.1	9.7	10.2	8.9	9.3	9.0	9.0	9.0	10.3

December

	1	2	3
Kenwood Beach	9.5	9.6	9.9
Plant Site	9.2	8.9	9.2
Rocky Point	9.5	9.2	9.4

Table 6-8. Numbers and weights (kg) of male and female crabs, number of pots, and average number of crabs per pot caught at three stations during 1968-1981 in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant.

Kenwood Beach

	Males		Females			
	No.	Wt.	No.	Wt.	No. Pots	Crabs/Pot
1968	57	11	24	5	99	0.82
1969	677	88	296	36	154	6.32
1970	394	65	209	27	207	2.91
1971	911	144	662	87	236	6.67
1972	541	85	290	37	247	3.36
1973	573	113	200	28	281	2.75
1974	996	184	562	86	279	5.58
1975	834	130	769	110	308	5.20
1976	406	56	476	65	275	3.21
1977	391	84	312	51	245	2.87
1978	491	82	461	73	284	3.35
1979	957	156	1,054	150	291	6.91
1980	527	106	487	81	283	3.58
1981	2,618	339	2,562	341	293	17.68
	10,373	1,643	8,364	1,177	3,482	5.38

Plant Site

	Males		Females			
	No.	Wt.	No.	Wt.	No. Pots	Crabs/Pot
1968	39	8	18	4	96	0.59
1969	720	96	270	34	156	6.35
1970	230	35	190	29	197	2.13
1971	771	117	629	85	247	5.67
1972	602	95	472	60	252	4.26
1973	632	103	572	78	296	4.07
1974	743	122	468	63	267	4.54
1975	827	139	708	133	307	5.00
1976	409	57	482	63	282	3.16
1977	347	69	361	56	253	2.80
1978	630	102	757	111	300	4.62
1979	1,002	150	776	108	295	6.03
1980	475	90	830	145	289	4.52
1981	2,495	311	2,813	373	300	17.69
	9,922	1,494	9,346	1,342	3,537	5.45

Table 6-8 (continued). Numbers and weights (kg) of male and female crabs, number of pots, and average number of crabs per pot caught at three stations during 1968-1981 in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant.

Rocky Point

	Males		Females			
	No.	Wt.	No.	Wt.	No. Pots	Crabs/Pot
1968	62	14	39	7	86	1.17
1969	598	78	272	35	160	5.44
1970	338	55	196	30	212	2.52
1971	978	157	833	122	247	7.33
1972	657	99	484	75	255	4.47
1973	548	79	534	79	278	3.90
1974	627	96	574	82	271	4.43
1975	720	116	1,044	150	308	5.73
1976	430	59	642	92	283	3.79
1977	344	64	337	54	252	2.70
1978	586	100	551	83	296	3.84
1979	1,075	172	877	129	293	6.66
1980	462	85	713	131	289	4.07
1981	1,740	212	2,878	396	303	15.24
	9,165	1,386	9,974	1,465	3,533	5.42

All Stations Combined

	Males		Females			
	No.	Wt.	No.	Wt.	No. Pots	Crabs/Pot
1968	158	33	81	15	281	0.85
1969	1,9[illegible]	262	838	105	470	6.03
1970	962	154	595	87	616	2.52
1971	2,660	418	2,124	294	730	6.55
1972	1,800	278	1,246	171	754	4.04
1973	1,753	295	1,306	185	855	3.58
1974	2,366	402	1,604	230	817	4.86
1975	2,381	385	2,521	393	923	5.31
1976	1,245	172	1,600	220	840	3.39
1977	1,082	217	1,010	161	750	2.79
1978	1,707	285	1,769	267	880	3.95
1979	3,034	478	2,707	386	879	6.53
1980	1,464	281	2,030	357	861	4.06
1981	6,853	863	8,253	1,110	896	16.86
	29,460	4,523	27,684	3,981	10,552	5.42

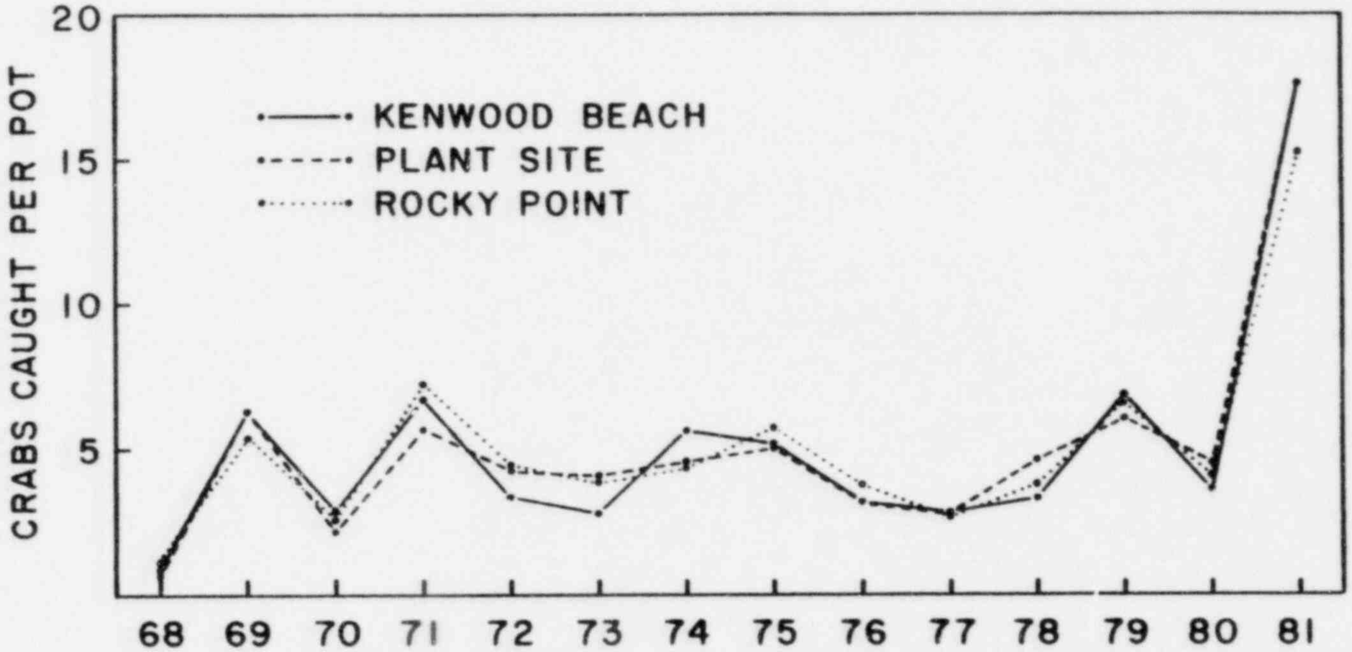

Figure 6-9. Annual mean number of crabs caught per pot at three stations in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant from 1968 through 1981.

Table 6-9. Mean weights (kg) of males and females caught per pot each year from 1968 to 1981 at three stations in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant.

	Males			Females		
	KB	PS	RP	KB	PB	RP
1968	0.11	0.08	0.16	0.05	0.04	0.08
1969	0.57	0.62	0.49	0.23	0.22	0.22
1970	0.31	0.18	0.26	0.13	0.15	0.14
1971	0.61	0.47	0.64	0.37	0.34	0.49
1972	0.34	0.38	0.39	0.15	0.24	0.29
1973	0.40	0.35	0.28	0.10	0.26	0.28
1974	0.66	0.46	0.35	0.31	0.24	0.30
1975	0.42	0.45	0.38	0.36	0.43	0.49
1976	0.20	0.20	0.21	0.24	0.22	0.33
1977	0.34	0.27	0.25	0.21	0.22	0.21
1978	0.29	0.34	0.34	0.26	0.37	0.28
1979	0.54	0.51	0.59	0.52	0.37	0.44
1980	0.38	0.31	0.29	0.28	0.50	0.45
1981	1.16	1.04	0.70	1.16	1.24	1.31
Mean	0.45	0.41	0.38	0.32	0.35	0.38

sum test (Hollander and Wolfe, 1973), no differences among stations were detected for either sex.

Although weights of both sexes were similar among stations over the years of study, the percentage of males was not (Fig. 6-6). An analysis of variance applied to the 14-yr data set revealed a significant difference ($p=0.005$) between the 55.4% males at KB and the 47.9% males at RP. The 51.5% males at PS did not differ significantly from either station. An analysis of covariance (Hicks, 1973) using logit-transformed data (Cox, 1970) revealed a significant decrease in the percent males since 1968 ($p<0.001$). The analysis also revealed no differences in the rate of decrease among stations ($p>0.99$); thus the decline has occurred equally at all stations.

Annual percentages, based on catch per unit effort (i.e., crabs per pot), of total catch for each station have ranged from 25.6 to 38.5% at KB, from 22.9 to 39.1% at PS, and from 30.0 to 45.4% at RP. In 1981, the 34.9, 35.0 and 30.1% of the total collected at KB, PS, and RP, respectively, fell within these ranges.

Except for a higher percentage of males at KB than at RP, no statistically significant long-term differences among stations were detected for the analyzed variables in crab populations.

Summary and Conclusions

During 1981, 896 crab pots yielded 15,106 crabs (16.86 per pot), a 315% increase from the 4.06 caught per pot in 1980. The total number caught in 1981 was about 2.6 times the highest total of the previous 13 years (5,741 in 1979). Legal-size crabs made up 67.6% of the total, and males accounted for 45.4%. The percentage of legal-size crabs was lower than any other year except 1976 (also 67.6%), because the huge 1980 year class, which made up most of the 1981 catch, took much of the season to attain legal-size. The male percentage was the third lowest in 14 years because of continuing high salinity. The PS station was the most productive with 35.0% of the total, but KB was nearly its equal with 34.9%. The RP station produced only 30.1% of the total. No statistically significant differences among stations were detected for this variable. Station differences were found for the number of males per pot, weight of males per pot, and total weight per pot with RP significantly less than PS and KB ($p<0.05$). No differences were detected between KB and PS. The percent males at RP was significantly less than at KB ($p<0.05$), but PS differed from neither. The number of sponge crabs in June was found to be significantly greater at PS than at KB or RP ($p<0.05$).

In 14 years of study a total of 10,552 pots yielded 57,144 crabs (an average of 5.42 per pot fished). Of these, 74.1%

were legal-size and 51.6% were male. Annual station percentages of the total catch, based on the number of crabs caught per pot, have ranged from 25.6 to 38.5% at KB, from 22.9 to 39.1% at PS, and from 30.0 to 45.4% at RP. KB produced 33.1% of the 14-yr total, while PS and RP produced 33.5% and 33.4%, respectively. These 14-yr percentages are nearly equal and indicate the long-term similarity in population size at the three stations.

Annual variation in catch size among stations has been moderate over time, but other than a higher percentage of males at KB than at RP, no statistically significant station differences were detected during preoperational (1968-74) or operational (1975-81) periods. There has, however, been a significant decrease in the percent males caught at each station since 1968, but this decrease has been equal among stations. While many of the variables showed changes from year to year, these changes appeared to result from natural fluctuations in population structure and be unrelated to plant operation.

Data from 7 years of preoperational study and 7 years of operational study show no evidence that the CCNPP has had an adverse effect on the abundance, distribution, size, or sex ratios of blue crabs in the vicinity of the plant in Chesapeake Bay.

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OYSTER TRAY STUDIES

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Introduction

The Calvert Cliffs area of Chesapeake Bay does not support an extensive oyster fishery. Although oyster beds are located north of Kenwood Beach at Governors Run, and both north and south of the Calvert Cliffs Nuclear Power Plant (CCNPP), oyster densities are relatively low. In the CCNPP area, low densities in 1979 (Abbe, 1980*a*) were similar to those reported for 1968 (ANSP, 1968), and observations of an oyster bed just south of the CCNPP, made during quarterly sampling since 1971, indicate that large fluctuations in population size during the intervening years have not occurred. In addition, many oysters near the CCNPP are attached to rocks, making them difficult to harvest. Nevertheless, both the Governors Run and plant site areas are occasionally worked by commercial watermen. With the increase in oyster-spat set which has occurred throughout much of the Chesapeake Bay during 1980 and 1981 (Dilley, 1982), including the area around the CCNPP, an increase in commercial oystering near Calvert Cliffs may be only a year or two away.

This report summarizes investigations designed to examine power-plant-induced effects on shell growth, meat condition and mortality of oysters (*Crassostrea virginica* Gmelin) and to determine the abundance of associated species at several locations in the Calvert Cliffs area of Chesapeake Bay. Studies were conducted using oysters of different age classes held in trays. A study of tray-held oysters offered advantages over a study of natural populations since the same oysters could be observed for a long time period. It was assumed that the effects of the environment would be similar on oysters in trays and on natural oyster populations in the same area. Growth, condition, and mortality data allowed an evaluation of environmental effects on oysters, and data derived from studies of associated species were used in determining the health of the rest of the oyster community. Changes in community structure (i.e., gain or loss in numbers of species) may indicate sublethal stresses which could affect the growth or condition of the oysters.

Materials and Methods

Program Design

Trays used in this study were similar to the Sea-Rac trays described by Hewatt and Andrews (1954), but were of vinyl-coated stainless steel with 2.5-cm mesh. The trays had hinged tops and measured 91 x 41 x 13 cm. Trays of oysters were fastened to the top rails of steel and concrete platforms which were located on the bottom at Kenwood Beach (KB), Plant Site (PS), Camp Conoy (CC), Rocky Point (RP), and Cove Point (CP) (Fig. 7.1-1). These platforms replaced the wooden platforms which were used from 1970 to 1978, and were 3.05 m long by 1.52 m wide. Trays were held 0.6 m off the bottom, and since no structure existed between the tops of the trays and the surface, neither trays nor platforms were subject to the ice damage that had previously occurred. January - March 1981 was the third consecutive winter with no losses. Although trays of oysters could only be retrieved by divers, the use of submerged concrete and steel platforms has prevented the seasonal loss of oysters.

Temperatures were recorded continuously throughout the study at KB, PS and RP by magnetic tape thermographs (General Oceanics model 6070). Preliminary data show that PS experienced the greatest temperature increase (averaging 0.5°C-1.5°C above temperatures at KB and reaching as much as 2.5°-3.0°C above KB on flood tides). RP also experienced temperature increases but to a lesser degree, and CC probably experienced an increase between that of PS and RP. KB and CP were essentially unaffected by the thermal discharge (see Section 6).

Three age classes of oysters (first-, second-, and third-year) were used to evaluate shell growth, mortality, and associated organisms. Since certain growth parameters of oysters increase more rapidly when the oysters are small (i.e., shell length and width), it seemed appropriate at the end of each study year to assign each age class to the next higher class; i.e., first-year oysters became second-year oysters, second-year became third-year, etc.; new first-year oysters were then obtained from a hatchery. Thus, a first-year oyster would be studied for 3 years, providing it had not died or been lost. During the period before operation of the CCNPP, oysters were set out in June 1970 and observed for 5 years so that by June 1975 the age classes could have been designated as sixth-, seventh- and eighth-year oysters.

Because platform losses due to ice in the winters of 1977 and 1978 ended the 1975 and 1977 studies after only 18 months and 6 months, respectively, the present data set is the longest since the preoperational study of 1970-75. Within the study reported here are four separate studies of oysters as follows:

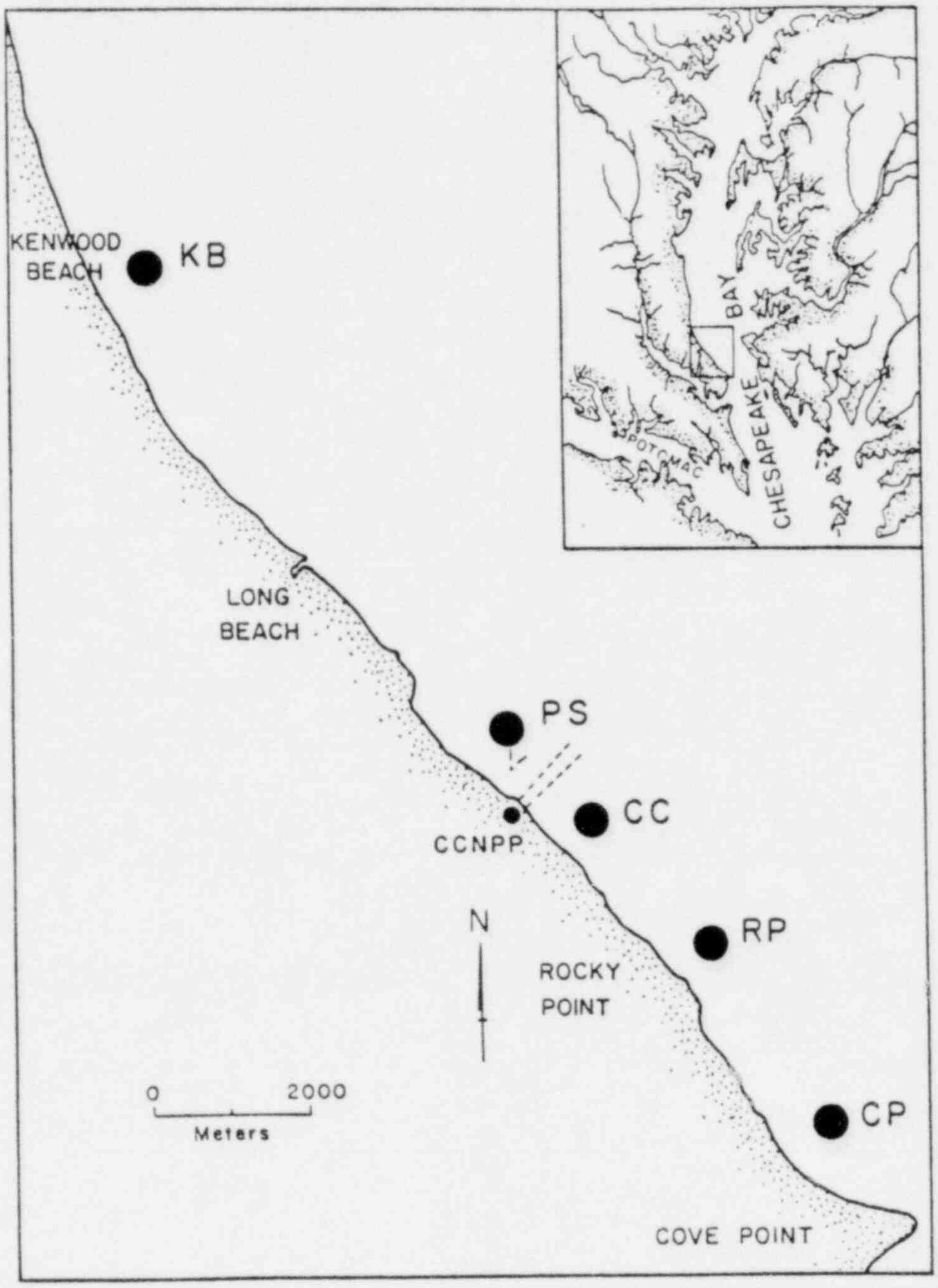


Figure 7.1-1. Locations of oyster trays at Kenwood Beach (KB), Plant Site (PS), Camp Conoy (CC), Rocky Point (RP), and Cove Point (CP) in the area of the Calvert Cliffs Nuclear Power Plant in Chesapeake Bay from 1978 to 1981.

Present year class	Installation date	Initial class designation	Initial mean size	Years studied
1st-year	June 1981	1st-year	28 mm	0.5
2nd-year	June 1980	1st-year	25 mm	1.5
3rd-year	June 1979	1st-year	28 mm	2.5
4th-year	June 1978	1st-year	31 mm	3.0

All oysters used in the 1978-81 studies were obtained from Chesapeake Bay Oyster Culture of Shady Side, Maryland.

Data from oysters at each station for this 1978-81 period are compared with each other and with preoperational data from 1970-73 (Abbe, 1975) where possible.

Four trays, each divided into four equal sections, were located at each platform. Ten oysters of each age class were held in the first three sections, respectively; the fourth section held fourth-year oysters which provided data on meat condition and metal concentrations (Section 7.2). Before installation, oysters were cleaned and shell dimensions were measured to the nearest millimeter.

Trays set in June 1978 were retrieved for examination in September and December 1978 and in March, June, September, and December of 1979, 1980 and 1981. All oysters were reclassified in June of each year when new hatchery oysters were installed in all trays. The following were recorded during each examination.

1. Growth - The length and width (mm) of each living oyster were measured. Length is the measurement from the hinge of the oyster to the advancing edge of the bill; width is the measurement across the right valve over the adductor muscle.

2. Condition - Ten fourth-year oysters from each station were shucked to determine meat condition, spawning activity, and presence of green coloration (which may indicate copper uptake). Meat condition was rated on a scale of 1 (low) to 10 (high), based on visual opacity due to glycogen content (P. Butler, EPA Gulf Breeze Laboratory, unpublished).

3. Mortality - The number of dead oysters among those examined was determined. Criteria for mortality were empty shells and oysters with gaping shells.

4. Associated organisms (fouling) - The abundances and species of a) organisms adhering to the tray which could compete for food or occlude the wire mesh of the tray and thus reduce water flow; b) organisms present inside the trays with the oysters, which could prey upon them or

reduce water circulation; and c) organisms associated with each oyster were determined.

5. Additional information - Siltation, signs of predation or damage to equipment, which could result in the loss of oysters, was noted.

After the oysters were examined, they were moved to a clean tray which was then replaced on the platform.

Statistical Analyses

Growth

Oyster growth (length) data for 1978-1981 were analyzed using regression techniques (Sokal and Rohlf, 1969) to compare growth curves of oysters at different stations. A growth curve was derived for each age class of oysters at each station and comparisons were made among classes of the same age. All stations were compared simultaneously to determine whether any station differences existed. If a difference was detected, then the station that appeared most different from the group was omitted and the analysis was repeated. This stepping procedure was repeated until no further differences were found and the stations were partitioned into groups with homogeneous growth curves.

The model used to describe growth in this analysis was

$$y = \alpha x^{\beta} e^{\varepsilon}$$

where y = length in millimeters,
x = age in days,
e^{ε} = random error assumed to have lognormal distribution,
α, β = parameters to be estimated.

This model was transformed by logarithms to yield a model tractable for linear regression methods:

$$\ln(y) = \ln(\alpha) + \beta \ln(x) + \varepsilon$$

The statistic used to test whether the growth curves of a group of stations could be satisfactorily explained by a single equation was

$$F_{v_1, v_2} = \frac{SSEp - SSEg/v_1}{SSEg/v_2}$$

where SSEp = error sum of squares from a regression with all stations included,

SSEg = sum of error sums of squares from regressions fitted to stations separately,

v_1 = reduction in error degrees of freedom by doing separate regressions rather than a pooled regression,

v_2 = sum of the error degrees of freedom from the separate station regressions.

Meat Condition

Oyster meat-condition data for 1979-81 were analyzed using a three-way fixed-factor analysis of variance (ANOVA) (Walpole and Myers, 1972) to test for differences among stations, seasons, and years. The model was:

$$y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + \alpha\beta_{ij} + \alpha\gamma_{ik} + \beta\gamma_{jk} + \varepsilon_{ijk}$$

where y_{ijk} = meat condition,
μ = overall mean,
α_i = station effect,
β_j = season effect,
γ_k = year effect,
$\alpha\beta_{ij}$ = station x season interaction,
$\alpha\gamma_{ik}$ = station x year interaction,
$\beta\gamma_{jk}$ = season x year interaction,
ε_{ijk} = error term.

To include 1978 data, a two-way ANOVA was used to analyze station and season effects.

To test the *a priori* hypothesis that meat condition improved in a down-bay direction, a contrast for linearity (Walpole and Myers, 1972) was partitioned from the station effect and tested.

Mortality

Nonparametric methods were used to determine differences in mortality among stations. Within each observation period, percent mortality for each year class at each station was used to rank the stations. The ranked values for each station were then summed over all periods and these sums were used to determine differences among stations by analysis with the Friedman rank sum test (Hollander and Wolfe, 1973).

Associated Organisms

The numbers of species attached to the oysters in 1981 were analyzed using ANOVA. A factorial model with three levels of class and five levels of station was used.

The response variable was the mean count of species per oyster for each replicate of a class at a station. Since counts generally follow a negative binomial distribution, the

mean counts were transformed by logarithms to stabilize variances among treatments.

The model for this design was

$$\ln (y_{ijk}) = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \varepsilon_{ijk}$$

where y_{ijk} = the mean number of species per oyster for a replicate of a class at a station,
μ = parameter to model overall mean,
α_i = parameter to model effect of station,
β_j = parameter to model effect of class,
$\alpha\beta_{ij}$ = parameter to model effect of station x class interaction,
ε_{ijk} = term to model random variation among replicates.

Since attachment of species to oysters is cumulative over the growing season, a separate ANOVA was conducted for each sampling date.

Results and Discussion

Growth of Oysters

Mean length and width of each age class and the size increases associated with them for each quarter from June 1978 to December 1981 are presented by station in Tables 7.1-1 through 7.1-5. Oysters are listed by age as of June 1981; thus, there are four year classes in each table. The fourth-year class was the first-year class of the June 1978-June 1979 study; the third-year class was the first-year class of the June 1979-June 1980 study; the second-year class was the first-year class of the June 1980-June 1981 study; and the present first-year class consisted of the new oysters set out in June 1981. Since June 1981 marked the end of growth studies on the oldest oysters, there are no measurements for fourth-year oysters after that time.

First-year Oysters

The average length of first-year oysters at RP increased by 38 mm during the second half of 1981. At CP the increases averaged 36 mm, and at KB, PS, and CC the increases averaged 35 mm. Average widths increased by 29 mm at RP and PS, by 27 mm at CC and CP, and by 26 mm at KB. No significant statistical differences were detected among stations for this age class ($p=0.590$).

From June to December 1981, the mean length increase of first-year oysters was 36 mm, well below the 49 mm gained by similar oysters in 1980 (Abbe, 1981*a*), but not unlike the 34 mm increases of 1979 (Abbe, 1980*b*).

Table 7.1-1. Mean lengths and widths of tray-held oysters and increases associated with them at Kenwood Beach in the Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant from June 1978 to December 1981. Oysters are listed by age as of June 1981.

	No. Oysters	Length Mean mm	Length Increase mm	Width Mean mm	Width Increase mm
First-year Oysters					
Jun 81	40	27.7	-	23.5	-
Sep 81	40	53.1	25.4	42.9	19.4
Dec 81	40	62.3	9.2	49.2	6.3
			34.6		25.7
Second-year Oysters					
Jun 80	40	25.0	-	21.4	-
Sep 80	39	64.3	39.3	51.0	29.6
Dec 80	39	80.5	16.2	61.5	10.5
Mar 81	38	78.0	-2.5	59.0	-2.5
Jun 81	38	87.8	9.8	69.4	10.4
Sep 81	36	98.8	11.0	73.4	4.0
Dec 81	35	103.7	4.9	74.1	0.7
			78.7		52.7
Third-year Oysters					
Jun 79	40	28.1	-	23.0	-
Sep 79	40	54.6	26.5	44.7	21.7
Dec 79	40	59.6	5.0	46.9	2.2
Mar 80	40	58.0	-1.6	45.3	-1.6
Jun 80	40	68.8	10.8	58.1	12.8
Sep 80	39	84.5	15.7	66.7	8.6
Dec 80	39	92.9	8.4	70.9	4.2
Mar 81	39	91.3	-1.6	68.2	-2.7
Jun 81	39	97.7	6.4	76.8	8.6
Sep 81	39	106.2	8.5	78.9	2.1
Dec 81	37	110.0	3.8	77.2	-1.7
			81.9		54.2
Fourth-year Oysters					
Jun 78	40	31.1	-	24.8	-
Sep 78	40	50.8	19.7	42.4	17.6
Dec 78	40	62.7	11.9	51.6	9.2
Mar 79	40	62.9	0.2	50.7	-0.9
Jun 79	39	65.5	2.6	53.0	2.3
Sep 79	37	73.4	7.9	59.0	6.0
Dec 79	36	74.8	1.4	60.1	1.1
Mar 80	36	73.2	-1.6	57.5	-2.6
Jun 80	36	80.8	7.6	66.6	9.1
Sep 80	35	93.2	12.4	72.8	6.2
Dec 80	35	97.5	4.3	74.5	1.7
Mar 81	35	96.3	-1.2	71.5	-3.0
Jun 81	35	102.0	5.7	77.6	6.1
			70.9		52.8

Table 7.1-2. Mean lengths and widths of tray-held oysters and increases associated with them at the Plant Site in the Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant from June 1978 to December 1981. Oysters are listed by age as of June 1981.

	No. Oysters	Length Mean mm	Length Increase mm	Width Mean mm	Width Increase mm
First-year Oysters					
Jun 81	40	29.2	-	24.6	-
Sep 81	40	54.9	25.7	46.0	21.4
Dec 81	40	64.2	9.3	53.2	7.2
			35.0		28.6
Second-year Oyters					
Jun 80	40	24.7	-	21.0	-
Sep 80	39	66.5	41.8	51.4	30.4
Dec 80	38	75.1	8.6	57.5	6.1
Mar 81	38	75.1	0.0	57.4	-0.1
Jun 81	38	85.0	9.9	67.6	10.2
Sep 81	36	99.8	14.8	73.4	5.8
Dec 81	36	106.3	6.5	76.7	3.3
			81.6		55.7
Third-year Oysters					
Jun 79	40	28.3	-	22.5	-
Sep 79	40	57.1	28.8	46.3	23.8
Dec 79	40	63.9	6.8	51.0	4.7
Mar 80	40	63.6	-0.3	50.0	-1.0
Jun 80	40	72.0	8.4	60.0	10.0
Sep 80	40	89.5	17.5	68.4	8.4
Dec 80	40	96.0	6.5	70.6	2.2
Mar 81	40	95.0	-1.0	68.1	-2.5
Jun 81	40	102.7	7.7	77.4	9.3
Sep 81	40	113.7	11.0	80.8	3.4
Dec 81	39	118.5	4.8	82.1	1.3
			90.2		59.6
Fourth-year Oysters					
Jun 78	40	31.7	-	25.4	-
Sep 78	38	54.5	22.8	44.2	18.8
Dec 78	37	68.7	14.2	55.6	11.4
Mar 79	37	69.2	0.5	55.2	-0.4
Jun 79	37	72.4	3.2	58.8	3.6
Sep 79	34	81.5	9.1	65.7	6.9
Dec 79	34	85.8	4.3	66.9	1.2
Mar 80	34	85.2	-0.6	65.2	-1.7
Jun 80	34	93.9	8.7	72.9	7.7
Sep 80	32	99.7	5.8	75.3	2.4
Dec 80	32	103.5	3.8	75.8	0.5
Mar 81	32	103.9	0.4	73.3	-2.5
Jun 81	32	111.8	7.9	82.0	8.7
			80.1		56.6

Table 7.1-3. Mean lengths and widths of tray-held oysters and increases associated with them at Camp Conoy in the Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant from June 1978 to December 1981. Oysters are listed by age as of June 1981.

	No. Oysters	Length Mean mm	Length Increase mm	Width Mean mm	Width Increase mm
First-year Oysters					
Jun 81	40	28.4	-	23.3	-
Sep 81	40	53.7	25.3	43.1	19.8
Dec 81	40	63.5	9.8	50.2	7.1
			35.1		26.9
Second-year Oysters					
Jun 80	40	25.0	-	21.2	-
Sep 80	40	61.2	36.2	49.3	28.1
Dec 80	40	71.2	10.0	57.1	7.8
Mar 81	40	71.0	-0.2	55.8	-1.3
Jun 81	39	81.7	10.7	67.8	12.0
Sep 81	39	92.0	10.3	71.3	3.5
Dec 81	38	100.2	8.2	75.4	4.1
			75.2		54.2
Third-year Oysters					
Jun 79	40	27.6	-	22.3	-
Sep 79	40	54.4	26.8	45.1	22.8
Dec 79	40	60.7	6.3	49.6	4.5
Mar 80	40	59.7	-1.0	47.1	-2.5
Jun 80	40	68.8	9.1	58.2	11.1
Sep 80	40	82.9	14.1	65.9	7.7
Dec 80	40	89.8	6.9	69.4	3.5
Mar 81	40	89.0	-0.8	67.5	-1.9
Jun 81	40	95.2	6.2	76.0	8.5
Sep 81	38	101.0	5.8	75.8	-0.2
Dec 81	37	107.0	6.0	77.9	2.1
			79.4		55.6
Fourth-year Oysters					
Jun 78	40	30.7	-	25.0	-
Sep 78	40	53.4	22.7	45.1	20.1
Dec 78	40	68.6	15.2	55.5	10.4
Mar 79	40	66.2	-2.4	54.2	-1.3
Jun 79	40	70.5	4.3	59.3	5.1
Sep 79	39	77.0	6.5	63.2	3.9
Dec 79	38	80.4	3.4	63.6	0.4
Mar 80	38	78.8	-1.6	59.7	-3.9
Jun 80	38	88.4	9.6	69.8	10.1
Sep 80	38	94.6	6.2	73.3	3.5
Dec 80	37	98.7	4.1	74.9	1.6
Mar 81	37	99.3	0.6	72.6	-2.3
Jun 81	37	104.1	4.8	81.5	8.9
			73.4		56.5

Table 7.1-4. Mean lengths and widths of tray-held oysters and increases associated with them at Rocky Point in the Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant from June 1978 to December 1981. Oysters are listed by age as of June 1981.

	No. Oysters	Length Mean mm	Length Increase mm	Width Mean mm	Width Increase mm
First-year Oysters					
Jun 81	40	28.4	-	23.8	-
Sep 81	40	57.9	29.5	46.8	23.0
Dec 81	40	66.5	8.6	52.4	5.6
			38.1		28.6
Second-year Oysters					
Jun 80	40	25.2	-	21.6	-
Sep 80	39	64.2	39.0	50.4	28.8
Dec 80	38	73.5	9.3	57.8	7.4
Mar 81	38	73.4	-0.1	55.5	-2.3
Jun 81	38	83.3	9.9	66.1	10.6
Sep 81	37	96.6	13.3	73.5	7.4
Dec 81	37	103.0	6.4	77.9	4.4
			77.8		56.3
Third-year Oysters					
Jun 79	40	29.4	-	23.7	-
Sep 79	38	53.9	24.5	44.6	20.9
Dec 79	38	62.1	8.2	50.1	5.5
Mar 80	38	60.7	-1.4	48.0	-2.1
Jun 80	38	70.2	9.5	59.5	11.5
Sep 80	38	81.9	11.7	65.6	6.1
Dec 80	38	87.7	5.8	67.3	1.7
Mar 81	38	86.0	-1.7	63.6	-3.7
Jun 81	37	94.9	8.9	74.5	10.9
Sep 81	37	103.5	8.6	77.2	2.7
Dec 81	36	110.2	6.7	77.6	0.4
			80.8		53.9
Fourth-year Oysters					
Jun 78	40	30.5	-	24.6	-
Sep 78	40	56.0	25.5	46.5	21.9
Dec 78	40	68.4	12.4	56.9	10.4
Mar 79	40	67.3	-1.1	55.4	-1.5
Jun 79	40	70.6	3.3	60.1	4.7
Sep 79	39	76.6	6.0	63.7	3.6
Dec 79	39	81.8	5.2	65.5	1.8
Mar 80	39	78.8	-3.0	61.9	-3.6
Jun 80	39	88.0	9.2	70.3	8.4
Sep 80	39	96.1	8.1	73.4	3.1
Dec 80	38	96.2	0.1	72.9	-0.5
Mar 81	38	95.1	-1.1	70.0	-2.9
Jun 81	38	103.7	8.6	80.6	10.6
			73.2		56.0

Table 7.1-5. Mean lengths and widths of tray-held oysters and increases associated with them at Cove Point in the Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant from June 1978 to December 1981. Oysters are listed by age as of June 1981.

	No. Oysters	Length		Width	
		Mean mm	Increase mm	Mean mm	Increase mm
First-year Oysters					
Jun 81	40	27.4	-	23.3	-
Sep 81	40	54.1	26.7	43.2	19.9
Dec 81	38	63.3	9.2	50.7	7.5
			35.9		27.4
Second-year Oyters					
Jun 80	40	24.4	-	20.9	-
Sep 80	32	57.9	33.5	47.3	26.4
Dec 80	32	67.3	9.4	52.9	5.6
Mar 81	32	66.2	-1.1	49.9	-3.0
Jun 81	32	80.1	13.9	65.0	5.1
Sep 81	32	91.8	11.7	71.0	6.0
Dec 81	32	98.1	6.3	73.8	2.8
			73.7		52.9
Third-year Oysters					
Jun 79	40	28.7	-	23.7	-
Sep 79	40	56.9	28.2	46.9	23.2
Dec 79	40	63.9	7.0	51.3	4.4
Mar 80	40	60.3	-3.6	48.2	-3.1
Jun 80	40	72.5	12.2	61.0	12.8
Sep 80	39	87.4	14.9	67.5	6.5
Dec 80	39	91.9	4.5	70.1	2.6
Mar 81	39	89.6	-2.3	64.8	-5.3
Jun 81	39	99.2	9.6	77.7	12.9
Sep 81	39	103.0	3.8	76.7	-1.0
Dec 81	38	107.0	4.0	77.3	0.6
			78.3		53.6
Fourth-year Oysters					
Jun 78	40	30.9	-	25.1	-
Sep 78	40	55.0	24.1	47.1	22.0
Dec 78	40	64.0	9.0	52.4	5.3
Mar 79	40	62.5	-1.5	50.6	-1.8
Jun 79	40	66.8	4.3	56.7	6.1
Sep 79	36	73.5	6.7	63.3	6.6
Dec 79	36	78.6	5.1	64.1	0.8
Mar 80	36	77.4	-1.2	61.6	-2.5
Jun 80	35	84.7	7.3	70.1	8.5
Sep 80	35	93.3	8.6	75.5	5.4
Dec 80	35	95.7	2.4	77.4	1.9
Mar 81	35	93.7	-2.0	73.3	-4.1
Jun 81	35	105.4	11.7	85.6	12.3
			74.5		60.5

Second-year Oysters

In the year and a half since this class was set out, the largest average length increase occurred at PS (82 mm). In descending order, those at KB grew 79 mm, at RP 78 mm, at CC 75 mm and at CP 74 mm. Width increases were greatest at PS and RP (56 mm) and least at KB and CP (53 mm). The width increase at CC was 54 mm. As with first-year oysters, no significant station differences were detected ($p=0.163$).

From June 1980 to December 1981, this class averaged a 77-mm length increase compared to a 63-mm increase for the same age class from June 1979 to December 1980 (Abbe, 1981*a*).

Third-year Oysters

In the 2.5 years since this class was set out in June 1979, oysters have shown the most growth at PS (90 mm). At KB, CC, RP, and CP the length increases were 82, 79, 81, and 78 mm, respectively. Width increases during this time were 60 mm at PS, 56 mm at CC, and 54 mm at KB, RP, and CP.

From June 1979 until December 1981, this class increased an average of 82 mm compared to 67 mm for a similar class from June 1978 to December 1980.

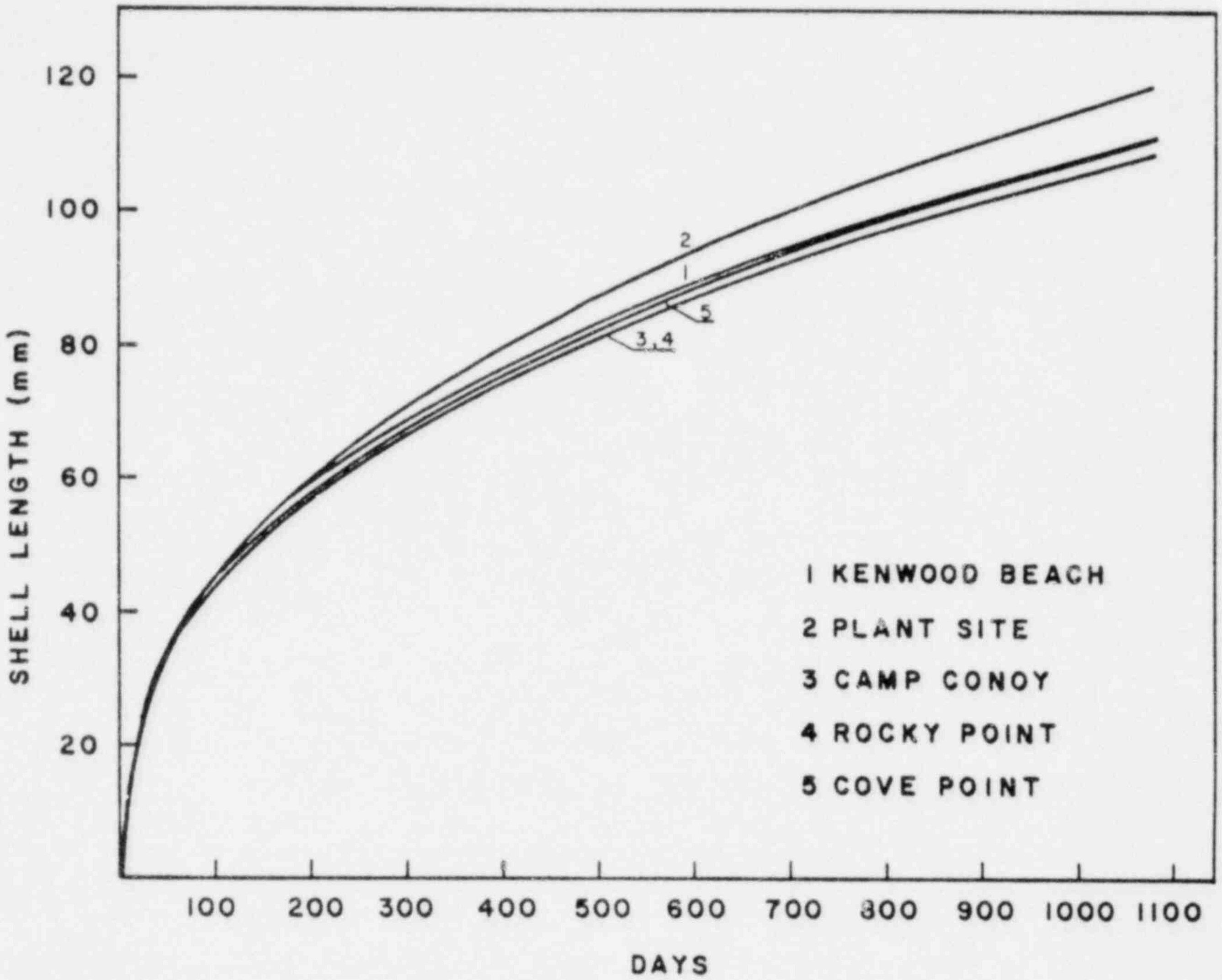
Data analysis revealed a significant station effect ($p=0.003$). When regression curves for all stations were plotted, the Plant Site appeared to be the most different (Fig. 7.1-2), so PS data were omitted and the analysis was repeated; no differences were found ($p=0.433$). Thus, PS was significantly greater than all other stations and the others were all similar to each other (Table 7.1-6).

Fourth-year Oysters

This class was set out in June 1978 as first-year oysters and had been monitored for a full 3 years as of June 1981. During this time oysters at PS increased in length an average 80 mm. Those at KB, CC, RP, and CP increased 71, 73, 73, and 74 mm, respectively. Widths increased by 53 mm at KB, 57 mm at PS, 56 mm at CC and RP, and 60 mm at CP.

Since this was the first group of oysters to be followed for 3 years during the operational phase, there is no other group which can be used for comparison.

Data analysis revealed a significant station effect ($p<0.001$). When PS was omitted from the analysis, a significant difference was detected among the remaining stations ($p=0.050$). Various data sets were omitted until all station differences were determined (Table 7.1-6). PS was greater than all other stations, and CC was greater than KB, but CP and RP differed from neither KB nor CC. Figure 7.1-3 shows the regression curves for all data sets.



1.	Kenwood Beach	length = 7.27 $(age)^{0.391}$	$r^2=0.951$
2.	Plant Site	length = 7.16 $(age)^{0.403}$	$r^2=0.962$
3.	Camp Conoy	length = 7.61 $(age)^{0.381}$	$r^2=0.961$
4.	Rocky Point	length = 8.33 $(age)^{0.367}$	$r^2=0.954$
5.	Cove Point	length = 8.26 $(age)^{0.372}$	$r^2=0.954$

Figure 7.1-2. Regression curves and their associated r^2 values (proportion of variation in the data that is explained by the model) computed from growth data of third-year oysters held in trays in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant from June 1979 to December 1981.

Table 7.1-6. F-ratios and significance levels associated with various station comparisons of oyster growth data in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant during 1978-81. Stations which do not differ significantly from each other are connected by lines.

First-year oysters

Station comparisons	F-ratio	Significance
KB, PS, CC, RP, CP	0.819	N.S.

Second-year Oysters

Station comparisons	F-ratio	Significance
KB, PS, CC, RP, CP	1.501	N.S.

Third-year Oysters

Station comparisons	F-ratio	Significance
KB, PS, CC, RP, CP	3.057	0.003
KB, CC, RP, CP	0.991	N.S.

Station groupings

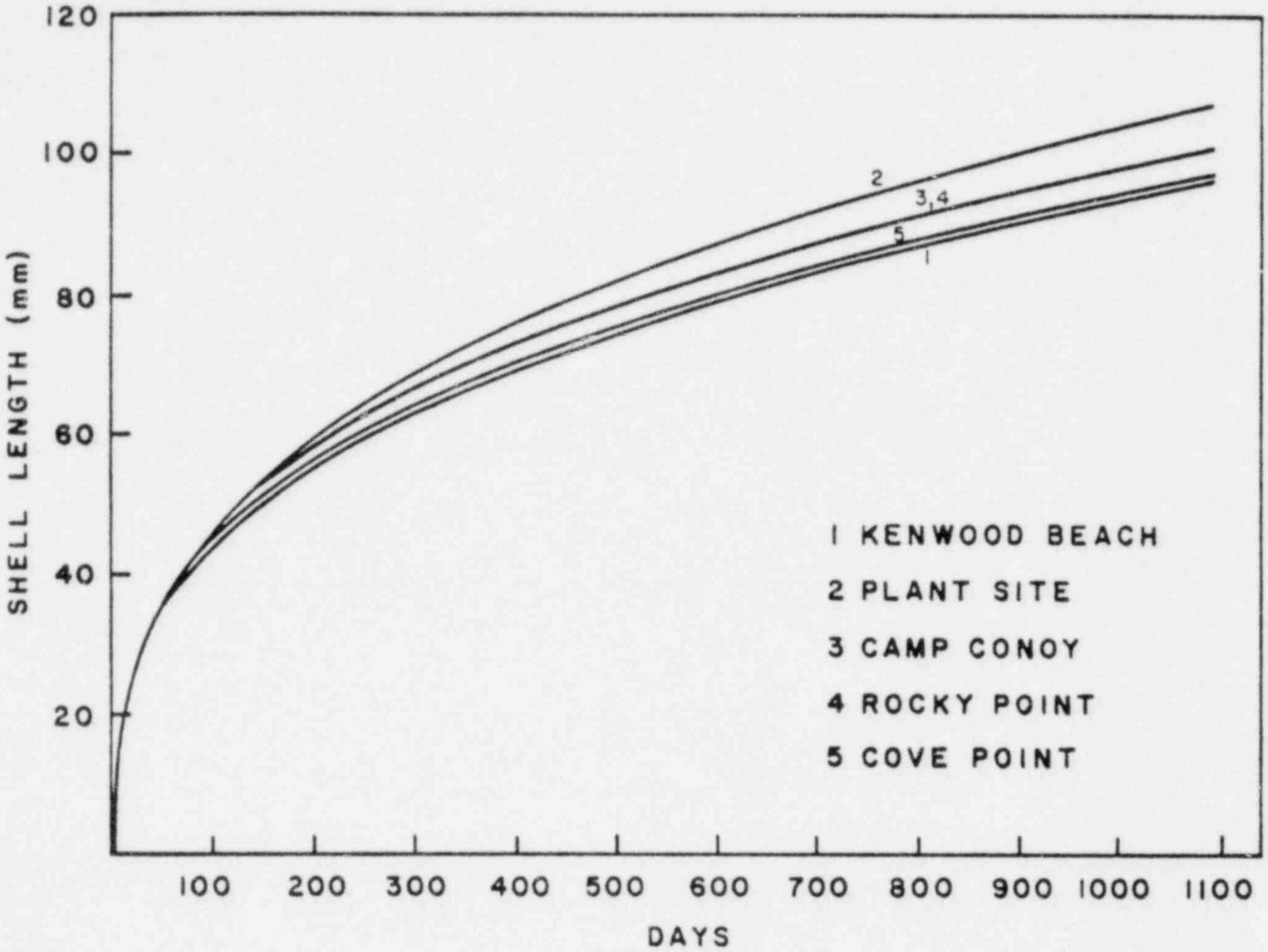
PS   KB   CP   CC   RP (KB, CP, CC, RP connected by a line)

Fourth-year oysters

Station comparisons	F-ratio	Significance
KB, PS, CC, RP, CP	5.047	<0.001
KB, CC, RP, CP	2.140	0.050
CC, RP, CP	1.366	N.S.
KB, RP, CP	2,041	N.S.
PS, CC	4.507	0.013

Station groupings

PS   CC   RP   CP   KB (CC, RP, CP connected by one line; RP, CP, KB connected by a second line)



1.	Kenwood Beach	length = 9.72 $(age)^{0.328}$	r^2=0.933
2.	Plant Site	length = 9.51 $(age)^{0.346}$	r^2=0.942
3.	Camp Conoy	length = 9.92 $(age)^{0.332}$	r^2=0.943
4.	Rocky Point	length = 10.35 $(age)^{0.323}$	r^2=0.931
5.	Cove Point	length = 10.12 $(age)^{0.323}$	r^2=0.920

Figure 7.1-3. Regression curves and their associated r^2 values (proportion of variation in the data that is explained by the model) computed from growth data of fourth-year oysters held in trays in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant from June 1978 to June 1981.

Comparison of Oyster Growth Studies

1978-1981: Through 1980, the first- and second-year classes showed no station differences, but third- and fourth-year oysters did (Abbe, 1981*a*). PS oysters showed the largest increases, and were significantly larger than third-year oysters at CP and KB and fourth-year oysters at KB, RP, and CP. However, they were no different than either class at CC or third-year oysters at RP. In 1981, first- and second-year oysters showed the same pattern as in 1980, and again differences were detected for third- and fourth-year oysters. But in 1981, growth at PS was greater than that at all other stations. Thus, it appears that the CCNPP does increase the growth of PS oysters, but differences cannot be detected until the third growing season using the present statistical model.

Growth of oysters of all classes at all stations was less in 1981 than in 1980. The reason for this is not understood. Salinity, which averaged 14.1 ^{o}/oo from May through November 1980 (Abbe, 1981*b*), increased to an average 18.0 ^{o}/oo in 1981 (see Section 6). Temperature averaged 20.9° from June to November 1980 compared to 20.6° in 1981. Thus it appears that neither temperature nor salinity was responsible for the lower growth rate in 1981. However, salinity may have had an indirect effect on growth, since large numbers of the tunicate *Molgula* were found on, and in, many of the trays in June and September. This organism not only competes for the same food as oysters, but can occlude the wire mesh of a tray, thereby reducing water flow and restricting the food supply. This effect was previously observed at RP in 1977 (Abbe, 1978).

1970-73 vs. 1978-81: The preoperational (1970-73) and operational (1978-81) periods were compared for differences in growth (length increases) of oysters. Data for the preoperational period were taken from Abbe (1975).

Growth of first-year oysters from KB, RP, and CP during June to December 1970 was compared with that of similar-aged oysters during June to December 1981. The average increase per oyster in 1970 was 44.5 mm compared to 36.2 mm in 1981. Whether this obvious difference in growth rate between the two groups was due to environmental differences, abundances of competing associated organisms, genetic variation, or a combination of these is unknown. Data on oyster growth at PS during 1981 was not used for comparison since the only first-year oysters installed at PS during the preoperational period were set out in September 1973 and were lost after one examination.

Growth of second-year oysters from KB, RP, and CP from June 1980 to December 1981 was compared with that of similar-aged oysters from June 1970 to December 1971. The average 1970-71 increase was 68.7 mm compared to 76.7 mm during 1980-81. With this class, the operational growth was better than growth in 1970-71, in contrast to the first-year oysters dis-

cussed above. This points to the need to observe more than one year class for more than 1 year.

Third-year oysters from KB, RP, and CP from June 1979 to December 1981 were compared with a similar group from June 1970 to December 1972. The average 1970-72 growth increase was 74.6 mm compared to 80.3 mm during 1979-81.

Fourth-year oysters from KB, RP, and CP from June 1978 to June 1981 were compared with a similar group from June 1970 to June 1973. The 1970 oysters grew 78.8 mm compared to 72.9 mm for the 1978 oysters.

Since two age classes grew better during the preoperational period and two grew better during the operational period, there is no evidence that one period was better than the other. Although oyster growth data from PS were not used to calculate any averages in the above comparisons, Table 7.1-2 shows that second-, third-, and fourth-year oysters at PS grew better than similar oysters averaged over KB, RP, and CP (Tables 7.1-1, 7.1-4, and 7.1-5) during the operational period. Operational PS averages were also better than preoperational averages (KB, RP, and CP combined) for second-, third-, and fourth-year oysters. This serves as another indication that the operation of the CCNPP has had no adverse effect on the growth of oysters in the immediate vicinity of the plant.

Oyster Meat Condition

Oyster meat-condition averages are presented in Table 7.1-7. KB yielded the lowest average (6.78 for September 1978 to December 1981). Meat condition increased in a down-bay direction with 6.96 at PS, 7.11 at CC, 7.16 at RP, and 7.49 at CP. A three-way ANOVA detected a significant difference among stations ($p<0.001$) and seasons ($p<0.001$), but not among years ($p=0.830$). To further investigate the station effect, a linear contrast (Walpole and Myers, 1972) partitioned the station sum of squares from the ANOVA into the sum of squares due to a linear trend and the sum of squares due to higher order trends. The linear trend accounted for 94.4% of the variation among stations and was significant ($p<0.001$). The higher order trends were collectively non-significant. An obvious explanation of this linear down-bay trend would be that salinity also increases linearly in a down-bay direction, but any correlation between meat condition and salinity in this case would be speculative. This trend was apparent during most observation periods and thus was not related to temperature. In addition, PS, which had the highest average temperatures and the highest growth rates, had the second lowest meat-condition average.

Average meat condition for the period 1978 through 1981 was lowest in September (6.25) and highest in December (7.46), although March (7.42) and June (7.42) were nearly the same as

Table 7.1-7. Average meat condition, percent of oysters showing gonad layer, and percent exhibiting green-colored meat. Values are based on 10 oysters held in trays in the Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant from June 1978 to December 1981.

	Kenwood Beach	Plant Site	Camp Conoy	Rocky Point	Cove Point
Meat Condition					
Sep 78	5.6	5.8	6.0	6.4	6.2
Dec 78	6.9	7.9	7.7	7.4	7.6
Mar 79	7.2	7.2	7.8	7.7	8.1
Jun 79	7.0	6.6	7.0	7.2	7.5
Sep 79	6.1	6.8	6.6	6.3	6.8
Dec 79	7.1	7.5	7.3	7.3	7.4
Mar 80	6.7	7.3	7.5	7.6	7.6
Jun 80	[illegible]	7.5	7.7	7.9	8.2
Sep 80	[illegible]	6.1	6.2	6.4	6.7
Dec 80	.3	7.3	7.4	7.4	8.1
Mar 81	7.0	7.5	7.5	7.1	7.5
Jun 81	7.9	7.3	7.4	7.3	7.8
Sep 81	6.4	5.6	6.0	6.4	6.8
Dec 81	6.9	7.0	7.5	7.8	8.5
Mean	6.78	6.96	7.11	7.16	7.49
Gonad Layer					
Sep 78	10%	0%	0%	20%	20%
Dec 78	0	0	0	0	0
Mar 79	0	0	0	0	0
Jun 79	30	20	20	10	20
Sep 79	30	40	20	60	40
Dec 79	0	0	0	0	0
Mar 80	10	0	0	0	10
Jun 80	70	40	80	80	100
Sep 80	40	30	60	30	0
Dec 80	0	0	0	10	0
Mar 81	0	0	0	0	0
Jun 81	60	70	80	50	100
Sep 81	20	0	0	10	0
Dec 81	0	0	0	0	0
Mean	19%	14%	19%	19%	21%
Green					
Sep 78	0%	0%	0%	0%	0%
Dec 78	0	10	0	0	0
Mar 79	0	0	0	0	0
Jun 79	0	0	0	0	0
Sep 79	0	0	0	0	0
Dec 79	0	0	0	0	0
Mar 80	0	0	0	0	0
Jun 80	0	0	0	0	0
Sep 80	0	0	0	0	0
Dec 80	0	0	0	0	0
Mar 81	0	0	0	0	0
Jun 81	0	0	0	10	0
Sep 81	0	0	0	0	0
Dec 81	0	0	0	0	0
Mean	0%	<1%	0%	<1%	0%

December. An ANOVA showed this season effect to be highly significant ($p<0.001$). Low meat condition in September is due to spawning-related losses. With gonadal tissue accounting for up to 41% of total body weight (Galtsoff, 1964), spawning can obviously expend a considerable amount of an oyster's reserves, thereby reducing the quality of the meat. By December, condition ratings are generally high as oysters prepare to undergo a period of about 3 months (January-March) without feeding. Feeding ceases when water temperature drops to 7 or 8°C (Galtsoff, 1964).

Analysis of the data using a two-way ANOVA also showed highly significant station and date effects ($p<0.001$), but a three-way ANOVA was used to determine that the date effect was due to season and not to year. Evidence of spawning activity (gonad layer) was observed in 72% of the oysters in June 1981 and 6% in September 1981 compared to 74% and 32% in June and September 1980, respectively (Table 7.1-7). Since 1978, the percentage of oysters bearing gonad layer was highest at CP and lowest at PS. During 1981 oysters bearing gonadal tissue were most abundant at CP and least abundant at RP, although differences between stations are minimal and not statistically different.

One green oyster was observed in June at RP. This was only the second green oyster seen from a total of 700 oysters in 3.5 years.

Mortality

The highest mortality for any age class during a quarter of 1981 was 5.3% among second-year oysters at KB and PS in September (Table 7.1-8). Friedman rank sum tests detected no significant station differences for any of the age classes during 1981. Second-year oysters had the highest annual mortality rate with 5.7% (8.5% during 1.5 years). Fourth-year oysters had a 2.9% annual rate (8.6% over 3 years), and third-year oysters had a 2.4% rate (6.0% for 2.5 years). The mortality for first-year oysters in 1981 was 0.0%.

Average annual mortality rates were low and similar at all stations (Table 7.1-8), ranging from a low of 2.3% at RP to a high of 3.7% at KB and CP. The overall average annual mortality rate during 1981 for all oysters at all stations was about 3%, the same as in 1980. Causes of death were undetermined, but the rates at all stations were low compared to the annual mortalities of tray-held oysters (25%) and bottom populations (30-42%) in the lower Chesapeake Bay (Hewatt and Andrews, 1954).

Table 7.1-8. Percent mortalities of tray-held oysters in the area of the Calvert Cliffs Nuclear Power Plant in Chesapeake Bay from June 1978 to December 1981. Oysters are listed by age as of June 1981. Totals are based on differences between first and last counts.

	Kenwood Beach	Plant Site	Camp Conoy	Rocky Point	Cove Point	Mean
First-year Oysters						
Sep 81	0.0	0.0	0.0	0.0	0.0	0.0
Dec 81	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0
Second-year Oysters						
Sep 80	2.5	2.5	0.0	0.0	10.0	3.0
Dec 80	0.0	2.6	0.0	2.6	0.0	1.0
Mar 81	2.6	0.0	0.0	0.0	0.0	0.5
Jun 81	0.0	0.0	2.5	0.0	0.0	0.5
Sep 81	5.3	5.3	0.0	2.6	0.0	2.6
Dec 81	2.8	0.0	2.6	0.0	0.0	1.1
	12.5	10.0	5.0	5.0	10.0	8.5
Third-year Oysters						
Sep 79	0.0	0.0	0.0	5.0	0.0	1.0
Dec 79	0.0	0.0	0.0	0.0	0.0	0.0
Mar 80	0.0	0.0	0.0	0.0	0.0	0.0
Jun 80	0.0	0.0	0.0	0.0	0.0	0.0
Sep 80	2.5	0.0	0.0	0.0	2.5	1.0
Dec 80	0.0	0.0	0.0	0.0	0.0	0.0
Mar 81	0.0	0.0	0.0	0.0	0.0	0.0
Jun 81	0.0	0.0	0.0	2.6	0.0	0.5
Sep 81	0.0	0.0	5.0	0.0	0.0	1.0
Dec 81	5.1	0.0	2.6	2.7	2.6	2.6
	7.5	0.0	7.5	10.0	5.0	6.0
Fourth-year Oysters						
Sep 78	0.0	5.0	0.0	0.0	0.0	1.0
Dec 78	0.0	2.6	0.0	0.0	0.0	0.5
Mar 79	0.0	0.0	0.0	0.0	0.0	0.0
Jun 79	0.0	0.0	0.0	0.0	0.0	0.0
Sep 79	5.1	5.4	2.5	0.0	10.0	4.6
Dec 79	2.7	0.0	2.6	0.0	0.0	1.1
Mar 80	0.0	0.0	0.0	0.0	0.0	0.0
Jun 80	0.0	0.0	0.0	0.0	2.8	0.6
Sep 80	0.0	0.0	0.0	0.0	0.0	0.0
Dec 80	0.0	0.0	2.6	2.6	0.0	1.0
Mar 81	0.0	0.0	0.0	0.0	0.0	0.0
Jun 81	0.0	0.0	0.0	0.0	0.0	0.0
	7.7	12.5	7.5	2.6	12.5	8.6
Annual average mortality by station	3.7	3.0	2.7	2.3	3.7	3.1

Associated Organisms

Organisms attached to, or associated with, the oysters included anemones, mussels, bryozoans, barnacles, amphipods (*Gammarus* and *Corophium*), polychaete worms, hydroids (*Bimeria*), flatworms, and tunicates (*Molgula*), as well as others which occurred less frequently (Tables 7.1-9 through 7.1-13). Generally, the species and abundances observed in 1981 were as expected. Both tunicates and flatworms were more abundant than in recent years, apparently due to continued high salinity. *Molgula* did not peak at KB until December, but at all other stations it peaked in September and showed major reductions by December. Flatworms were abundant at KB in December 1980, but nowhere else. In 1981, however, they were again abundant in December, and at all stations; the greatest abundance was at CP, where they were found on 81% of the second-year oysters (Table 7.1-13).

Table 7.1-14 lists the average number of species per oyster by class, station, and month. Analysis of March data detected a significant station effect ($p<0.001$). Duncan's multiple range test revealed KB (4.07) > PS (2.50), CC (2.11), RP (1.78) > CP (1.26) ($p<0.05$).

June data revealed a significant station difference ($p<0.001$), but the pattern was totally different from that for March. Duncan's test showed that PS (7.37), RP (6.87) > KB (6.31), CC (5.90), CP (6.03) ($p<0.05$).

A station effect was evident in September ($p<0.001$) and Duncan's multiple range test indicated PS (6.18), CC (6.58), RP (6.48), CP (6.55) > KB (4.84) ($p<0.05$).

In December, a station effect was once again evident ($p=0.003$), but for the fourth time in as many seasons, a new pattern was detected. Duncan's test showed CC (6.57), RP (6.28) > KB (5.14), PS (5.34) ($p<0.05$). CP (6.00) differed from none of the other stations.

The number of spat oysters which set on oysters in trays was high in 1981. The percentages of oysters with spat on them are shown in Table 7.1-15. Percentages for March and June represent spat which set during 1980. Generally, spat were more abundant down-Bay than up-Bay, and they were more abundant in September (after the spawning season) than at other times, although they were nearly as common in December. Analysis of the spat data, using the Friedman rank sum test, revealed RP (14.5%) and KB (3.2%) were the most different, but the difference was not significant ($p=0.11$).

Table 7.1-9. Percentage of oysters bearing various associated organisms at Kenwood Beach in the Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant from June 1978 to December 1981. Oysters are listed by age as of June 1981.

	Anemones	Clams	Mussels	*Gammarus*	*Molgula*	Barnacles	*Corophium*	Bryozoa	Mud Crabs	Polychaetes	Flatworms	*Bimeria*
First-year Oysters												
Sep 81	100%	0%	30%	2%	100%	20%	8%	90%	0%	65%	0%	0%
Dec 81	95	5	22	5	100	88	5	42	0	55	15	5
Second-year Oysters												
Sep 80	90%	0%	8%	0%	0%	15%	0%	100%	5%	79%	0%	5%
Dec 80	82	0	18	3	23	97	10	95	3	72	67	0
Mar 81	84	0	16	0	13	79	16	87	0	29	29	0
Jun 81	95	13	29	71	84	100	39	100	5	84	29	0
Sep 81	100	0	83	3	17	100	3	100	3	92	0	14
Dec 81	100	6	66	14	100	100	11	57	0	63	34	3
Third-year Oysters												
Sep 79	85%	0%	25%	2%	0%	2%	5%	98%	8%	72%	0%	18%
Dec 79	95	0	22	2	0	0	12	100	0	72	0	38
Mar 80	75	0	15	0	0	2	18	90	0	5	0	35
Jun 80	38	0	12	0	0	68	0	100	8	78	0	2
Sep 80	100	0	38	0	0	77	3	100	8	95	3	26
Dec 80	87	0	44	8	23	100	8	97	8	67	79	8
Mar 81	97	0	31	0	13	92	16	89	0	28	49	8
Jun 81	100	0	41	49	69	100	59	100	0	90	13	0
Sep 81	100	0	95	0	3	100	0	100	8	100	3	3
Dec 81	100	5	76	3	100	100	3	65	5	65	24	0
Fourth-year Oysters												
Sep 78	95%	0%	32%	0%	0%	8%	0%	98%	0%	8%	0%	8%
Dec 78	100	0	30	0	0	2	20	100	2	70	0	22
Mar 79	100	0	15	0	2	2	15	88	0	10	0	2
Jun 79	38	0	18	3	0	100	87	100	0	33	0	5
Sep 79	97	0	35	3	0	43	11	100	11	68	0	38
Dec 79	100	0	33	3	0	6	6	100	0	83	0	33
Mar 80	100	0	33	3	0	14	19	86	0	19	0	28
Jun 80	69	0	17	0	0	86	0	100	0	83	0	0
Sep 80	100	0	60	0	0	89	0	100	23	86	0	29
Dec 80	86	0	51	3	6	100	3	100	0	80	74	11
Mar 81	97	0	51	0	6	97	9	94	0	40	34	11
Jun 81	97	3	43	54	69	100	46	100	3	83	14	0

Table 7.1-10. Percentage of oysters bearing various associated organisms at the Plant Site in the Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant from June 1978 to December 1981. Oysters are listed by age as of June 1981.

	Anemones	Clams	Mussels	*Gammarus*	*Molgula*	Barnacles	*Corophium*	Bryozoa	Mud Crabs	Polychaetes	Flatworms	*Bimeria*
First-year Oysters												
Sep 81	98%	0%	2%	98%	100%	2%	12%	85%	2%	68%	0%	12%
Dec 81	100	12	0	38	2	38	15	40	2	65	30	20
Second-year Oysters												
Sep 80	97%	0%	8%	49%	0%	3%	8%	100%	10%	82%	0%	13%
Dec 80	92	0	8	76	95	71	3	100	0	95	3	16
Mar 81	87	0	5	18	0	13	18	55	0	5	0	5
Jun 81	95	66	39	100	95	100	92	100	0	32	16	0
Sep 81	97	0	49	91	100	91	9	100	17	71	0	26
Dec 81	100	19	47	86	0	56	17	67	6	72	19	94
Third-year Oysters												
Sep 79	95%	0%	58%	95%	0%	25%	20%	100%	20%	50%	0%	12%
Dec 79	90	0	38	72	0	10	10	100	0	68	0	10
Mar 80	95	0	28	30	0	5	60	95	0	15	0	20
Jun 80	100	8	28	98	0	100	100	100	5	90	0	0
Sep 80	100	0	25	60	8	92	2	95	40	82	0	2
Dec 80	98	0	18	98	100	82	2	100	0	90	8	28
Mar 81	95	0	12	12	5	22	12	65	0	10	0	5
Jun 81	95	52	45	95	92	100	95	100	8	52	5	0
Sep 81	100	2	70	90	100	75	10	100	22	82	0	30
Dec 81	100	18	67	87	10	77	13	77	3	74	10	95
Fourth-year Oysters												
Sep 78	100%	0%	34%	5%	0%	11%	0%	95%	0%	50%	0%	32%
Dec 78	100	0	16	65	0	8	0	84	0	57	0	16
Mar 79	95	0	16	30	0	11	19	89	0	5	3	5
Jun 79	92	5	24	92	0	100	100	100	3	78	3	11
Sep 79	100	0	76	97	0	56	65	100	35	56	0	29
Dec 79	88	0	62	88	0	21	6	100	0	88	0	29
Mar 80	100	0	65	35	0	18	59	94	0	12	0	24
Jun 80	97	18	47	100	0	100	100	100	3	97	6	3
Sep 80	100	0	53	50	0	100	6	100	56	84	0	12
Dec 80	100	0	38	97	100	88	3	100	0	94	3	12
Mar 81	100	0	28	12	3	44	22	78	0	6	0	0
Jun 81	94	31	56	94	100	100	97	100	9	50	0	0

Table 7.1-11. Percentage of oysters bearing various associated organisms at Camp Conoy in the Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant from June 1978 to December 1981. Oysters are listed by age as of June 1981.

	Anemones	Clams	Mussels	*Gammarus*	*Molgula*	Barnacles	*Corophium*	Bryozoa	Mud Crabs	Polychaetes	Flatworms	*Bimeria*
First-year Oysters												
Sep 81	98%	0%	10%	98%	100%	20%	42%	95%	0%	55%	0%	25%
Dec 81	100	2	15	58	0	100	20	78	0	52	48	60
Second-year Oysters												
Sep 80	92%	0%	8%	80%	0%	30%	38%	100%	8%	78%	0%	12%
Dec 80	95	0	5	95	98	30	2	100	0	68	2	18
Mar 81	62	0	2	5	8	12	20	35	0	2	0	8
Jun 81	90	15	26	92	33	97	44	87	0	49	13	3
Sep 81	100	0	36	100	97	82	51	100	10	89	0	46
Dec 81	100	0	42	79	8	100	21	100	0	74	45	95
Third-year Oysters												
Sep 79	90%	0%	60%	88%	0%	22%	50%	100%	5%	60%	0%	10%
Dec 79	95	0	18	38	0	12	12	100	2	85	0	35
Mar 80	50	0	12	0	0	10	8	85	0	2	0	28
Jun 80	30	2	5	85	0	100	92	100	0	90	0	2
Sep 80	100	0	48	88	0	98	35	98	28	70	0	15
Dec 80	100	0	25	98	100	95	0	100	2	68	8	18
Mar 81	95	0	8	10	8	28	12	38	0	2	0	6
Jun 81	88	20	28	100	50	100	60	92	2	55	12	0
Sep 81	100	0	58	97	100	76	55	79	16	74	0	24
Dec 81	100	5	76	78	8	100	24	100	5	70	57	92
Fourth-year Oysters												
Sep 78	100%	0%	32%	12%	0%	38%	8%	92%	0%	68%	0%	25%
Dec 78	100	2	28	38	8	18	0	98	0	70	2	32
Mar 79	92	0	12	2	2	10	0	72	0	2	0	10
Jun 79	60	0	8	92	0	100	98	100	0	10	0	20
Sep 79	97	0	67	92	0	72	56	100	18	74	0	10
Dec 79	100	0	37	74	0	26	0	100	3	84	0	26
Mar 80	87	0	18	3	0	0	5	92	0	5	0	5
Jun 80	58	0	0	87	0	97	100	97	0	79	3	0
Sep 80	100	0	34	84	3	100	26	100	26	76	0	18
Dec 80	100	0	38	100	97	97	0	100	5	70	3	16
Mar 81	97	0	11	27	14	57	5	46	0	3	0	5
Jun 81	97	14	30	97	38	100	62	100	0	62	3	3

Table 7.1-12. Percentage of oysters bearing various associated organisms at Rocky Point in the Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant from June 1978 to December 1981. Oysters are listed by age as of June 1981.

	Anemones	Clams	Mussels	*Gammarus*	*Molgula*	Barnacles	*Corophium*	Bryozoa	Mud Crabs	Polychaetes	Flatworms	*Bimeria*
First-year Oysters												
Sep 81	98%	0%	0%	55%	100%	5%	48%	85%	2%	70%	0%	12%
Dec 81	100	0	8	20	2	100	2	80	8	75	68	45
Second-year Oysters												
Sep 80	97%	0%	8%	79%	41%	31%	38%	97%	3%	49%	0%	8%
Dec 80	89	0	8	97	82	50	0	100	0	74	13	26
Mar 81	55	0	0	3	3	8	5	37	0	5	0	3
Jun 81	87	53	79	97	84	100	55	100	3	24	16	0
Sep 81	100	0	22	92	100	100	59	100	11	89	0	24
Dec 81	97	5	24	43	3	100	22	100	3	95	62	92
Third-year Oysters												
Sep 79	95%	0%	61%	100%	0%	26%	71%	97%	0%	58%	0%	16%
Dec 79	100	0	50	55	3	5	21	100	0	45	0	39
Mar 80	65	0	30	3	0	3	16	51	0	3	0	14
Jun 80	24	0	16	68	0	100	97	100	0	95	0	0
Sep 80	92	0	58	92	55	92	37	100	21	66	0	18
Dec 80	97	5	39	95	97	97	0	100	0	79	8	29
Mar 81	74	0	32	3	0	16	0	39	0	8	0	5
Jun 81	95	51	73	100	73	100	49	100	0	32	19	0
Sep 81	100	0	46	84	100	100	51	100	5	92	0	35
Dec 81	100	6	44	67	0	100	14	100	0	86	53	100
Fourth-year Oysters												
Sep 78	98%	0%	42%	58%	0%	62%	0%	100%	0%	50%	0%	35%
Dec 78	100	0	45	90	22	15	0	100	5	80	2	38
Mar 79	75	0	28	48	2	0	30	30	0	18	0	5
Jun 79	50	10	22	75	0	100	75	100	0	42	2	10
Sep 79	100	0	90	100	0	87	54	100	21	64	0	10
Dec 79	100	0	69	74	3	15	26	100	3	74	0	21
Mar 80	87	0	41	3	0	0	5	74	0	5	0	3
Jun 80	42	0	26	71	0	100	89	87	3	30	3	0
Sep 80	97	0	67	74	46	97	31	100	54	67	0	10
Dec 80	100	0	29	92	100	97	0	100	0	82	8	11
Mar 81	89	0	18	8	5	24	0	39	0	8	0	8
Jun 81	100	42	55	100	74	100	37	100	0	50	13	3

Table 7.1-13. Percentage of oysters bearing various associated organisms at Cove Point in the Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant from June 1978 to December 1981. Oysters are listed by age as of June 1981.

	Anemones	Clams	Mussels	*Gammarus*	*Molgula*	Barnacles	*Corophium*	Bryozoa	Mud Crabs	Polychaetes	Flatworms	*Bimeria*
First-year Oysters												
Sep 81	82%	0%	8%	98%	98%	28%	55%	100%	0%	68%	0%	0%
Dec 81	84	8	0	37	0	97	8	84	0	68	68	0
Second-year Oysters												
Sep 80	90%	0%	6%	90%	10%	77%	55%	97%	3%	55%	3%	10%
Dec 80	44	0	0	53	81	81	0	100	0	91	19	22
Mar 81	9	0	0	0	0	28	3	0	0	6	0	3
Jun 81	31	47	41	100	94	100	47	100	3	28	12	0
Sep 81	100	0	25	97	100	100	41	100	22	88	0	3
Dec 81	100	6	25	53	0	100	19	100	0	97	81	78
Third-year Oysters												
Sep 79	88%	0%	32%	88%	0%	0%	55%	100%	10%	72%	0%	0%
Dec 79	78	0	2	60	0	20	45	100	0	50	5	5
Mar 80	22	0	2	0	0	2	10	50	0	0	0	0
Jun 80	0	2	0	48	0	98	98	98	2	88	0	2
Sep 80	97	0	26	92	18	100	67	100	33	72	5	23
Dec 80	87	0	21	69	92	97	0	100	3	90	18	18
Mar 81	49	0	13	3	0	21	8	28	0	8	3	5
Jun 81	49	13	38	100	82	100	64	100	0	10	13	0
Sep 81	100	0	23	100	100	100	51	100	15	90	0	5
Dec 81	97	21	29	66	0	100	5	100	0	87	66	74
Fourth-year Oysters												
Sep 78	98%	0%	0%	98%	0%	95%	5%	92%	0%	55%	0%	28%
Dec 78	98	2	0	92	55	15	0	100	2	82	0	32
Mar 79	35	0	0	40	2	0	52	5	0	12	0	0
Jun 79	22	0	0	62	0	100	78	100	2	32	0	10
Sep 79	100	3	47	92	0	94	72	100	33	78	0	3
Dec 79	100	0	17	53	0	22	50	100	0	78	3	8
Mar 80	67	0	11	0	0	0	8	36	0	6	0	0
Jun 80	3	0	6	43	0	100	94	100	0	77	0	3
Sep 80	91	0	26	100	23	100	77	100	31	77	0	14
Dec 80	97	3	23	86	77	100	0	100	0	91	11	20
Mar 81	71	0	11	3	0	49	6	37	0	0	6	3
Jun 81	83	17	54	97	74	100	69	100	6	31	3	0

Table 7.1-14. Average number of species per oyster for tray-held oysters in the Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant from June 1978 to December 1981. Oysters are listed by age as of June 1981.

	Kenwood Beach	Plant Site	Camp Conoy	Rocky Point	Cove Point
First-year Oysters					
Sep 81	4.15	4.80	5.50	4.78	5.75
Dec 81	4.40	3.70	5.50	5.15	4.73
Mean (1981)	4.28	4.25	5.50	4.96	5.24
Second-year Oysters					
Sep 80	3.05	3.74	4.45	4.59	5.06
Dec 80	4.74	5.68	5.12	5.42	4.94
Mar 81	3.52	2.11	1.57	1.29	0.52
Jun 81	6.58	7.34	5.52	6.75	6.01
Sep 81	5.17	6.67	7.34	7.17	7.02
Dec 81	5.52	5.91	6.79	6.67	6.64
Mean (1980-81)	4.76	5.24	5.13	5.32	5.03
Mean (1981)	5.20	5.51	5.31	5.47	5.05
Third-year Oysters					
Sep 79	3.15	4.75	4.88	5.25	4.55
Dec 79	3.42	3.98	3.98	4.17	3.65
Mar 80	2.40	3.48	1.95	1.92	0.88
Jun 80	3.05	6.28	5.05	5.00	4.35
Sep 80	4.51	5.12	5.82	6.42	6.44
Dec 80	5.31	6.25	6.25	6.61	6.00
Mar 81	4.28	2.45	2.10	1.97	1.41
Jun 81	6.22	7.42	6.10	7.06	5.71
Sep 81	5.19	7.08	6.90	7.49	6.88
Dec 81	5.50	6.42	7.42	7.02	6.62
Mean (1979-81)	4.30	5.32	5.04	5.29	4.65
Mean (1981)	5.30	5.84	5.63	5.88	5.16
Fourth-year Oysters					
Sep 78	2.48	3.25	3.75	4.58	4.70
Dec 78	3.48	3.45	3.95	5.00	4.80
Mar 79	2.35	2.72	2.05	2.35	1.48
Jun 79	3.88	5.44	4.88	4.88	4.08
Sep 79	4.04	6.10	5.87	6.24	6.14
Dec 79	3.64	4.96	4.49	4.87	4.33
Mar 80	3.03	4.06	2.16	2.18	1.28
Jun 80	3.56	6.71	5.21	4.97	4.46
Sep 80	4.89	5.66	5.74	6.62	6.49
Dec 80	5.20	6.31	6.27	6.21	6.09
Mar 81	4.41	2.94	2.65	2.09	1.86
Jun 81	6.14	7.34	6.08	6.79	6.38
Mean (1978-81)	3.92	4.91	4.42	4.73	4.34
Mean (1981)	5.28	5.14	4.36	4.44	4.12

Table 7.1-15. Percentage of oysters with spat (baby oysters) attached to them at five stations in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant during 1981. Oysters are listed by age as of June 1981.

	Kenwood Beach	Plant Site	Camp Conoy	Rocky Point	Cove Point
First-year Oysters					
Sep 81	0	0	8	2	40
Dec 81	2	8	18	8	18
Second-year Oysters					
Mar 81	0	5	2	11	0
Jun 81	8	0	3	3	0
Sep 81	6	14	23	19	19
Dec 81	0	6	21	19	22
Third-year Oysters					
Mar 81	3	5	10	18	5
Jun 81	0	2	2	14	0
Sep 81	8	25	13	38	5
Dec 81	3	13	30	33	13
Fourth-year Oysters					
Mar 81	0	3	0	5	0
Jun 81	6	3	3	5	0
Average Station Percents					
Mar 81	1	4	4	11	2
Jun 81	5	2	3	7	0
Sep 81	5	13	15	20	21
Dec 81	2	9	23	20	18

Summary and Conclusions

Growth of tray-held oysters in the Chesapeake Bay near Calvert Cliffs, Maryland during 1981 was less than growth during 1980. No significant station differences were detected for first- and second-year oysters, but third- and fourth-year oysters did show significant station effects. Generally, station differences indicated highest growth rates at PS with rates decreasing as proximity to the CCNPP decreased. In 1981, PS third- and fourth-year oysters showed significantly greater increases than similar oysters at all other stations. In 1980, PS was similar to CC and RP.

Meat condition showed a strong station effect increasing in a down-bay direction; however, this increase was linear and seemed unrelated to the presence of the power plant.

Mortalities were low at all stations during the year and no significant differences were detected. Highest mortality rates were among second-year oysters (5.7% annually), and decreased among fourth-, third-, and first-year oysters which had annual rates of 2.9, 2.4, and 0.0%, respectively.

Associated-organism data indicated the typical pattern of fewer species per oyster during periods following winter months than during or following warm-water periods. Significant station effects were observed during all seasons, but no pattern was evident among stations as to highest or lowest number of species.

Data from 1978-81 studies showed no detectable adverse effects on the growth, meat condition, or mortality of tray-held oysters, or on organisms associated with them in the area influenced by the discharge of the Calvert Cliffs Nuclear Power Plant. Although a statistically significant station effect was detected which may be related to plant operation (i.e., accelerated growth of oysters), this effect cannot be viewed as detrimental.

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HEAVY METAL ANALYSES OF OYSTERS

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Introduction

Many marine and estuarine organisms are capable of accumulating and concentrating trace elements from their environments. One such organism, the American oyster (*Crassostrea virginica* Gmelin), has been studied extensively (McFarren, Campbell, and Engle, 1962; Galtsoff, 1964; Pringle et al., 1968; Shuster and Pringle, 1969; and Kopfler and Mayer, 1973). Because of its sedentary habits and ability to concentrate metals, the oyster is an excellent biological tool for monitoring environmental changes in metal concentrations which could affect other components of an ecosystem. In addition, high concentrations of certain metals in oysters may reduce the value of these commercially important shellfish, or render them unfit for human consumption. For example, Ratkowsky et al. (1974) reported that some people who ate Pacific oysters (*Crassostrea gigas*) containing high concentrations of copper, zinc, and cadmium became ill.

Oysters sampled from wild populations often show sizeable variations in the amount of metal accumulated. In sampling oysters from Maine to North Carolina in areas selected without regard to the possible influence of chemical pollution, Pringle et al. (1968) found a range of copper concentrations from 7 to 517 ppm (mean - 91.5 ppm). Nickel concentrations in the same samples ranged from 0.08 to 1.80 ppm and averaged 0.19 ppm. Huggett, Bender, and Slone (1973) stated that metal concentrations often vary 100 to 300% among oysters collected from the same area.

Because saltwater erosion of the 70-30 copper-nickel-alloy condenser tubing in the Calvert Cliffs Nuclear Power Plant (CCNPP) could cause additions of these two metals to the environment, studies were begun by the Academy of Natural Sciences of Philadelphia (ANSP) in 1973, prior to plant operation, to determine copper and nickel accumulation by tray-held oysters in the vicinity of Calvert Cliffs.

If oysters accumulated metals released by the power plant, then increases in metal concentration ratios (plant site/ control site) should be evident when operational data (June 1975-December 1981) are compared with preoperational data (September 1973-March 1975) and when control-site oysters are compared with plant-site oysters. In addition, zinc concentra-

tions were determined from September 1973 through December 1976 and again during 1980 and 1981 to aid in estimating natural variation in the amount of copper present. If zinc were not released from the CCNPP as copper might be, and assuming the source of these geochemically-similar metals in a non-industrialized area was the same (the natural weathering of rocks), then the ratio of these metals should remain fairly constant (Huggett, Bender, and Slone, 1973; O'Connor, 1976). If the concentration of one metal increased relative to the concentration of the other, then a man-related source would be suspected. Some release of zinc from the plant does occur, however, since zinc sacrificial anodes are attached to the intake screens (E. Bauereis, Baltimore Gas and Electric Company, personal communication). Thus, copper/zinc ratios are conservative, even when the amount of zinc released is small. As the amount of released zinc increases, the ratios used to estimate copper become even more conservative.

Materials and Methods

From September 1973 to December 1975, five oysters (100-130 mm in shell length) from each of three locations (Kenwood Beach (KB) oyster bed, KB oyster tray, and Plant Site (PS) oyster tray; see Fig. 7.1-1) were collected quarterly (March, June, September, and December) and analyzed for copper, nickel and zinc content. Until June 1975, oysters were shucked immediately after collection and frozen whole. After that time, each of the five oysters was homogenized in a blender before freezing, a procedure that yielded a uniform sample and eliminated the bias inherent in spot-sampling various types of tissue (which had occurred when only portions of whole oysters were used).

During 1976 oysters were collected quarterly from the oyster bed at KB, and from trays at KB, PS (December only), Rocky Point (RP), and Cove Point (CP). Oysters were returned to the laboratory where they were scrubbed and rinsed with distilled water, shucked, rinsed again and blotted dry. Oysters were then individually homogenized, bagged and frozen.

In 1977, sampling of the KB oyster-bed station was discontinued, and data for RP and CP were incomplete because of ice-related losses of oysters. Again in 1978, no data were available for the first half of the year because of ice-related losses. In June 1978, oysters were set at all stations and a new station was added at Camp Conoy (CC). The present study is a continuation of the one begun in June 1978, and all of the oysters collected and analyzed from 1978-1981 were installed at that time. Oysters collected during 1977-1981 were processed by the same methods used in 1976, except that during 1978-81 each oyster was weighed before homogenization. No oysters were analyzed for zinc during 1977 through 1979.

At the time of analysis, oysters were thawed and a 5-g sample of tissue was weighed and placed in a micro-Kjeldahl flask. Each 5-g sample was digested by boiling with concentrated HNO_3 until the resulting solution was clear (Shuster and Pringle, 1969; Huggett, Bender, and Slone, 1973; Ayling, 1974; O'Connor, 1976). The solution was then diluted to a constant volume with distilled-deionized water. Copper and zinc concentrations were determined by aspirating the sample solution into a Perkin-Elmer 460 atomic absorption spectrophotometer, and nickel levels were determined by injecting the sample into a Perkin-Elmer HGA 2100 graphite furnace.

Data from the 1981 study were analyzed using a two-way fixed-factor analysis of variance (ANOVA). When differences were detected among seasons or stations, Duncan's multiple range test (Walpole and Myers, 1972) was used to determine where these differences occurred. Data were examined over time (1980-81 or 1979-81) using a three-way fixed-factor ANOVA, and when differences were detected among years, seasons or stations, Duncan's test was again used. Preoperational and operational periods were compared using data from KB and PS since these were the only stations sampled consistently throughout the study. These data were analyzed using a three-factor, partially-crossed, partially-nested ANOVA (Hicks, 1973). The model for this design was as follows:

$$y_{ijkl} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \gamma_k(\alpha_i) + \beta\gamma_{jk}(\alpha_i) + \varepsilon_{ijkl}$$

where y_{ijkl} = dependent variable

μ = overall mean

α_i = fixed effect of plant introducton

β_j = fixed effect of station

$\alpha\beta_{ij}$ = fixed effect of interaction of plant introduction and station

$\gamma_k(\alpha_i)$ = random effect of dates within preoperational and operational periods

$\beta\gamma_{jk}(\alpha_i)$ = random effect of dates and station interacting with preoperational and operational periods

ε_{ijkl} = random error

Results and Discussion

Copper, nickel and zinc concentrations in oysters, expressed as milligrams of metal per kilogram of wet tissue, for 1973-1975, 1976-1977, 1978-1981 are presented in Tables 7.2-1

through 7.2-3, respectively. During 1973-75, when each collection of five oysters was treated as a single sample, the sample was analyzed in duplicate and the results averaged; thus, only means are listed in Table 7.2-1. During 1976-81, oysters were analyzed individually, allowing calculation of ranges, means, and standard errors of the means (Tables 7.2-2 and 7.2-3).

Copper (1978-81)

The mean copper concentration of five randomly selected oysters at the time oysters were set out in June 1978 was 52 mg/kg with a range of 7-80 mg/kg (Table 7.2-3). Concentrations at KB, CC, RP, and CP generally decreased until the fall of 1980 when copper levels began to increase at CC, RP, and CP. Copper concentrated by oysters during the second half of 1980 was eliminated during the winter of 1981, and by March 1981, average copper levels were the lowest in 3 years (Fig. 7.2-1). During 1981, KB and CP oysters continued to have the lowest copper concentrations while those at PS continued to have the highest. Generally, during this period concentrations at PS peaked during the fall-winter, declining through the spring and summer. This was most evident in the sharp increase in September 1981 to 82 mg/kg and subsequent decrease to 35 mg/kg in December. Rapid uptake of copper during summer is due to increased metabolic activity of oysters possibly coupled with higher copper levels in the water associated with elevated plant-operating temperatures and condenser cleaning operations. Increased concentrations have been detected at some time during the second half of each of the last 4 years. However, average concentration has never exceeded the 82 mg/kg observed in 1981, well below the mean for oysters from New Hampshire to North Carolina (138 mg/kg) sampled by McFarren, Campbell and Engle (1962) and also below the 133 mg/kg average for oysters from Maine to North Carolina sampled by Pringle et al. (1968). Neither mean values nor those for individual oysters exceeded the recommended maximum allowable copper level for human consumption of 100 mg/kg (Roosenburg, 1969).

Analysis of 1981 data revealed significant station effects ($p<0.001$) and season (month) effects ($p<0.001$). In the comparisons below, stations and months are ranked according to their mean values and stations similar to each other (Duncan's multiple range test, $p<0.05$) are underlined. All values are in mg/kg wet weight.

KB	CP	CC	RP	PS
8.8	14.3	21.8	28.3	43.6

Table 7.2-1. Copper, nickel and zinc concentrations (mg/kg wet weight) in oysters collected from stations in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant, 1973 through 1975. (Values are means of two analyses of samples consisting of five oysters.)

		Copper	Nickel	Zinc
September 1973	Kenwood Beach Tray	60	2.2	1555
	Kenwood Beach Bed	5.5	4.3	292
	Plant Site Tray	85	9.0	892
December 1973	Kenwood Beach Tray	43	2.0	1212
	Kenwood Beach Bed	8.6	0.3	438
	Plant Site Tray	82	1.6	1214
March 1974	Kenwood Beach Tray	19	2.5	699
	Kenwood Beach Bed	62	2.8	1723
	Plant Site Tray	84	3.4	1578
June 1974	Kenwood Beach Tray	7.4	2.4	300
	Kenwood Beach Bed	53	1.7	1021
	Plant Site Tray	56	0.9	1176
September 1974	Kenwood Beach Tray	26	3.0	1030
	Kenwood Beach Bed	33	3.2	1390
	Plant Site Tray	41	3.4	1530
December 1974	Kenwood Beach Tray	25	2.2	940
	Kenwood Beach Bed	24	2.2	920
	Plant Site Tray	18	2.5	550
March 1975	Kenwood Beach Tray	30	<1	828
	Kenwood Beach Bed	42	<1	850
	Plant Site Tray	56	<1	736
June 1975	Kenwood Beach Tray	28	<1	787
	Kenwood Beach Bed	55	<1	1200
	Plant Site Tray	54	<1	626
September 1975	Kenwood Beach Tray	14	<1	680
	Kenwood Beach Bed	22	<1	680
	Plant Site Tray	68	<1	560
December 1975	Kenwood Beach Tray	20	<1	420
	Kewood Beach Bed	19	<1	400
	Plant Site Tray*	9.2	<1	238

* Sampled in February 1976

Table 7.2-2. Copper, nickel and zinc concentrations (mg/kg wet weight) in oysters collected from stations in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant, 1976 through 1977. Zinc analyses were not done after December 1976. (Values are based on five oysters analyzed individually. Beginning of new study is designated by ***.)

	Copper			Nickel			Zinc		
	Range	Mean	Std. Err.	Range	Mean	Std. Err.	Range	Mean	Std. Err.
March 1976 * **									
Kenwood Beach Bed	7- 9	9	0.36	<0.2 - 0.2	<0.2	0.00	172- 276	237	39
Kenwood Beach Tray	9- 10	10	0.22	<0.2 -<0.2	<0.2	0.00	166- 262	228	37
Rocky Point Tray	9- 9	9	0.00		*				
Cove Point Tray	9- 9	9	0.00		*				
June 1976									
Kenwood Beach Bed	7- 13	10	1.12	<0.2 -<0.2	<0.2	0.00	146- 244	194	39
Kenwood Beach Tray	6- 9	7	0.49	<0.2 - 0.4	0.3	0.04	110- 218	157	39
Rocky Point Tray	20- 40	30	3.23		*				
Cove Pont Tray	15- 26	19	1.85		*				
September 1976									
Kenwood Beach Bed	12- 32	21	3.44	0.52- 1.20	0.88	0.12	360- 700	508	135
Kenwood Beach Tray	4- 60	18	10.46	0.56- 1.08	0.78	0.09	120- 760	380	253
Rocky Point Tray	12- 56	37	7.31	0.10- 0.88	0.63	0.14			
Cove Point Tray	20- 56	42	6.01	0.64- 0.96	0.78	0.05			
December 1976									
Kenwood Beach Bed	11- 34	23	4.20	0.76- 1.44	1.10	0.52	180- 920	632	288
Kenwood Beach Tray	12- 60	30	8.36	0.60- 1.40	1.03	0.13	140- 420	308	104
Plant Site Tray	36- 80	58	8.63	0.92- 1.12	1.01	0.03	200-1040	700	369
Rocky Point Tray	32- 80	53	9.67	0.76- 1.44	1.02	0.13			
Cove Point Tray	32- 48	40	2.53	0.76- 1.40	0.97	0.12			
March 1977									
Kenwood Beach Tray	20-120	60	16.55	<0.02- 0.38	0.14	0.07			
Plant Site Tray	20-200	100	30.41	0.12- 0.24	0.17	0.02			
Cove Point Tray	20-200	124	32.50	0.04- 0.14	0.09	0.02			
June 1977									
Kenwood Beach Tray	10- 30	20	3.13	0.20- 0.40	0.32	0.04			
Plant Site Tray	10- 50	35	7.60	0.50- 0.60	0.58	0.02			
September 1977* **									
Kenwood Beach Tray	2- 16	11	2.68	0.28- 0.52	0.40	0.04			
Plant Site Tray	24- 44	35	3.58	0.36- 0.50	0.46	0.03			
December 1977									
Kenwood Beach Tray	10- 15	13	1.34	0.44- 1.12	0.70	0.12			
Plant Site Tray	26- 44	34	3.13	0.36- 0.62	0.47	0.05			
Rocky Point Tray	10- 16	13	0.98	0.24- 0.58	0.37	0.07			
Cove Point Tray	10- 22	15	3.71	0.72- 0.84	0.77	0.03			

* Missing data

Table 7.2-3. Copper, nickel and zinc (1980-81 only) concentrations (mg/kg wet weight) in oysters collected from stations in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant, 1978 through 1981. (Values are based on five oysters analyzed individually.)

	Oyster Weight (g)	Copper Range	Copper Mean	Copper Std. Err.	Nickel Range	Nickel Mean	Nickel Std. Err.
June 1978							
Initial Sample	10.6	7- 80	52	12.50	0.01-0.15	0.10	0.02
September 1978							
Kenwood Beach	11.1	12- 32	19	3.44	0.06-0.26	0.13	0.03
Plant Site	9.4	44- 89	64	9.47	0.20-0.70	0.48	0.08
Camp Conoy	9.5	34- 54	45	3.38	0.01-0.44	0.19	0.09
Rocky Point	9.8	20- 74	38	9.44	0.06-0.50	0.32	0.08
Cove Point	11.4	18- 40	26	4.75	0.02-0.52	0.25	0.09
December 1978							
Kenwood Beach	18.2	11- 19	14	1.56	0.14-0.48	0.24	0.06
Plant Site	16.5	65- 75	70	1.64	0.16-0.20	0.18	0.01
Camp Conoy	15.9	35- 57	47	4.13	0.10-0.40	0.18	0.06
Rocky Point	17.0	13- 37	27	5.01	0.12-0.24	0.18	0.02
Cove Point	17.1	21- 29	25	1.46	0.14-0.22	0.17	0.01
March 1979							
Kenwood Beach	19.9	9- 17	12	1.51	0.18-0.70	0.34	0.10
Plant Site	20.1	32- 49	43	3.19	0.16-0.40	0.22	0.04
Camp Conoy	24.7	20- 50	37	6.08	0.04-0.22	0.15	0.03
Rocky Point	17.9	5- 37	19	6.62	0.04-0.32	0.18	0.05
Cove Point	17.7	18- 28	23	2.05	0.10-0.34	0.22	0.04
June 1979							
Kenwood Beach	15.9	4- 14	10	2.29	0.12-0.20	0.16	0.01
Plant Site	11.8	14- 21	19	1.37	0.14-0.26	0.19	0.02
Camp Conoy	17.7	19- 46	34	5.04	0.14-0.24	0.20	0.02
Rocky Point	17.6	7- 38	16	5.57	0.01-0.10	0.05	0.02
Cove Point	16.2	14- 48	32	6.05	0.02-0.08	0.05	0.01
September 1979							
Kenwood Beach	17.8	4- 23	12	4.28	0.46-0.96	0.61	0.09
Plant Site	16.0	28-100	66	12.77	0.62-0.96	0.80	0.05
Camp Conoy	16.4	14- 67	33	9.65	0.32-0.90	0.57	0.11
Rocky Point	16.8	31- 46	38	2.66	0.72-1.02	0.86	0.05
Cove Point	17.1	23- 38	27	2.72	0.58-0.78	0.66	0.04
December 1979							
Kenwood Beach	21.4	8- 20	14	2.40	0.16-0.26	0.21	0.02
Plant Site	21.8	12- 69	33	11.56	0.22-0.38	0.29	0.03
Camp Conoy	21.7	16- 43	32	5.03	0.16-0.28	0.21	0.02
Rocky Point	21.3	26- 47	35	4.26	0.12-0.30	0.20	0.03
Cove Point	22.1	11- 23	16	2.22	0.08-0.30	0.16	0.04

Table 7.2-3 (continued). Copper, nickel and zinc (1980-81 only) concentrations (mg/kg wet weight) in oysters collected from stations in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant, 1978 through 1981. (Values are based on five oysters analyzed individually.)

	Oyster Weight (g)	Copper Range	Copper Mean	Copper Std. Err.	Nickel Range	Nickel Mean	Nickel Std. Err.	Zinc Range	Zinc Mean	Zinc Std. Err.
March 1980										
Kenwood Beach	15.6	17- 31	25	2.94	0.21-1.64	0.92	0.26	515- 830	686	59
Plant Site	16.4	41- 93	68	8.59	0.27-0.65	0.39	0.07	540- 965	771	72
Camp Conoy	21.4	24- 51	37	5.44	0.18-1.12	0.86	0.18	420- 865	648	72
Rocky Point	22.0	11- 46	30	6.56	0.21-1.02	0.45	0.15	145- 890	602	134
Cove Point	24.0	15- 28	20	2.22	0.16-0.75	0.39	0.14	220- 590	440	63
June 1980										
Kenwood Beach	17.3	10- 26	17	2.71	0.63-1.14	0.89	0.09	95- 680	430	101
Plant Site	22.2	18- 57	36	6.97	0.44-0.80	0.65	0.07	130- 735	407	99
Camp Conoy	21.7	16- 54	30	6.95	0.42-2.05	0.84	0.34	140- 715	405	105
Rocky Point	21.2	12- 39	25	5.40	0.67-1.59	0.96	0.17	120- 700	406	117
Cove Point	26.0	9- 22	16	2.25	0.52-0.67	0.59	0.03	55- 470	282	67
September 1980										
Kenwood Beach	19.2	2- 21	13	4.22	0.66-0.98	0.81	0.08	452- 796	592	76
Plant Site	15.7	17- 77	31	11.67	0.72-0.80	0.76	0.01	60-1230	358	221
Camp Conoy	22.7	23- 84	54	10.02	0.38-0.82	0.60	0.08	368-1228	870	150
Rocky Point	21.0	23- 47	32	4.83	0.60-0.94	0.84	0.06	340-1132	810	130
Cove Point	19.0	11- 26	21	2.73	0.52-0.92	0.71	0.07	506- 808	622	53
December 1980										
Kenwood Beach	23.6	2- 26	11	4.42	0.20-0.78	0.43	0.10	64-1038	420	174
Plant Site	21.6	32- 70	51	8.07	0.43-0.73	0.54	0.06	279- 625	453	62
Camp Conoy	25.8	17- 69	44	9.90	0.42-0.65	0.52	0.04	319- 878	571	109
Rocky Point	23.7	16- 69	42	9.29	0.26-0.72	0.49	0.08	343-1062	624	132
Cove Point	22.3	19- 49	32	5.56	0.31-0.55	0.41	0.04	342- 752	560	84

Table 7.2-3 (continued). Copper, nickel and zinc (1980-81 only) concentrations (mg/kg wet weight) in oysters collected from stations in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant, 1978 through 1981. (Values are based on five oysters analyzed individually.)

	Oyster Weight (g)	Copper Range	Copper Mean	Copper Std. Err.	Nickel Range	Nickel Mean	Nickel Std. Err.	Zinc Range	Zinc Mean	Zinc Std. Err.
March 1981										
Kenwood Beach	22.6	1- 11	5	1.96	0.08-0.25	0.13	0.03	15- 487	236	90
Plant Site	25.5	8- 39	25	5.50	0.08-0.19	0.12	0.02	88- 619	330	86
Camp Conoy	26.5	4- 31	15	4.62	0.08-0.49	0.30	0.07	110- 643	313	98
Rocky Point	21.7	5- 44	16	7.14	0.08-0.08	0.08	0.00	106- 970	344	158
Cove Point	23.3	4- 17	11	2.74	0.08-0.19	0.13	0.02	96- 552	310	83
June 1981										
Kenwood Beach	18.9	3- 18	9	2.45	0.23-0.61	0.41	0.06	98- 467	310	66
Plant Site	23.2	14- 83	33	12.85	0.22-0.61	0.39	0.07	237-1670	629	267
Camp Conoy	25.7	5- 24	14	3.29	0.11-0.51	0.30	0.06	158- 505	295	67
Rocky Point	18.4	14- 51	29	6.82	0.42-0.80	0.52	0.07	72-1528	551	256
Cove Point	21.9	3- 27	13	4.59	0.26-0.63	0.45	0.07	88-1224	455	218
September 1981										
Kenwood Beach	22.8	2- 15	9	2.84	0.08-0.42	0.20	0.06	96- 574	354	104
Plant Site	18.2	64- 94	82	5.73	0.19-0.50	0.31	0.05	567- 940	788	68
Camp Conoy	18.2	14- 53	30	6.40	0.19-0.85	0.54	0.14	305- 610	400	56
Rocky Point	18.6	27- 46	34	2.62	0.08-0.66	0.28	0.10	415- 700	557	51
Cove Point	19.7	2- 36	20	5.92	0.13-2.20	0.66	0.39	308- 858	589	87
December 1981										
Kenwood Beach	28.5	7- 16	11	1.47	0.85-1.90	1.38	0.21	141- 457	347	57
Plant Site	24.9	8- 67	35	11.27	0.17-1.20	0.51	0.18	53- 632	357	113
Camp Conoy	27.1	21- 38	29	3.31	0.16-0.56	0.39	0.07	345- 756	536	69
Rocky Point	28.3	31- 40	34	1.63	1.66-4.42	3.07	0.58	433- [illegible]	542	35
Cove Point	33.9	8- 20	13	2.18	0.08-0.30	0.19	0.04	233- 526	360	59
Grand Mean										
Kenwood Beach	19.4	1- 32	13	1.31	0.06-1.90	0.49	0.10	15-1038	422	53
Plant Site	18.7	8-100	47	5.27	0.08-1.20	0.42	0.06	53-1670	512	67
Camp Conoy	21.0	4- 84	34	2.99	0.01-2.05	0.42	0.06	110-1228	505	68
Rocky Point	19.6	5- 74	30	2.20	0.01-4.42	0.61	0.21	72-1528	554	50
Cove Point	20.7	2- 49	21	1.82	0.02-2.20	0.36	0.06	55-1224	452	46

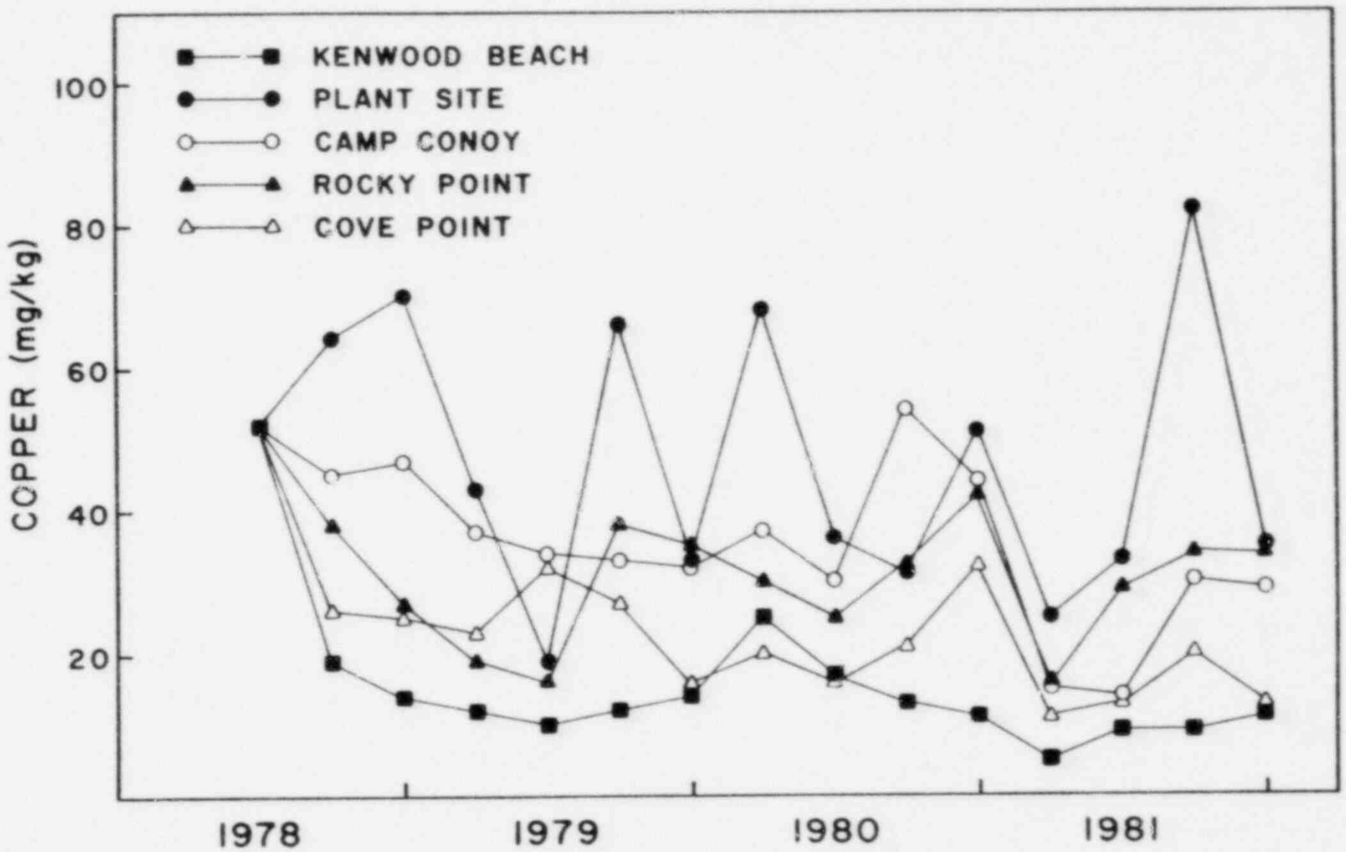

Figure 7.2-1. Mean copper concentrations (mg/kg wet tissue weight) in oysters collected from five stations in Chesapeake Bay near the Calvert Cliff Nuclear Power Plant from 1978 through 1981.

March	June	December	September
14.4	19.4	24.5	35.2

Analysis of 1979-81 data revealed significant station, season and year effects (all $p<0.001$). Comparisons are presented below.

KB	CP	RP	CC	PS
12.4	20.4	29.3	32.2	43.5

June	March	December	September
22.1	25.7	28.9	33.7

1981	1979	1980
23.4	27.6	31.8

Differences determined by analyzing the 1- and 3-yr data sets were consistent; i.e., PS had higher copper levels than any other station and September concentrations were higher than any other time of year. Copper concentrations were high in September because oysters had generally completed spawning by that time. Since gonadal tissue comprises up to 41% of an oyster's weight (Galtsoff, 1964), and since the mantle and gills are the primary storage area for copper (Galtsoff, 1964), spawning eliminates a considerable volume of low-copper-level tissue. The remaining tissue retains the highest copper concentration so that the ratio of copper to wet tissue weight is higher than it was before spawning.

Nickel (1978-81)

In June 1978, nickel concentrations ranged from 0.01 to 0.15 mg/kg and averaged 0.10 mg/kg (Table 7.2-3). Since then, concentrations have generally been higher, but were nearly the same in June 1979 as in June 1978. Nickel levels were high at all stations in September 1979, but were low again in December 1979. During 1980, concentrations were higher throughout the year than had previously been detected, although they did decrease by December 1980; and by March 1981, were low at all stations (Fig. 7.2-2). Levels during 1981 were generally lower than in 1980 except for KB and RP in December (Table 7.2-3); the 1.38 mg/kg at KB and the 3.07 mg/kg at RP were the first averages to exceed 1.00 mg/kg since December 1976 (Tables 7.2-1 and 7.2-2). Because RP average oyster concentration was so high, and yet concentrations in oysters from nearby stations were not (CC oysters averaged 0.39 mg/kg and CP averaged 0.19 mg/kg), the RP values are difficult to explain. Either the oysters were contaminated after collection, an error occurred

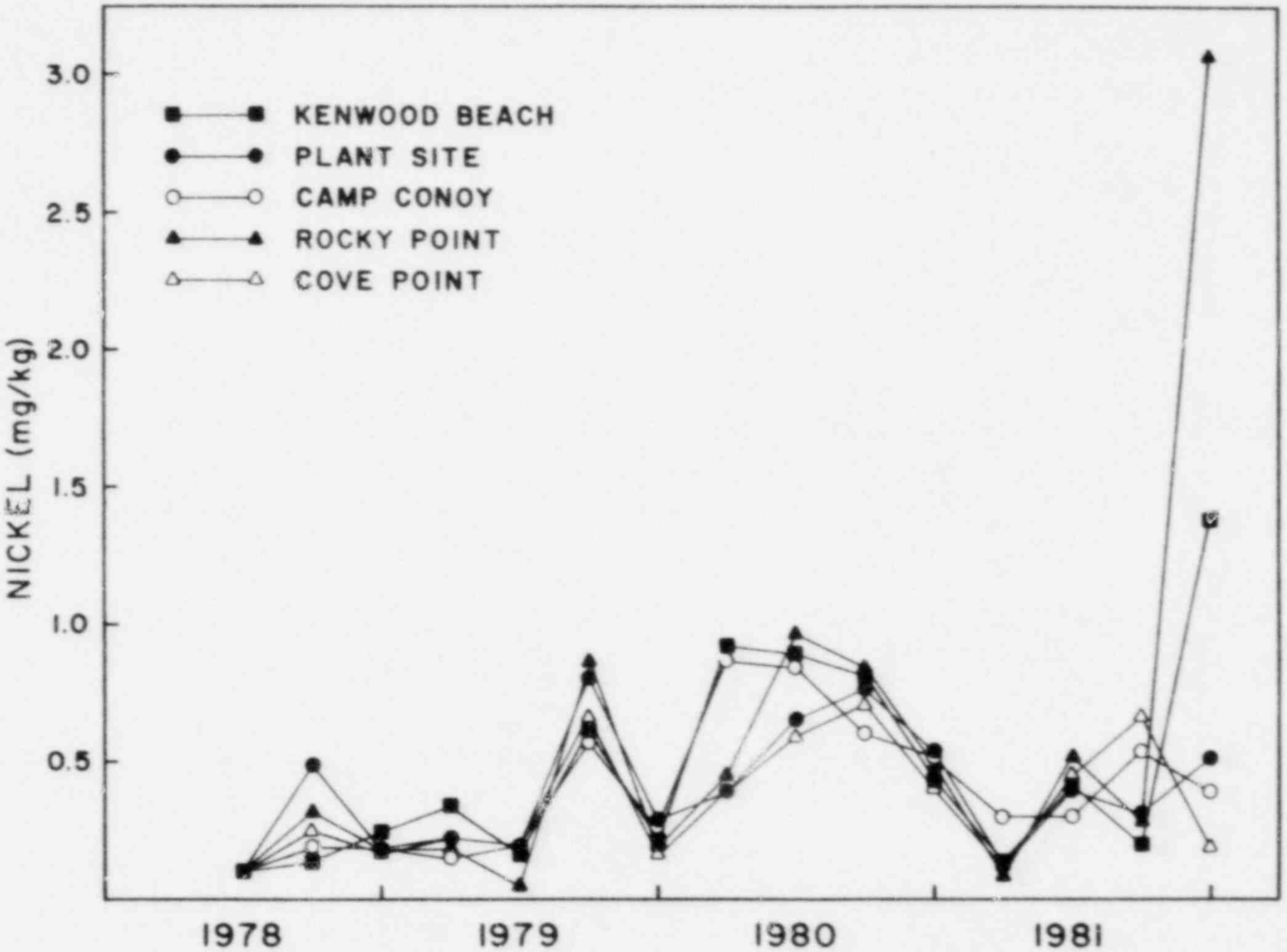

Figure 7.2-2. Mean nickel concentrations (mg/kg wet tissue weight) in oysters collected from five stations in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant from 1978 through 1981.

during analysis, or nickel contamination actually occurred in the vicinity of RP. If a spill did occur, then the CCNPP can be eliminated as a possible source because of the much lower concentrations at PS (0.51 mg/kg) and CC (Table 7.2-3).

Analysis of 1981 data, with December data included, show highly significant station and season effects ($p<0.001$) with RP and December different from all other stations and months, respectively, due to the extreme nickel concentrations in December at RP. Analyzing the data with December excluded revealed a season effect ($p=0.001$), but no station effect ($p=0.405$). The season comparison is shown below (values in mg/kg wet weight).

March	September	June
0.151	0.399	0.414

Analysis of 1979-81 data included December 1981 since its removal would have required removal of December 1980 and 1979 also. Significant station, season and year effects were detected; comparisons are presented below.

CP	PS	CC	KB	RP
0.386	0.431	0.457	0.536	0.665

March	June	December	September
0.325	0.443	0.601	0.611

1979	1981	1980
0.317	0.518	0.651

In contrast to copper, no station or season was unique for nickel. The fact that PS had one of the lowest average concentrations, however, indicates the lack of effect of the CCNPP on the amount of nickel concentrated by oysters.

Zinc (1980-81)

Initial zinc concentrations were not determined when oysters were analyzed at the time they were set out in June 1978; no analyses for zinc were done from 1977-1979. Zinc concentrations were determined in 1980 and 1981 mainly to evaluate copper-zinc relationships. Analysis of 1981 data revealed no station differences for zinc ($p=0.108$) although PS did have the highest average (526 mg/kg) (Table 7.2-3). There was, however, a season effect ($p=0.038$); comparisons are shown below. Values are in mg/kg wet weight.

March	December	June	September
307	428	448	538

Zinc data for 1980 and 1981 are plotted in Figure 7.2-3. An analysis of these data revealed significant differences for season ($p=0.011$) and for year ($p=0.002$), but again no station effect ($p=0.199$). Analysis of the 2-yr data set showed the highest average was at RP, thus the use of zinc sacrificial anodes on the screens at the plant appears to have little, if any, effect on zinc concentrations in oysters at the plant site. Comparisons for season and year are presented below.

June	March	December	September
417	468	477	594

1981	1980
430	547

Copper/zinc (1980-81)

The copper/zinc ratios reflected the concentrations of these two metals at the sampling stations. Analysis of 1981 data revealed a station effect ($p<0.001$), but no season effect ($p=0.706$). A comparison of 1981 station means is presented below; values are ratios and have no units.

KB	CP	CC	RP	PS
0.030	0.036	0.056	0.074	0.087

Analysis of 1980-81 data revealed a significant station effect ($p<0.001$), but season ($p=0.198$) and year ($p=0.084$) were not significant. Station comparisons are shown below.

KB	CP	CC	RP	PS
0.032	0.044	0.062	0.067	0.099

These results are expected since highly significant station effects were found for copper and no station effect was found for zinc. Thus a station effect similar to that for copper would be expected. Copper/zinc means, in fact, ranked the same as 1981 copper means and almost the same as 1979-81 copper means. PS was significantly greater than all other stations because it had the highest copper concentrations, and zinc concentrations were similar at all stations. If there were no man-related copper contamination in the area, and all copper and zinc came from natural sources, then the ratios would be similar at all stations (Huggett, Bender, and Slone, 1973). Because copper and zinc are geochemically similar, and because

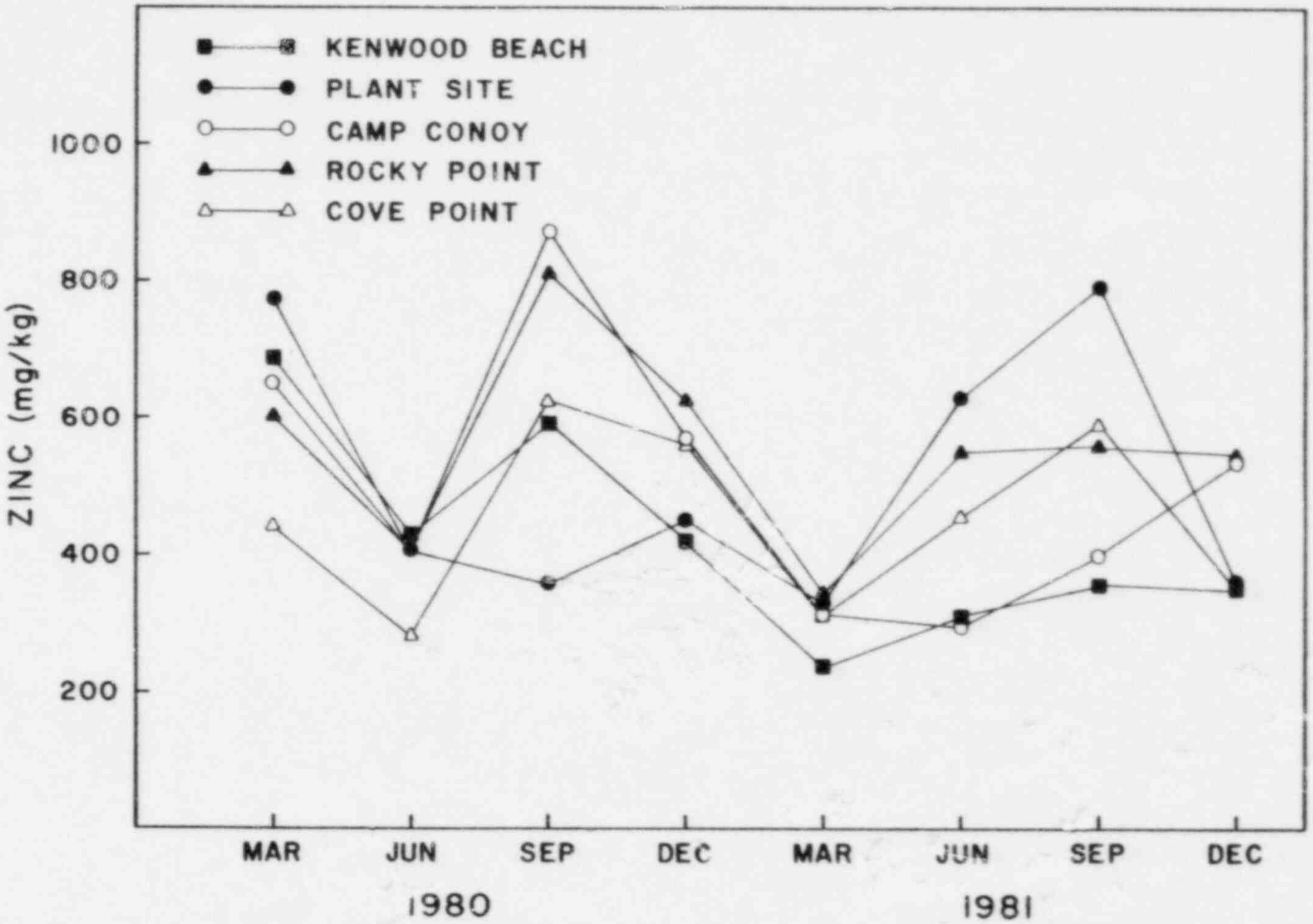

Figure 7.2-3. Mean zinc concentrations (mg/kg wet tissue weight) in oysters collected from five stations in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant during 1980 and 1981.

PS had the highest concentrations of copper, one would expect to find high concentrations of zinc there also. However, since zinc concentrations were not higher at PS than elsewhere, a man-related source of copper must be located somewhere near PS.

1973-1981

In 8 years of study, copper concentrations have ranged from 4-200 mg/kg wet weight, well within the ranges detected by others (Pringle et al., 1968; Shuster and Pringle, 1969). The data from oysters collected at KB and PS were analyzed by a three-factor ANOVA (by period, season and station) and a significant difference between the 41.0 mg/kg of the preoperational period and the 31.7 mg/kg of the operational period was determined ($p=0.025$). No season effect was evident, but station was highly significant ($p=0.001$). During the entire 8-yr period, copper concentration at KB averaged 18.7 mg/kg while at PS it averaged 49.0 mg/kg. This difference also indicates a copper source in the PS area.

During the preoperational period, mean copper concentration at KB was 31.3 mg/kg and since operation began the level has decreased to 17.0 mg/kg (a 46% decrease). A decrease was also observed at PS where the preoperational concentration (60.3 mg/kg) decreased to 48.2 mg/kg (a 20% decrease). Since the difference between KB and PS was 29.0 mg/kg during the preoperational period and 31.2 mg/kg during the operational period, it appears that environmental conditions at the two stations have not changed relative to each other. However, since PS copper concentrations continued to be much higher than those at KB, it was unclear whether the source of the copper was bottom sediments, the CCNPP or another unidentified source.

To resolve this question, zinc concentrations and copper/zinc ratios were examined. Analysis of zinc data revealed a significant difference between the preoperational and operational periods ($p<0.05$), but no other differences were detected. Preoperational concentrations at KB and PS were 943 and 1097 mg/kg, respectively. During the operational period, concentrations decreased to 434 and 509 mg/kg for these same stations (a 54% decrease at each station).

The analysis of copper/zinc ratios revealed a highly significant station effect ($p<0.001$) as well as a significant period effect ($p<0.01$). KB has averaged 0.033 copper/zinc over all years examined while PS has averaged 0.092 for the same years. When periods were examined, the preoperational period was found to have a 0.040 copper/zinc ratio and the operational period had a 0.064 copper/zinc ratio. The ratio of copper to zinc at KB during the preoperational period was 0.031 and increased to 0.038 during the operational period, a 9.7% increase (Fig. 7.2-4). However, at PS, the copper/zinc ratio during the preoperational period was 0.057 and increased to 0.098 (a 71.9%

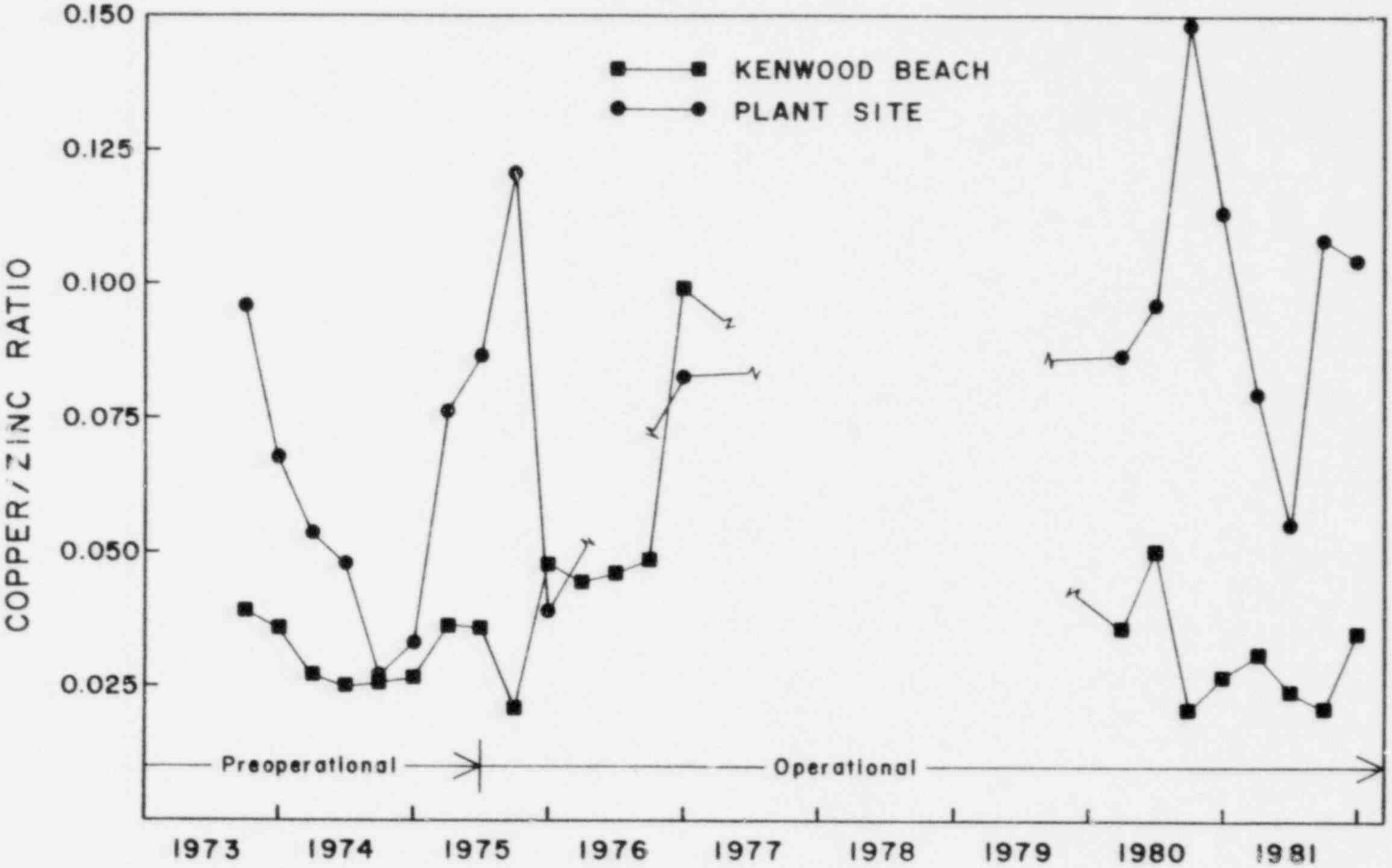

Figure 7.2-4. Copper-zinc ratios computed from data for oysters collected at two stations in Chesapeake Bay near the Calvert Cliffs Nuclear Power Plant from 1973 through 1976 and during 1980 and 1981.

increase). These ratio increases resulted from the large reductions in zinc concentrations, not from copper increases. Nevertheless, if the ratio of copper to zinc in non-industrialized areas is as constant as Huggett, Bender, and Slone (1973) suggest, then PS copper should have decreased (along with zinc) even more than it did. Based on means for copper and copper/zinc ratios determined from this study, it appears that a man-related copper source exists in the PS area. However, comparisons of preoperational and operational data, which show higher copper levels and higher copper/zinc ratios at PS than at KB before the plant began operating, indicate a source of copper in the area other than the plant. The fact that copper/zinc ratios increased during the operational period compared to the preoperational period indicates some additional input from the CCNPP. It has been reported that corrosion of condenser tubing can cause additions of copper to the environment (O'Connor, 1976), and Abbe and Krueger (1977) have shown that the Morgantown Generating Station on the Potomac River was a source of copper for oysters, although most of the uptake was by oysters in the Morgantown effluent canal and not by oysters in the receiving water. Although the CCNPP is probably releasing some copper, the amount is small; and concentrations in oysters at PS, while higher than at other stations, are well within acceptable limits.

In more than 8 years of study, nickel levels in oysters have ranged from about 0.01 mg/kg wet weight to 9.0 mg/kg, a range of values so far above those detected by Pringle et al. (1968) that its validity must be questioned. However, from 1976, when the Academy's instrument technology was refined, through 1980, nickel concentrations have ranged from about 0.01 to 2.05 mg/kg. No station mean exceeded 1.00 mg/kg during the 1977-80 period. However, two stations had high averages in December 1981 (1.38 mg/kg at KB and 3.07 mg/kg at RP). The reason for these high levels is unknown.

The computed nickel means for the preoperational and operational periods were 2.50 mg/kg (Table 7.2-1) and 0.50 mg/kg (Tables 7.2-1 through 7.2-3), respectively. Where less-than signs appear in Tables 7.2-1 and 7.2-2, maximum values were used for computation of means; thus, means are slightly high. The periods differed significantly ($p<0.05$), but as mentioned earlier, the validity of some preoperational data is questioned.

No difference was detected between the mean nickel concentration at KB (0.71 mg/kg) and at PS (0.64 mg/kg) for the 8-yr period. Preoperational concentrations at KB and PS were 2.20 and 3.11 mg/kg, respectively. Operational levels decreased to 0.52 and 0.46 mg/kg, respectively, for KB and PS. These data indicate no effect of the CCNPP on concentrations of nickel in oysters in the area of the plant.

Summary and Conclusions

Concentration of copper in oysters in the Calvert Cliffs area of Chesapeake Bay decreased with increasing distance from the CCNPP. Data analyses revealed that copper concentrations in PS oysters during 1981 (43.6 mg/kg) and 1979-81 (43.5 mg/kg) were significantly greater than at all other stations. The lowest station mean was at KB, the station farthest from the plant, averaging 8.8 and 12.4 mg/kg during 1981 and 1979-81, respectively. It was significantly less than all other stations except CP (14.3 mg/kg) in 1981.

The difference in mean copper concentration between KB and PS for the June 1975-December 1981 period was 31.2 mg/kg, compared to 29.0 mg/kg for the preoperational period of September 1973-March 1975. Thus, it is not readily evident from these data that higher copper levels at PS are related to CCNPP operation. However, from examination of zinc data and computed copper/zinc ratios, it is evident that the plant was contributing some copper to the environment. Since the relationship between copper and zinc in an uncontaminated area should remain fairly constant, when zinc concentrations decrease so should those of copper. Zinc concentrations decreased 54% at both KB and PS from the preoperational to the operational period, and copper decreased 46% at KB. Thus, the copper/zinc ratio at KB increased only slightly. However, the copper concentration at PS decreased only 20%, causing a substantial increase in the copper/zinc ratio. It is this increase in the copper/zinc ratio that indicates that the CCNPP is one source of copper in addition to another, unidentified source which existed before the plant began operating.

Nickel concentrations are not related to plant operation, and have been much lower during the operating phase of this study than during the preoperational period. In addition, concentrations at KB and PS were about the same within the two periods.

From these data, it is evident that the CCNPP has added some copper to the waters of Chesapeake Bay in the immediate vicinity of the plant, but such additions have been small and have not adversely affected the oysters in this area. While concentrations of copper in oysters were higher at PS than at other stations, they were nevertheless well within acceptable limits. No effects on nickel or zinc concentrations resulting from plant operation were detected.

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IMPINGEMENT STUDIES. 1. IMPINGEMENT COUNTS

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Introduction

Studies at Calvert Cliffs Nuclear Power Plant (CCNPP) have been carried out annually since 1975 to determine species composition and to estimate numbers, weight, and size of fish and selected invertebrates impinged during the year.

Approximately 9.08 x 10^6 l/min (2.4 x 10^6 gal/min) of Chesapeake Bay water are circulated through the CCNPP condensers for cooling. The water passes under a 171-m long curtain wall, which extends from slightly above the water surface to a depth of 8.5 m, at a velocity of less than 0.15 m/sec. The cooling water is drawn approximately 91.4 m across an embayment into the intake structure, where the velocity increases to 0.3 m/sec. At the intake, organisms unable to avoid the current or those that move with it encounter 10 pairs (6 pairs at Unit 1, 4 pairs at Unit 2) of rotating, 1-cm^2 mesh screens, and two pairs of 12.7-mm x 3.2-mm Royce screens (at Unit 2). Each of the six pairs of screens servicing each unit rotates in succession for a period of 10 minutes and remains stationary during the other 50 minutes of every hour. Organisms larger than the mesh size may be impinged on these screens; as the screen rotates, impinged organisms are washed into a trough and returned to the Chesapeake Bay.

In this report, data for impinged organisms collected from January through December 1981 are examined.

Materials and Methods

Sampling frequency was based on 6-day cycles. On each sampling day, 1-h collections were made at each of the two generating units (if one unit was not in operation, all samples were collected at the operating unit). At Unit 1 a collecting net was placed in the trough and left for approximately 1 h. At Unit 2 this same net (consisting of 1.27-cm stretch-mesh nylon) was placed in the trough and left for 40 min to sample screens 21-24 (standard mesh screens) and then placed in the trough and left for 10-min to sample screens 25 A & B and 10 min for screens 26 A & B (Royce screens).

The unit to be sampled first alternated each day. The initial 6-day sampling period, and succeeding odd-numbered 6-day periods, were scheduled as follows: the first collection began at 0000, 0400, 0800, 1200, 1600, 2000 h on the 1st, 2nd, 3rd, 4th, 5th and 6th days, respectively. The second collections on each day began 2 h after the first collections had begun. The second 6-day sampling period, and succeeding even-numbered sampling periods were scheduled as follows: the first collections began at 0100, 0500, 0900, 1300, 1700 and 2100 h on the 1st, 2nd, 3rd, 4th, 5th, and 6th days, respectively. On each day the second collection began 2 h after the first had begun. Therefore, all hours of the day were sampled in two 6-day sampling periods.

Impinged organisms were identified to species and the number of each species collected was counted. Lengths of up to 50 individuals of each species (carapace width for blue crab, *Callinectes sapidus*) collected were measured at Unit 1 and from screens 21-24 (standard screens) at Unit 2. Lengths of fish impinged on the Royce screens (25 A & B, 26 A & B) were obtained during the survival study and are analyzed in Section 8.2 (Survival Estimates of Impinged Fish). A total weight for each species was also obtained. Before each sample was collected, the number of circulators operating was noted.

Numbers of coelenterates and ctenophores were estimated by counting three 5-minute sub-samples each hour and expanding these numbers to obtain the estimated number impinged per hour. The Unit 2 estimates were made from pooled samples from the standard mesh and Royce screens.

Statistical Methods

The mean count and weight of each species impinged per hour at each unit were calculated for each month. These mean values were multiplied by the total number of operating hours in the month for each unit to provide estimates of monthly impingement rates for each species. Estimates for yearly totals were made by summing all monthly estimates.

Variance estimates were based upon procedures in Cochran (1977). The variance of each monthly estimate was calculated as:

$$\frac{N_i(N_i - n_i)}{n_i} \times var_i$$

where N_i=total number of operating hours in month i

n_i=number of hourly samples in month i

var_i=variance of the n_i samples

Variances of the yearly estimates were calculated as the sum of the monthly variances. Approximate 95% confidence limits were calculated as $\bar{X} \pm 1.96\sqrt{\Sigma var_i}$, where $\bar{X}$ = the monthly estimate of total individuals impinged for each species.

Differences between the numbers of individuals impinged on the standard and on the Royce screens were analyzed statistically using paired t-tests. Samples containing at least one impinged individual of the species being analyzed at either Screens 21-24 (Standard screens) or 25 A & B and 26 A & B (Royce screens) were included; those samples with no individuals impinged were excluded. Each test observation thus consisted of the difference between the log of the numbers impinged on standard screens plus one and the log of twice the number impinged on Royce screens plus one (because there were only half the number of Royce screens). This transformation was used to normalize the data. The paired t-tests then tested the significance of the difference between the two screen types over the entire sample set. Analyses were performed for blue crabs, menhaden, bay anchovy, spot, hogchoker, and the total of all species of fish and blue crabs.

Results and Discussion

A total of 46,244 fish was collected at both units combined in 1981 compared to a total of 55,735 in 1980 (Hirshfield, Hixson, and White, 1981). The total number of each species, and the number of male and female blue crabs (*Callinectes sapidus*) collected at both units combined for each month are presented in Table 8.1-1. Total number of each species, number of male and female blue crabs, the number of hours sampled each month and the mean number of fish collected each hour are presented in Tables 8.1-2 (Unit 1), 8.1-3 (Unit 2 all screens), 8.1-4 (Unit 2 screens 21-24), 8.1-5 (Unit 2 screens 25 A & B) and 8.1-6 (Unit 2 screens 26 A & B). Finfish species dominant in collections at each unit included bay anchovy (*Anchoa mitchilli*), hogchoker (*Trinectes maculatus*), spot (*Leiostomus xanthurus*), and Atlantic menhaden (*Brevoortia tyrannus*). These species accounted for 90.3% of the total catch at both units combined, 80.0% of the catch at Unit 1 and 93.2% at Unit 2.

A total of 10,225 finfish was collected at Unit 1 (Table 8.1-2) during 1981. At Unit 2 (all screens combined, Table 8.1-3), a total of 36,019 finfish was collected. Of the 36,019 fish collected at Unit 2, 15,398 were collected from screens 25 A & B (Royce screens, Table 8.1-5) and 9899 were collected from 26 A & B (Royce screens, Table 8.1-6); the remainder (10,722) were collected from the four pairs of standard screens (Table 8.1-4). The majority of bay anchovy (82.3%) and spot (82.4%) collected at Unit 2 were collected from the two pairs of Royce screens, in large part accounting for the higher numbers collected at the Royce screens. Blue crabs were also collected in

Table 8.1-1. Total number of fish of various species and blue crabs (*Callinectes sapidus*) collected monthly at Units 1 and 2 during impingement studies at the Calvert Cliffs Nuclear Power Plant, January through December 1981.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Anguilla rostrata	3	5	3	0	0	2	0	0	0	0	0	1	14
Alosa aestivalis	247	306	9	8	0	416	18	2	0	0	0	8	1014
Alosa pseudoharengus	19	8	0	0	0	0	0	0	0	0	0	0	27
Brevoortia tyrannus	7	0	116	83	165	579	123	8	3	2	35	352	1473
Dorosoma cepedianum	1	8	27	0	0	0	0	0	0	0	0	0	36
Anchoa mitchilli	584	0	4	1807	3285	13,476	676	0	21	13	216	53	20,135
Notemigonus crysoleucas	0	0	0	1	0	0	0	0	0	0	0	0	1
Opsanus tau	0	0	0	0	2	216	404	79	6	0	6	3	716
Gobiesox strumosus	11	0	1	1	0	0	0	0	0	1	75	20	109
Urophycis regius	0	0	1	5	0	2	0	0	0	0	0	0	8
Strongylura marina	0	0	0	0	0	0	0	0	0	1	0	0	1
Cyprinodon variegatus	0	0	0	4	1	0	0	0	0	0	1	0	6
Fundulus diaphanus	0	0	1	0	0	0	0	0	0	0	0	0	1
Fundulus heteroclitus	0	0	0	0	1	0	0	0	0	0	2	0	3
Fundulus majalis	0	0	0	0	0	0	0	0	0	0	3	0	3
Membras martinica	0	0	0	0	0	0	0	0	0	0	1	0	1
Menidia beryllina	0	0	0	0	0	0	0	0	0	0	1	0	1
Menidia menidia	146	62	72	1	0	9	0	0	0	3	12	44	349
Apeltes quadracus	0	0	2	0	0	0	0	0	0	0	0	0	2
Gasterosteus aculeatus	2	22	12	0	1	0	0	0	0	0	0	0	37
Hippocampus erectus	0	0	0	1	1	1	0	0	0	0	0	1	4
Syngnathus fuscus	2	0	1	0	3	1	0	0	1	1	5	2	16
Prionotus carolinus	0	0	0	0	0	0	8	4	0	0	0	0	12
Morone americana	1	4	4	0	0	0	0	0	0	0	0	0	9
Morone saxatilis	0	0	1	0	0	0	0	0	0	0	0	0	1
Lepomis gibbosus	0	0	2	0	1	0	0	0	0	0	0	0	3
Perca flavescens	0	0	5	0	0	0	0	0	0	0	0	0	5
Cynoscion regalis	0	0	0	0	0	0	0	0	0	4	5	5	14
Leiostomus xanthurus	0	0	0	0	3034	2697	561	37	0	0	6	63	6398
Micropogonias undulatus	338	0	0	0	0	0	0	0	0	0	4	467	809
Hypsoblennius hentzi	0	0	0	0	1	0	0	0	0	2	4	0	7
Chasmodes bosquianus	0	0	0	0	0	0	0	0	0	0	1	0	1
Peprilus triacanthus	0	0	0	0	0	0	0	0	4	2	6	8	20
Paralichthys dentatus	3	0	1	3	0	0	16	7	1	0	1	2	34
Scophthalmus aquosus	0	0	1	0	0	0	0	0	0	0	0	0	1
Pseudopleuronectes americanus	1	0	1	0	110	958	143	0	0	0	0	3	1216
Trinectes maculatus	1	0	2	6	24	7899	4480	1297	32	0	10	6	13,757
Total Fish	1366	415	266	1920	6629	26,256	6429	1434	68	29	394	1038	46,244
Callinectes sapidus ♂	0	0	0	1444	1170	5214	10,103	2796	84	296	55	0	21,162
♀	0	0	0	1883	1125	9181	11,867	3339	811	1527	358	4	30,095

Table 8.1-2. Total number of fish of various species and blue crab (*Callinectes sapidus*), number of hours sampled and mean number of fish collected per hour for each month at Unit 1 during impingement studies at the Calvert Cliffs Nuclear Power Plant, January through December 1981.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Anguilla rostrata	0	5	3	0	0	1	0	0	0	0	0	0	9
Alosa aestivalis	246	306	7	2	0	140	8	1	0	0	0	2	712
Alosa pseudoharengus	19	8	0	0	0	0	0	0	0	0	0	0	27
Brevoortia tyrannus	0	0	43	26	12	264	42	2	0	1	13	136	539
Dorosoma cepedianum	0	8	26	0	0	0	0	0	0	0	0	0	34
Anchoa mitchilli	12	0	0	308	267	855	217	0	9	3	52	10	1733
Opsanus tau	0	0	0	0	2	97	127	40	3	0	1	1	271
Gobiesox strumosus	3	0	1	1	0	0	0	0	0	0	13	12	30
Urophycis regius	0	0	1	3	0	1	0	0	0	0	0	0	5
Fundulus diaphanus	0	0	1	0	0	0	0	0	0	0	0	0	1
Fundulus heteroclitus	0	0	0	0	0	0	0	0	0	0	1	0	1
Fundulus majalis	0	0	0	0	0	0	0	0	0	0	3	0	3
Membras martinica	0	0	0	0	0	0	0	0	0	0	1	0	1
Menidia menidia	84	62	60	0	0	3	0	0	0	0	5	18	232
Gasterosteus aculeatus	2	22	12	0	0	0	0	0	0	0	0	0	36
Hippocampus erectus	0	0	0	1	0	1	0	0	0	0	0	1	3
Syngnathus fuscus	1	0	0	0	1	0	0	0	0	0	3	0	5
Prionotus carolinus	0	0	0	0	0	0	2	2	0	0	0	0	4
Morone americana	0	4	1	0	0	0	0	0	0	0	0	0	5
Morone saxatilis	0	0	1	0	0	0	0	0	0	0	0	0	1
Lepomis gibbosus	0	0	2	0	0	0	0	0	0	0	0	0	2
Perca flavescens	0	0	5	0	0	0	0	0	0	0	0	0	5
Cynoscion regalis	0	0	0	0	0	0	0	0	0	2	0	2	4
Leiostomus xanthurus	0	0	0	0	15	519	129	15	0	0	0	18	696
Micropogonias undulatus	0	0	0	0	0	0	0	0	0	0	0	193	193
Hypsoblennius hentzi	0	0	0	0	0	0	0	0	0	0	2	0	2
Peprilus triacanthus	0	0	0	0	0	0	0	0	4	1	3	3	11
Paralichthys dentatus	0	0	0	1	0	0	3	4	0	0	1	0	9
Pseudopleuronectes americanus	1	0	1	0	25	343	67	0	0	0	0	2	439
Trinectes maculatus	1	0	1	3	3	3136	1425	625	14	0	3	1	5212
Total Fish	369	415	165	345	325	5360	2020	689	30	7	101	399	10,225
Number of Hours Sampled	27	34	29	19	20	19	19	20	19	17	20	18	261
Mean No. Fish Per Hour	13.67	12.21	5.69	18.16	16.25	282.11	106.32	34.45	1.58	0.41	5.05	22.17	39.18
Callinectes sapidus ♂	0	0	0	482	345	2638	4027	1460	45	60	30	0	9087
♀	0	0	0	666	314	4892	4683	1769	462	465	157	2	13,410

Table 8.1-3. Total number of fish of various species and blue crabs (*Callinectes sapidus*), number of hours sampled and mean number of fish collected per hour for each month at Unit 2 (all screens) during impingement studies at the Calvert Cliffs Nuclear Power Plant, January through December 1981.

Species	Jan	Feb*	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Anguilla rostrata	3	-	0	0	0	1	0	0	0	0	0	1	5
Alosa aestivalis	1	-	2	6	0	276	10	1	0	0	0	6	302
Brevoortia tyrannus	7	-	73	57	153	315	81	6	3	1	22	216	934
Dorosoma cepedianum	1	-	1	0	0	0	0	0	0	0	0	0	2
Anchoa mitchilli	572	-	4	1499	3018	12,621	459	0	12	10	164	43	18,402
Notemigonus crysoleucas	0	-	0	1	0	0	0	0	0	0	0	0	1
Opsanus tau	0	-	0	0	0	119	277	39	3	0	5	2	445
Gobiesox strumosus	8	-	0	0	0	0	0	0	0	1	62	8	79
Urophycis regius	0	-	0	2	0	1	0	0	0	0	0	0	3
Strongylura marina	0	-	0	0	0	0	0	0	0	1	0	0	1
Cyprinodon variegatus	0	-	0	4	1	0	0	0	0	0	1	0	6
Fundulus heteroclitus	0	-	0	0	1	0	0	0	0	0	1	0	2
Menidia beryllina	0	-	0	0	0	0	0	0	0	0	1	0	1
Menidia menidia	62	-	12	1	0	6	0	0	0	3	7	26	117
Apeltes quadracus	0	-	2	0	0	0	0	0	0	0	0	0	2
Gasterosteus aculeatus	0	-	0	0	1	0	0	0	0	0	0	0	1
Hippocampus erectus	0	-	0	0	1	0	0	0	0	0	0	0	1
Syngnathus fuscus	1	-	1	0	2	1	0	0	1	1	2	2	11
Prionotus carolinus	0	-	0	0	0	0	6	2	0	0	0	0	8
Morone americana	1	-	3	0	0	0	0	0	0	0	0	0	4
Lepomis gibbosus	0	-	0	0	1	0	0	0	0	0	0	0	1
Cynoscion regalis	0	-	0	0	0	0	0	0	0	2	5	3	10
Leiostomus xanthurus	0	-	0	0	3019	2178	432	22	0	0	6	45	5702
Micropogonias undulatus	338	-	0	0	0	0	0	0	0	0	4	274	616
Hypsoblennius hentzi	0	-	0	0	1	0	0	0	0	2	2	0	5
Chasmodes bosquianus	0	-	0	0	0	0	0	0	0	0	1	0	1
Peprilus triacanthus	0	-	0	0	0	0	0	0	0	1	3	5	9
Paralichthys dentatus	3	-	1	2	0	0	13	3	1	0	0	2	25
Scophthalmus aquosus	0	-	1	0	0	0	0	0	0	0	0	0	1
Pseudopleuronectes americanus	0	-	0	0	85	615	76	0	0	0	0	1	777
Trinectes maculatus	0	-	1	3	21	4763	3055	672	18	0	7	5	8545
Total Fish	997	-	101	1575	6304	20896	4409	745	38	22	293	639	36,019
Number of Hours Sampled	13	-	17	19	22	19	25	20	16	25	17	18	211
Mean No. Fish Per Hour	76.69	-	5.94	82.89	286.55	1099.79	176.36	37.25	2.38	0.88	17.24	35.50	170.71
Callinectes sapidus ♂	0	-	0	962	825	2576	6076	1336	39	236	25	0	12,075
♀	0	-	0	1217	811	4289	7184	1570	349	1062	201	2	16,685

* Unit Shut Down

Table 8.1-4. Total number of fish of various species and blue crabs (*Callinectes sapidus*), number of hours sampled and mean number of fish collected per hour for each month at Unit 2 (standard screens 21-24) during impingement studies at the Calvert Cliffs Nuclear Power Plant, January through December 1981.

Species	Jan*	Feb**	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Anguilla rostrata	3	-	0	0	0	1	0	0	0	0	0	0	4
Alosa aestivalis	1	-	2	3	0	122	2	0	0	0	0	0	130
Brevoortia tyrannus	7	-	42	44	23	220	51	5	2	1	14	111	520
Dorosoma cepedianum	1	-	1	0	0	0	0	0	0	0	0	0	2
Anchoa mitchilli	572	-	3	247	393	1827	139	0	3	5	44	18	3251
Opsanus tau	0	-	0	0	0	82	150	22	0	0	3	1	258
Gobiesox strumosus	8	-	0	0	0	0	0	0	0	0	25	3	36
Urophycis regius	0	-	0	0	0	1	0	0	0	0	0	0	1
Cyprinodon variegatus	0	-	0	0	1	0	0	0	0	0	0	0	1
Menidia menidia	62	-	3	0	0	5	0	0	0	3	3	11	87
Hippocampus erectus	0	-	0	0	1	0	0	0	0	0	0	0	1
Syngnathus fuscus	1	-	0	0	0	0	0	0	0	0	0	1	2
Prionotus carolinus	0	-	0	0	0	0	3	1	0	0	0	0	4
Morone americana	1	-	2	0	0	0	0	0	0	0	0	0	3
Cynoscion regalis	0	-	0	0	0	0	0	0	0	1	1	0	2
Leiostomus xanthurus	0	-	0	0	23	719	229	9	0	0	4	19	1003
Micropogonias undulatus	338	-	0	0	0	0	0	0	0	0	2	108	448
Hypsoblennius hentzi	0	-	0	0	0	0	0	0	0	2	0	0	2
Chasmodes bosquianus	0	-	0	0	0	0	0	0	0	0	1	0	1
Peprilus triacanthus	0	-	0	0	0	0	0	0	0	0	3	2	5
Paralichthys dentatus	3	-	1	0	0	0	2	3	0	0	0	2	11
Scophthalmus aquosus	0	-	1	0	0	0	0	0	0	0	0	0	1
Pseudopleuronectes americanus	0	-	0	0	11	157	37	0	0	0	0	0	205
Trinectes maculatus	0	-	1	2	14	2911	1399	403	10	0	3	1	4744
Total Fish	997	-	56	296	466	6045	2012	443	15	12	103	277	10,722
Number of Hours Sampled	13.00	-	11.34	12.66	14.66	12.66	16.66	13.33	10.66	16.66	11.33	12.00	128.63
Mean No. Fish Per Hour	76.69	-	4.94	23.38	31.79	477.49	120.77	33.23	1.41	0.72	9.09	23.08	83.36
Callinectes sapidus ♂	0	-	0	405	514	1471	3712	781	22	122	15	0	7042
♀	0	-	0	527	435	2601	4224	912	205	616	70	0	9590

*All Screens Sampled
**Unit Shut Down

Table 8.1-5. Total number of fish of various species and blue crabs (*Callinectes sapidus*), number of hours sampled and mean number of fish collected per hour for each month at Unit 2 (Royce screens 25 A & B) during impingement studies at the Calvert Cliffs Nuclear Power Plant, January through December 1981.

Species	Jan*	Feb**	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Anguilla rostrata	-	-	0	3	0	119	3	0	0	0	0	3	128
Brevoortia tyrannus	-	-	19	6	58	44	17	1	0	0	6	46	197
Anchoa mitchilli	-	-	0	1086	1056	8388	179	0	4	1	74	15	10,803
Notemigonus crysoleucas	-	-	0	1	0	0	0	0	0	0	0	0	1
Opsanus tau	-	-	0	0	0	9	42	6	2	0	0	1	60
Gobiesox strumosus	-	-	0	0	0	0	0	0	0	1	13	0	14
Strongylura marina	-	-	0	0	0	0	0	0	0	1	0	0	1
Cyprinodon variegatus	-	-	2	0	0	0	0	0	0	0	0	0	2
Fundulus heteroclitus	-	-	0	0	0	0	0	0	0	0	1	0	1
Menidia menidia	-	-	3	1	0	1	0	0	0	0	1	3	9
Syngnathus fuscus	-	-	0	0	0	1	0	0	1	0	1	0	3
Prionotus carolinus	-	-	0	0	0	0	2	1	0	0	0	0	3
Morone americana	-	-	1	0	0	0	0	0	0	0	0	0	1
Cynoscion regalis	-	-	0	0	0	0	0	0	0	1	1	0	2
Leiostomus xanthurus	-	-	0	0	1536	757	78	3	0	0	1	6	2381
Micropogonias undulatus	-	-	0	0	0	0	0	0	0	0	2	64	66
Hypsoblennius hentzi	-	-	0	0	1	0	0	0	0	0	1	0	2
Peprilus triacanthus	-	-	0	0	0	0	0	0	0	0	0	2	2
Paralichthys dentatus	-	-	0	0	0	0	4	0	1	0	0	0	5
Pseudopleuronectes americanus	-	-	0	0	10	139	18	0	0	0	0	1	168
Trinectes maculatus	-	-	0	0	3	732	655	150	4	0	3	2	1549
Total w/crabs 21,089													
Total Fish	-	-	23	1099	2664	10,190	998	161	12	4	104	143	15,398
Number of Hours Sampled	-	-	2.83	3.17	3.67	3.17	4.17	3.33	2.67	4.17	2.83	3.00	33.01
Mean No. Fish Per Hour	-	-	8.13	346.69	725.89	3214.51	339.33	48.35	4.49	0.96	36.75	47.67	466.46
Callinectes sapidus ♂	-	-	0	227	118	479	1074	275	11	58	7	0	2249
♀	-	-	0	323	189	811	1419	327	76	228	67	2	3442

*All Screens Sampled Together, Totals on Table 8.1-3.
**Unit Shut Down

Table 8.1-6. Total number of fish of various species and blue crabs (*Callinectes sapidus*), number of hours sampled and mean number of fish collected per hour for each month at Unit 2 (Royce screens 26 A & B) during impingement studies at the Calvert Cliffs Nuclear Power Plant, January through December 1981.

Species	Jan*	Feb**	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Anguilla rostrata	-	-	0	0	0	0	0	0	0	0	0	1	1
Alosa aestivalis	-	-	0	0	0	35	5	1	0	0	0	3	44
Brevoortia tyrannus	-	-	12	7	72	51	13	0	1	0	2	59	217
Anchoa mitchilli	-	-	1	166	1569	2406	141	0	5	4	46	10	4348
Opsanus tau	-	-	0	0	0	28	85	11	1	0	2	0	127
Gobiesox strumosus	-	-	0	0	0	0	0	0	0	0	24	5	29
Urophycis regius	-	-	0	2	0	0	0	0	0	0	0	0	2
Cyprinodon variegatus	-	-	0	2	0	0	0	0	0	0	1	0	3
Fundulus heteroclitus	-	-	0	0	1	0	0	0	0	0	0	0	1
Menidia beryllina	-	-	0	0	0	0	0	0	0	0	1	0	1
Menidia menidia	-	-	6	0	0	0	0	0	0	0	3	12	21
Apeltes quadracus	-	-	2	0	0	0	0	0	0	0	0	0	2
Gasterosteus aculeatus	-	-	0	0	1	0	0	0	0	0	0	0	1
Syngnathus fuscus	-	-	1	0	2	0	0	0	0	1	1	1	6
Prionotus carolinus	-	-	0	0	0	0	1	0	0	0	0	0	1
Lepomis gibbosus	-	-	0	0	1	0	0	0	0	0	0	0	1
Cynoscion regalis	-	-	0	0	0	0	0	0	0	0	3	3	6
Leiostomus xanthurus	-	-	0	0	1460	702	125	10	0	0	1	20	2318
Micropogonias undulatus	-	-	0	0	0	0	0	0	0	0	0	102	102
Hypsoblennius hentzi	-	-	0	0	0	0	0	0	0	0	1	0	1
Peprilus triacanthus	-	-	0	0	0	0	0	0	0	1	0	1	2
Paralichthys dentatus	-	-	0	2	0	0	7	0	0	0	0	0	9
Pseudopleuronectes americanus	-	-	0	0	64	319	21	0	0	0	0	0	404
Trinectes maculatus	-	-	0	1	4	1120	1001	119	4	0	1	2	2252
Total Fish	-	-	22	180	3174	4661	1399	141	11	6	85	219	9899
Number of Hours Sampled	-	-	2.83	3.17	3.67	3.17	4.17	3.33	2.67	4.17	2.83	3.00	33.01
Mean No. Fish Per Hour	-	-	7.77	56.78	864.85	1470.35	335.49	42.34	4.12	1.44	30.39	73.00	449.75
Callinectes sapidus ♂	-	-	0	330	193	626	1290	280	6	56	3	0	2784
♀	-	-	0	367	187	877	1541	331	68	218	64	0	3653

*All Screens Sampled Together, Totals on Table 8.1-3.
**Unit Shut Down

large numbers at both units. A total of 51,257 (21,162 male and 30,095 female) blue crabs was collected at both Units during 1981. A total of 22,497 (9,087 male and 13,410 female) blue crabs was collected at Unit 1 and 28,760 (12,075 male and 16,685 female) blue crabs were collected at Unit 2.

A total of 30 finfish species was collected at Unit 1 (Table 8.1-2) during 261 hours of sampling; 31 were collected at Unit 2 (Table 8.1-3) during 211 hours of sampling effort. A total of 37 finfish species (Table 8.1-1) was collected at both units during 1981. Finfishes collected only at Unit 1 included alewife (*Alosa pseudoharengus*), banded killifish (*Fundulus diaphanus*), striped killifish (*Fundulus majalis*), rough silverside (*Membras martinica*), striped bass (*Morone saxatilis*) and yellow perch (*Perca flavescens*). Finfishes collected only at Unit 2 included golden shiner (*Notemigonus crysoleucas*), Atlantic needlefish (*Strongylura marina*), sheepshead minnow (*Cyprinodon variegatus*), tidewater silverside (*Menidia beryllina*), fourspine stickleback (*Apeltes quadracus*), striped blenny (*Chasmodes bosquianus*), and windowpane (*Scophthalmus aquosus*). These species were rarely collected, generally yielding less than 10 individuals for the year.

The largest numbers of finfish at Unit 1 were collected (Table 8.1-2) in June and July. Largest mean numbers per hour at this unit were also collected during these months with 282.11 and 106.32 fish per hour collected in June and July, respectively. At Unit 2 (Table 8.1-3) largest numbers were collected in May, June and July. Again, largest mean numbers per hour were also collected during these months.

The largest numbers of bay anchovy were collected at both Units in April, May, June and July (Tables 8.1-2 and 8.1-3). These four months accounted for 95.0% of the total bay anchovy catch at Unit 1, and 95.6% of the catch for the year at Unit 2.

Largest numbers of hogchoker were collected at both Units in June, July and August. At Unit 1 (Table 8.1-2) there were 5212 hogchokers collected for the year; at Unit 2 (Table 8.1-3) 8545 were collected during 1981.

Spot were collected in largest numbers at Unit 1 (Table 8.1-2) during June and July. At Unit 2 (Table 8.1-3) largest numbers were collected from May through July; the majority collected in May were from the two pairs of Royce screens. In June and July, totals for the standard and Royce screens were similar.

Atlantic menhaden were collected in largest numbers at Unit 1 (Table 8.1-2) during June and December. At Unit 2 (Table 8.1-3) largest numbers were collected in May, June and December. Seasonal patterns of catch for these four species were similar to those in previous years.

Blue crabs were collected in largest numbers at both Units from April through November. The total number collected at both Units (51,257) was much larger than the 15,091 collected in 1980 (Hirshfield, Hixson and White, 1981). Numbers of blue crabs peaked in July at both units when 8,710 were collected at Unit 1 (Table 8.1-2) and 13,260 were collected at Unit 2 (Table 8.1-3).

The estimated mean numbers of coelenterates and ctenophores collected per hour during each month are presented in Tables 8.1-7 and 8.1-8, respectively. Coelenterates were abundant from May through November. The mean number of coelenterates collected per hour for the year was 1731.4 at Unit 1 and 2530.7 at Unit 2. Ctenophores (Table 8.1-8) were abundant from September through December with 65.5 per hour collected at Unit 1 and 114.5 collected per hour at Unit 2 during 1981.

Monthly estimates and confidence intervals for numbers and total weights for total fish, bay anchovy, spot, hogchoker, Atlantic menhaden and blue crab abundance are presented in Table 8.1-9. Yearly estimates were much higher (3,274,180) than in 1980 (1,605,754; Hirshfield, Hixson and White, 1981); many more blue crabs and hogchokers were collected in 1981.

Statistical analyses determined that more individuals were impinged on the Royce screens than on the standard screens at Unit 2 (Table 8.1-10). All species examined were impinged at higher rates on the Royce screens, with spot and anchovy showing the strongest differences. Two possible explanations exist for this effect, and are not mutually exclusive. The first possibility is that the differences between the screen types result from differences in mesh size; since the Royce screens have a smaller mesh, the differences could be due to impingement of smaller individuals on these screens, individuals that might pass through the standard screens. The second possibility is that the differences are the result of the positions of the screens; because the Royce screens are nearest the side wall of the intake embayment, fish moving along the side wall might be expected to be impinged upon the screens nearest the wall.

Neither hypothesis can be ruled out or confirmed by the available information. If differences between screen types were primarily the result of impingement of smaller fishes on the Royce screens, this fact should have been reflected in differences in the size of fish impinged on the two screen types. Examination of length distributions (Chapter 8.2) does not indicate consistent differences in the mean lengths of impinged fish between the two screen types, although there was a tendency for the fish impinged on the Royce screens to be slightly smaller. If screen position were primarily responsible, there should have been differences between screens 25 A & B and 26 A & B, with the latter showing a higher impingement rate because of its position nearest the wall. Statistical

Table 8.1-7. Mean number of coelenterates collected each hour by month during impingement studies at Units 1 and 2 at the Calvert Cliffs Nuclear Power Plant, 1980.

Month	Unit 1	Unit 2
January	0.0	0.0
February	0.0	*
March	0.0	0.0
April	40.6	125.4
May	1192.8	2624.5
June	2062.9	2654.9
July	3918.2	4563.3
August	8111.2	7810.9
September	5916.5	6671.8
October	2110.9	1753.2
November	153.9	146.0
December	1.5	3.1
Mean no./h for year	1731.4	2530.7

*Unit Shut Down

Table 8.1-8. Mean number of ctenophores collected each hour by month during impingement studies at Units 1 and 2 at the Calvert Cliffs Nuclear Power Plant, 1980.

Month	Unit 1	Unit 2
January	0.0	0.0
February	0.0	*
March	0.0	0.0
April	0.0	0.0
May	6.9	2.1
June	7.2	5.6
July	0.0	0.6
August	0.0	0.0
September	112.6	242.8
October	316.2	410.2
November	186.2	123.9
December	310.3	431.6
Mean no./h for year	65.5	114.5

*Unit Shut Down

Table 8.1-9. Monthly estimate and approximate 95% confidence intervals for total fish, numbers of major fish species, blue crabs and total fish weight impinged at the Calvert Cliffs Nuclear Power Plant, 1981.

Month	Estimate of Fish	95% Confidence Interval	Estimate of Weight (g)
All Species			
J	32169	28045-36293	181664
F	8202	4999-11405	50657
M	7685	4668-10702	122311
A	195243	70765-319721	885649
M	288751	184312-393190	679004
J	1540459	992191-2088727	58196508
J	748701	570928-926474	55870552
A	280860	254841-306879	23564008
S	39426	30102-48750	4163167
O	58382	31403-85361	5322666
N	31233	16079-46387	1294060
D	43069	29425-56713	205036
T	3274180	3155423-3412941	150535282
Anchoa mitchilli			
J	13753	6036-21470	16065
F	0	0-0	0
M	116	4-298	275
A	67239	1807-135565	147598
M	109973	37696-182250	224999
J	510669	69710-951628	1661562
J	17822	13742-21902	61681
A	0	0-0	0
S	860	402-1318	4320
O	410	168-652	1600
N	8360	1411-15309	29775
D	2191	1317-3065	15554
T	731393	634080-828704	2163429

Table 8.1-9 (continued). Monthly estimate and approximate 95% confidence intervals for total fish, numbers of major fish species, blue crabs and total fish weight impinged at the Calvert Cliffs Nuclear Power Plant, 1981.

Month	Estimate of Fish	95% Confidence Interval	Estimate of Weight (g)
Leiostomus xanthurus			
J	0	0-0	0
F	0	0-0	0
M	0	0-0	0
A	0	0-0	0
M	101570	44936-158204	229444
J	102202	31382-173022	290158
J	14790	8197-21383	143800
A	1376	339-2413	7157
S	0	0-0	0
O	0	0-0	0
N	232	6-569	2859
D	2604	1825-3383	52080
T	222774	203084-242466	725498
Trinectes maculatus			
J	24	1-61	415
F	0	0-0	0
M	58	2-125	1681
A	223	57-389	8261
M	803	414-1192	22870
J	299331	163484-435178	9923729
J	118109	100233-135985	4422856
A	47542	37565-57519	1678272
S	1310	551-2069	46624
O	0	0-0	0
N	387	151-623	13308
D	248	6-491	7192
T	468035	438484-497584	16125208

Table 8.1-9 (continued). Monthly estimate and approximate 95% confidence intervals for total fish, numbers of major fish species, blue crabs and total fish weight impinged at the Calvert Cliffs Nuclear Power Plant, 1981.

Month	Estimate of Fish	95% Confidence Interval	Estimate of Weight (g)
Brevoortia tyrannus			
J	165	7-225	1665
F	0	0-0	0
M	3351	379-6323	52612
A	3088	803-5373	77981
M	5524	1235-9813	52764
J	21941	2989-40893	138679
J	3243	1695-4791	63828
A	298	43-553	13689
S	123	3-253	10710
O	63	2-151	3385
N	1355	333-2377	44197
D	14549	10461-18637	113892
T	53700	49337-58063	573402
Callinectes sapidus			
J	0	0-0	0
F	0	0-0	0
M	0	0-0	0
A	123799	53325-194273	814813
M	76830	38865-114795	1055533
J	545495	398721-692269	28206355
J	579209	419268-739150	48549837
A	228222	209656-246788	21468721
S	36642	27713-45571	4045147
O	57468	30431-84505	5299706
N	15984	9070-22898	926092
D	165	14-316	248
T	1663814	1614648-1712980	110366452

Table 8.1-10. Results of statistical comparisons of the difference between impingement rates of major fish species and blue crabs on standard and Royce screens at Unit 2 of the Calvert Cliffs Nuclear Power Plant, 1981. $\alpha = 0.05$.

Species	$\bar{\Delta}$ [a]	t	N	P
Callinectes sapidus	-0.44	-6.2	160	<0.001
Brevoortia tyrannus	-0.3	-2.5	82	<0.05
Anchoa mitchilli	-1.34	-9.9	127	<0.001
Leiostomus xanthurus	-1.76	-7.1	77	<0.001
Trinectes maculatus	-0.41	-5.1	93	<0.001
Total fish and crabs	-0.75	-9.3	194	<0.001

[a] $\bar{\Delta} = (\sum_{i=1}^{N} \Delta_i)/N$; $\Delta_i = \ln (X_{21-24} + 1) - \ln (2(X_{25} + X_{26}) + 1)$, where X_{21-24}, X_{25}, and X_{26} represent the numbers of individuals impinged on Screens 21-24, 25 A and B, and 26 A and B respectively, t is the value from the paired t-test, and N is the number of samples.

analyses of the difference between the two did not show such an effect. Paired t-tests, performed like those used to compare screen types, indicated a significant difference ($p<0.05$) only for hogchokers.

Thus, if there is a position effect, it must cause higher impingement rates at both sets of Royce screens. In conclusion, the reasons for the clear difference in impingement rates between the two types of screens cannot be determined unambiguously. It would appear that screen position is the more likely reason; certainly there is no evidence of a strong difference in the sizes of fish impinged, which would indicate that mesh size was primarily responsible for the difference.

Conclusions

Total fish catch was dominated by four species, bay anchovy, spot, hogchoker and Atlantic menhaden. These four species accounted for 90.3% of the total catch at Units 1 and 2 combined, 80.0% at Unit 1 and 93.2% at Unit 2. Total estimated fish and blue crab catch in 1981 (3,274,180) was higher than the estimated 1980 (1,605,754) catch. More fish per hour were captured at Unit 2, and a significantly larger number of fish and blue crabs at Unit 2 were collected from the Royce screens. Seasonal patterns of impingement appear to be similar to those in previous years.

Literature Cited

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Hirshfield, M. F., J. H. Hixson, III, and J. D. White. 1981. Impingement studies I. Impingement Counts. Pages 9.1-1 to 9.1-14, *in* Non-radiological environmental monitoring report, Calvert Cliffs Nuclear Power Plant. January-December 1980. Baltimore Gas and Electric Company, Baltimore, MD.

IMPINGEMENT STUDIES. 2. SURVIVAL ESTIMATES OF IMPINGED FISH

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Introduction

Calvert Cliffs Nuclear Power Plant (CCNPP) is located on the western shore of the Chesapeake Bay in Calvert County, Maryland. The plant has two units which are capable of generating net electric outputs of 850 MWe each. Both reactors are cooled by a once-through cooling system which uses approximately 9.06 x 10^6 l/min (2.4 x 10^6 gal/min) of Chesapeake Bay water.

Water used for cooling purposes is drawn from the Bay under a 171-m long curtain wall, which extends below the water surface to a depth of 8.5 m. During wintertime plant operation, all removable panels in the curtain wall are left in place, providing a surface barrier (to a depth of 8.5 m) to potentially impingeable species. During summertime operations, three or four panels are removed from the curtain wall to prevent entrapment of fish species which may be adversely affected by dissolved oxygen (DO) sags within the embayment area.

Water entering the embayment area under the curtain wall moves at a velocity of less than 0.15 m/sec. Cooling water travels approximately 91.4 m from the curtain wall to the intake structure and the velocity increases to 0.3 m/sec at the traveling screens. The 12 traveling screens (Link-belt, FMC) at each unit are designed to prevent organisms larger than the 1-cm^2 mesh from entering the plant. Organisms smaller than the screen mesh pass through the plant's condenser system and are returned to the Bay via a submerged discharge conduit.

During normal plant operations, the 12 screens on each unit (6 pairs of standard screens at Unit 1, 4 pairs of standard and 2 pairs of Royce screens at Unit 2) are sequentially operated in pairs (2 rotating screens/circulator pump) for 10 min each hour. During this rotation period, organisms that are impinged during nonrotating periods (50 min of each hour) are removed from the traveling screens with high-pressure water jets and returned to the Bay via a storm-drain system.

The objective of the studies conducted during 1981 was to examine the effects of impingement and transit through the

storm-drain system on the survival rates of fish impinged at Units 1 and 2. A further objective was to examine survival rates at Unit 2, comparing the smaller-mesh Royce screens (0.40 cm^2) vs. standard larger-mesh (1 cm^2) screens.

Materials and Methods

Collections

Faunal collections were made in the animal surveillance pools (9.1 x 3.7 x 0.6 m) located near the terminus of the storm-drain systems for each generating unit. Sampling was conducted Monday-Friday from January through December 1981. A minimum of one sample per day was collected at each unit, but more samples were collected if sufficient time was available. Unit 1 was sampled for 1 hr and at Unit 2 a 20-min sample was collected from Royce screens, and a 40-min sample from standard screens. If either unit was shut down, all samples were collected at the operating unit. The total volume of the storm-drain system for each unit was diverted into the surveillance pools by closing the storm-drain discharge flowgates and opening the gates to the pools. Collection periods were terminated by opening the storm-drain discharge flowgate and closing the pool gate. Observations were made immediately following the collection period.

Numbers of live, dead, and organisms exhibiting loss of equilibrium (LOE) were recorded during each observation. The criterion for death was failure to exhibit opercular or all other overt movements whether induced spontaneously or in response to mild mechanical stimulation. The criterion for LOE was the inability of fish to maintain an upright position in the water. A maximum of 25 individuals of each species (haphazardly chosen if more than 25 individuals were present in a collection) was measured for total length (to the nearest 0.1 cm) and weighed to the nearest 0.1 gm.

Species Not Analyzed

Burton (1976) demonstrated that hogchokers (*Trinectes maculatus*) and blue crabs (*Callinectes sapidus*) were virtually unaffected (>99% survival) by impingement at Calvert Cliffs. Consequently, data for these two species were not included in the analysis. However, hogchoker totals, percent survival and LOE are reported in the appropriate tables.

Statistical Analysis

Estimates of survival rates for all species were calculated using ratio-estimation techniques (Cochran, 1977). Since these techniques are based on a normal distribution approxima-

tion of the binomial distribution, sequential collections were pooled until the number of fish collected was greater than or equal to 30 to form each datum. With these data the estimate of survival was computed as:

$$\hat{S} = \frac{\text{number of fish alive}}{\text{number of fish collected}} = \frac{\sum_{i=1}^{n} a_i}{\sum_{i=1}^{n} m_i}$$

where: $\hat{S}$ = estimated survival

m_i = number of fish collected for each datum after pooling

a_i = the associated number of fish alive for each datum after pooling

n = the number of samples pooled.

Specimens exhibiting loss of equilibrium were considered dead for these estimates.

Variance in survival estimates was calculated only for species having at least 300 individuals in survival-studies' collections over the year. The value of 300 was chosen to provide at least 10 estimates of survival with 30 fish collected for each estimate. Bay anchovy, (*Anchoa mitchilli*), spot (*Leiostomus xanthurus*), winter flounder (*Pseudopleuronectes americanus*), blueback herring (*Alosa aestivalis*) and oyster toadfish (*Opsanus tau*) were abundant enough to allow analysis.

Variance of the estimated survival ($\hat{S}$) was calculated for these species, following Cochran (1977), as:

$$\text{var}(\hat{S}) = \frac{a_i^2 - 2S\Sigma a_i m_i + S^2 \Sigma m_i^2}{n(n-1)(\bar{m})^2}$$

where: $\bar{m} = \frac{1}{n} \sum_{i=1}^{n} m_i$.

Approximate 95% confidence limits for ($\hat{S}$) were calculated as:

$$\hat{S} \pm 1.96 \times \sqrt{\text{Var}(\hat{S})}$$

Chi-square analysis comparing the survival rates of the aforementioned species impinged on large- and small-mesh screens were performed in accordance with Fleiss (1981).

Results and Discussion

A total of 57,717 fish representing 31 species was collected in 1981 at Units 1 and 2 (Table 8.2-1). Over the year, 28 species were collected at Unit 1 and 19 species were collected at Unit 2. At Unit 2 there were 18 species collected from the large-mesh screens (21-24) with 17 species collected from the Royce screens (25 and 26).

The major species collected during the year were bay anchovy (*Anchoa mitchilli*), spot (*Leiostomus xanthurus*), winter flounder (*Pseudopleuronectes americanus*) and hogchoker (*Trinectes maculatus*). Together these species accounted for 94.9% of the total catch at both units combined. Species collected only at Unit 1 included alewife (*Alosa pseudoharengus*), gizzard shad (*Dorosoma cepedianum*), skilletfish (*Gobiesox strumosus*), rough silverside (*Membras martinica*), threespine stickleback (*Gasterosteus aculeatus*), white perch (*Morone americana*), striped bass (*Morone saxatilis*), yellow perch (*Perca flavescens*), weakfish (*Cynoscion regalis*), Atlantic croaker (*Micropogonias undulatus*), feather blenny (*Hypsoblennius hentzi*), and butterfish (*Peprilus triacanthus*). Species collected only at Unit 2 included bluntnose stingray (*Dasyatis sayi*), spotted seatrout (*Cynoscion nebulosus*) and naked goby (*Gobiosoma bosci*).

Summaries of species, percent survival and percent LOE for fish collected at Units 1, 2 (all screens combined), 2 (standard screens), 2 (Royce screens), and Units 1 and 2 combined are presented in Tables 8.2-2 through 8.2-6, respectively.

Survival estimates and confidence limits for the five most abundant species are summarized in Table 8.2-7. Winter flounder had a mean survival rate of 93.4%. Spot and oyster toadfish had survival rates between 75% and 85%. Bay anchovy and blueback herring had survival rates below 75%. Comparison with results of the 1980 study (Hirshfield and Hixson, 1981) shows that anchovy and spot had higher mean survival rates in 1980 (88.6% and 88.8%, respectively), whereas winter flounder had a lower mean survival rate in 1980 (91.2%).

Results of comparisons between large- and small-mesh screens to determine whether the smaller-mesh screens retained smaller individuals were inconclusive. Although the trend over the entire year did show that smaller fish were retained by the smaller-mesh screens, the results were not consistent throughout the year (Tables 8.2-8 through 8.2-12).

Chi-square analyses for spot, oyster toadfish and winter flounder showed that survival rates did not differ significantly with screen mesh size. Survival rates were significantly higher for blueback herring (Tables 8.2-4 and 8.2-5) retained by small-mesh screens ($\chi^2 = 24.8$; $p<0.005$). However, survival rate for bay anchovy (Table 8.2-4 and 8.2-5) was significantly lower for those individuals retained by the smaller mesh ($\chi^2 = 53.8$; $p<0.005$).

Table 8.2-1. Total numbers of each species collected at Units 1 and 2 during survival studies at Calvert Cliffs Nuclear Power Plant, January-December 1981.

Species	Unit 1 Screens 11-16	Unit 2 Screens 21-24	Unit 2 Screens 25 and 26
Dasyatis sayi	0	1	0
Anguilla rostrata	22	3	6
Alosa aestivalis	790	179	163
Alosa pseudoharengus	32	0	0
Brevoortia tyrannus	330	92	58
Dorosoma cepedianum	21	0	0
Anchoa mitchilli	5935	7513	8227
Opsanus tau	152	356	152
Gobiesox strumosus	99	0	0
Urophycis regius	7	4	4
Fundulus heteroclitus	3	1	2
Fundulus majalis	1	3	3
Membras martinica	2	0	0
Menidia menidia	229	7	13
Gasterosteus aculeatus	6	0	0
Hippocampus erectus	1	3	2
Syngnathus fuscus	6	6	8
Prionotus carolinus	1	3	3
Morone americana	2	0	0
Morone saxatilis	1	0	0
Perca flavescens	1	0	0
Cynoscion nebulosus	0	0	1
Cynoscion regalis	28	0	0
Leiostomus xanthurus	839	6284	12634
Micropogonias undulatus	84	0	0
Hypsoblennius hentzi	3	0	0
Gobiosoma bosci	0	3	0
Peprilus triacanthus	11	0	0
Paralichthys dentatus	18	6	7
Pseudopleuronectes americanus	1055	643	304
Trinectes maculatus	5139	4209	1996
TOTAL	14818	19316	23583

Total - All Fish Both Units = 57717
527 Samples Total Both Units

Table 8.2-2. Summary of species, percent survival and percent loss of equilibrium for fish impinged at Unit 1, Calvert Cliffs Nuclear Power Plant, January-December 1981.

Species	Total Number	% Total Catch	% Survival	% LOE
Anguilla rostrata	22	0.1	27.3	22.7
Alosa aestivalis	790	5.3	41.8	26.6
Alosa pseudoharengus	32	0.2	65.6	31.2
Brevoortia tyrannus	330	2.2	36.7	26.7
Dorosoma cepedianum	21	0.1	42.9	23.8
Anchoa mitchilli	5935	40.1	75.1	3.8
Opsanus tau	152	1.0	78.9	0.7
Gobiesox strumosus	99	0.7	100.0	0.0
Urophycis regius	7	0.0	14.3	0.0
Fundulus heteroclitus	3	0.0	100.0	0.0
Fundulus majalis	1	0.0	100.0	0.0
Membras martinica	2	0.0	100.0	0.0
Menidia menidia	229	1.5	45.4	14.8
Gasterosteus aculeatus	6	0.0	50.0	0.0
Hippocampus erectus	1	0.0	100.0	0.0
Syngnathus fuscus	6	0.0	83.3	16.7
Prionotus carolinus	1	0.0	100.0	0.0
Morone americana	2	0.0	100.0	0.0
Morone saxatilis	1	0.0	0.0	100.0
Perca flavescens	1	0.0	100.0	0.0
Cynoscion regalis	28	0.2	64.3	10.7
Leiostomus xanthurus	839	5.7	65.0	6.0
Micropogonias undulatus	84	0.6	88.1	7.1
Hypsoblennius hentzi	3	0.0	100.0	0.0
Peprilus triacanthus	11	0.0	100.0	0.0
Paralichthys dentatus	18	0.1	50.0	5.6
Pseudopleuronectes americanus	1055	7.1	94.8	1.5
Trinectes maculatus	5139	34.7	99.5	0.1

Total Number of Fish 14818

Total Number of Samples: 269

Table 8.2-3. Summary of species, percent survival and percent loss of equilibrium for fish impinged at Unit 2 (all screens), Calvert Cliffs Nuclear Power Plant, January-December 1981.

Species	Total Number	% Total Catch	% Survival	% LOE
Dasyatis sayi	1	0.00	100.00	0.00
Anguilla rostrata	9	0.02	55.56	11.11
Alosa aestivalis	342	0.80	54.97	11.99
Alosa pseudoharengus	0	0.00	0.00	0.00
Brevoortia tyrannus	150	0.35	36.00	24.00
Dorosoma cepedianum	0	0.00	0.00	0.00
Anchoa mitchilli	15740	36.69	68.78	10.06
Opsanus tau	508	1.18	81.69	1.38
Gobiesox strumosus	0	0.00	0.00	0.00
Urophycis regius	8	0.02	37.50	0.00
Fundulus heteroclitus	3	0.01	100.00	0.00
Fundulus majalis	6	0.01	100.00	0.00
Membras martinica	0	0.00	0.00	0.00
Menidia menidia	20	0.05	55.00	25.00
Gasterosteus aculeatus	0	0.00	0.00	0.00
Hippocampus erectus	5	0.01	100.00	0.00
Syngnathus fuscus	14	0.03	85.71	14.29
Prionotus carolinus	6	0.01	66.67	0.00
Morone americana	0	0.00	0.00	0.00
Morone saxatilis	0	0.00	0.00	0.00
Perca flavescens	0	0.00	0.00	0.00
Cynoscion nebulosus	1	0.00	0.00	0.00
Cynoscion regalis	0	0.00	0.00	0.00
Leiostomus xanthurus	18918	44.10	79.75	7.84
Micropogonias undulatus	0	0.00	0.00	0.00
Hypsoblennius hentzi	0	0.00	0.00	0.00
Gobiosoma bosci	3	0.01	100.00	0.00
Peprilus triacanthus	0	0.00	0.00	0.00
Paralichthys dentatus	13	0.03	84.62	0.00
Pseudopleuronectes americanus	947	2.21	91.34	1.80
Trinectes maculatus	6205	14.46	99.11	0.02

Total Number of Fish 42899

Total Number of Samples: 258

Table 8.2-4. Summary of species, percent survival and percent loss of equilibrium for fish impinged at Unit 2 (Screens 21-24), Calvert Cliffs Nuclear Power Plant, January-December 1981.

Species	Total Number	% Total Catch	% Survival	% LOE
Dasyatis sayi	1	0.01	100.00	0.00
Anguilla rostrata	3	0.02	100.00	0.00
Alosa aestivalis	179	0.93	41.90	11.73
Alosa pseudoharengus	0	0.00	0.00	0.00
Brevoortia tyrannus	92	0.48	41.30	23.91
Dorosoma cepedianum	0	0.00	0.00	0.00
Anchoa mitchilli	7513	38.90	71.62	7.13
Opsanus tau	356	1.84	82.30	1.69
Gobiesox strumosus	0	0.00	0.00	0.00
Urophycis regius	4	0.02	25.00	0.00
Fundulus heteroclitus	1	0.01	100.00	0.00
Fundulus majalis	3	0.02	100.00	0.00
Membras martinica	0	0.00	0.00	0.00
Menidia menidia	7	0.04	28.57	42.86
Gasterosteus aculeatus	0	0.00	0.00	0.00
Hippocampus erectus	3	0.02	100.00	0.00
Syngnathus fuscus	6	0.03	100.00	0.00
Prionotus carolinus	3	0.02	33.33	0.00
Morone americana	0	0.00	0.00	0.00
Morone saxatilis	0	0.00	0.00	0.00
Perca flavescens	0	0.00	0.00	0.00
Cynoscion nebulosus	0	0.00	0.00	0.00
Cynoscion regalis	0	0.00	0.00	0.00
Leiostomus xanthurus	6284	32.53	79.41	6.41
Micropogonias undulatus	0	0.00	0.00	0.00
Hypsoblennius hentzi	0	0.00	0.00	0.00
Gobiosoma bosci	3	0.02	100.00	0.00
Peprilus triacanthus	0	0.00	0.00	0.00
Paralichthys dentatus	6	0.03	83.33	0.00
Pseudopleuronectes americanus	643	3.33	90.82	2.02
Trinectes maculatus	4209	21.79	98.98	0.02

Total Number of Fish 19316

Total Number of Samples: 134

Table 8.2-5. Summary of species, percent survival and percent loss of equilibrium for fish impinged at Unit 2 (Screens 25 and 26, Royce Screens), Calvert Cliffs Nuclear Power Plant, January-December 1981.

Species	Total Number	% Total Catch	% Survival	% LOE
Dasyatis sayi	0	0.00	00.00	0.00
Anguilla rostrata	6	0.03	33.33	16.67
Alosa aestivalis	163	0.69	69.33	12.27
Alosa pseudoharengus	0	0.00	0.00	0.00
Brevoortia tyrannus	58	0.25	27.59	24.14
Dorosoma cepedianum	0	0.00	0.00	0.00
Anchoa mitchilli	8227	34.89	66.18	12.73
Opsanus tau	152	0.64	80.26	0.66
Gobiesox strumosus	0	0.00	0.00	0.00
Urophycis regius	4	0.02	50.00	0.00
Fundulus heteroclitus	2	0.01	100.00	0.00
Fundulus majalis	3	0.01	100.00	0.00
Membras martinica	0	0.00	0.00	0.00
Menidia menidia	13	0.06	69.23	15.38
Gasterosteus aculeatus	0	0.00	0.00	0.00
Hippocampus erectus	2	0.01	100.00	0.00
Syngnathus fuscus	8	0.03	75.00	25.00
Prionotus carolinus	3	0.01	100.00	0.00
Morone americana	0	0.00	0.00	0.00
Morone saxatilis	0	0.00	0.00	0.00
Perca flavescens	0	0.00	0.00	0.00
Cynoscion nebulosus	1	0.00	0.00	0.00
Cynoscion regalis	0	0.00	0.00	0.00
Leiostomus xanthurus	12634	53.57	79.93	8.55
Micropogonias undulatus	0	0.00	0.00	0.00
Hypsoblennius hentzi	0	0.00	0.00	0.00
Gobiosoma bosci	0	0.00	0.00	0.00
Peprilus triacanthus	0	0.00	0.00	0.00
Paralichthys dentatus	7	0.03	85.71	0.00
Pseudopleuronectes americanus	304	1.29	92.43	1.32
Trinectes maculatus	1996	8.46	99.40	0.00

Total Number of Fish 23583

Total Number of Samples: 124

Table 8.2-6. Summary of species, percent survival and percent loss of equilibrium for fish impinged at Units 1 and 2 (combined), Calvert Cliffs Nuclear Power Plant, January-December 1981.

Species	Total Number	% Total Catch	% Survival	% LOE
Dasyatis sayi	1	0.0	100.0	0.0
Anguilla rostrata	31	0.1	35.5	19.4
Alosa aestivalis	1132	2.0	45.8	22.2
Alosa pseudoharengus	32	0.1	65.6	31.2
Brevoortia tyrannus	480	0.8	36.5	25.8
Dorosoma cepedianum	21	0.0	42.9	23.8
Anchoa mitchilli	21675	37.6	70.5	8.4
Opsanus tau	660	1.1	81.1	1.2
Gobiesox strumosus	99	0.2	100.0	0.0
Urophycis regius	15	0.0	26.7	0.0
Fundulus heteroclitus	6	0.0	100.0	0.0
Fundulus majalis	7	0.0	100.0	0.0
Membras martinica	2	0.0	100.0	0.0
Menidia menidia	249	0.4	46.2	15.7
Gasterosteus aculeatus	6	0.0	50.0	0.0
Hippocampus erectus	6	0.0	100.0	0.0
Syngnathus fuscus	20	0.0	85.0	15.0
Prionotus carolinus	7	0.0	71.4	0.0
Morone americana	2	0.0	100.0	0.0
Morone saxatilis	1	0.0	0.0	100.0
Perca flavescens	1	0.0	100.0	0.0
Cynoscion nebulosus	1	0.0	0.0	0.0
Cynoscion regalis	28	0.0	64.3	10.7
Leiostomus xanthurus	19757	34.2	79.1	7.8
Micropogonias undulatus	84	0.1	88.1	7.1
Hypsoblennius hentzi	3	0.0	100.0	0.0
Gobiosoma bosci	3	0.0	100.0	0.0
Peprilus triacanthus	11	0.0	100.0	0.0
Paralichthys dentatus	31	0.1	64.5	3.2
Pseudopleuronectes americanus	2002	3.5	93.2	1.6
Trinectes maculatus	11344	19.7	99.3	0.0

Total Number of Fish 57717

Total Number of Samples: 527

Table 8.2-7. Survival estimates and 95% confidence limits for the five most abundant fish species collected at Units 1 and 2 during impingement survival studies at Calvert Cliffs Nuclear Power Plant, January-December 1981.

Species	Number Analyzed	Percent Survival	Upper Confidence Limits	Lower Confidence Limits
Anchoa mitchilli	21655	70.53	79.47	61.58
Leiostomus xanthurus	19736	79.18	85.60	72.75
Pseudopleuronectes americanus	1979	93.38	97.37	89.39
Alosa aestivalis	1132	45.76	55.64	35.88
Opsanus tau	641	80.81	86.46	75.16

Table 8.2-8. Mean total lengths (cm) and number of individuals measured of bay anchovy (*Anchoa mitchilli*) impinged weekly on large- and small-mesh screens at Unit 2, Calvert Cliffs Nuclear Power Plant, April-September 1981.

Month	Week	Large Mesh		Small Mesh	
		$\bar{x}$	n	$\bar{x}$	n
Apr	1	-	-	5.50	12
	2	6.09	75	5.66	161
	3	6.74	173	6.15	210
	4	6.71	59	6.28	60
May	1	4.96	369	5.29	363
	2	5.78	150	5.13	106
	3	6.53	78	5.89	82
	4	5.98	142	5.85	118
Jun	1	7.01	47	6.46	135
	2	6.53	199	6.53	126
	3	6.65	123	6.45	94
	4	6.00	1	-	-
Jul	1	6.50	10	6.87	15
	2	6.91	170	6.89	89
	3	6.97	232	7.03	117
	4	6.86	57	7.15	48
Aug	1	7.00	21	7.00	13
	2	6.76	71	6.96	51
	3	6.95	57	6.74	47
	4	6.50	6	6.79	14
Sep	1	6.36	11	6.00	4
	2	-	-	-	-
	3	5.67	3	5.50	2
Total		6.29	2054	6.08	1867

Table 8.2-9. Mean total lengths (cm) and number of individuals measured of spot (*Leiostomus xanthurus*) impinged weekly on large- and small-mesh screens at Unit 2, Calvert Cliffs Nuclear Power Plant, April-September 1981.

		Large Mesh		Small Mesh	
Month	Week	$\bar{x}$	n	$\bar{x}$	n
Apr	1	-	-	-	-
	2	-	-	-	-
	3	-	-	-	-
	4	1.71	14	1.14	42
May	1	2.13	381	2.17	378
	2	3.14	258	3.07	225
	3	4.44	201	3.74	188
	4	4.17	109	3.54	127
Jun	1	4.60	61	5.45	74
	2	5.32	96	4.48	106
	3	5.89	94	5.95	84
	4	7.41	75	6.17	58
Jul	1	5.83	42	6.53	38
	2	6.88	234	6.23	80
	3	6.87	181	7.03	69
	4	6.90	29	7.57	7
Aug	1	6.96	24	6.00	2
	2	6.00	1	-	-
	3	6.00	3	7.00	1
	4	-	-	-	-
Sep	1	12.00	1	-	-
	2	-	-	8.00	1
	3	-	-	-	-
Total		4.65	1804	3.89	1480

Table 8.2-10. Mean total lengths (cm) and number of individuals measured of winter flounder (*Pseudopleuronectes americanus*) impinged weekly on large- and small-mesh screens at Unit 2, Calvert Cliffs Nuclear Power Plant, April-September 1981.

		Large Mesh		Small Mesh	
Month	Week	$\bar{x}$	n	$\bar{x}$	n
Apr	1	-	-	-	-
	2	-	-	-	-
	3	-	-	-	-
	4	-	-	-	-
May	1	-	-	-	-
	2	5.88	8	5.22	22
	3	5.10	40	5.18	39
	4	5.43	21	4.90	10
Jun	1	5.47	19	5.04	38
	2	7.40	30	5.83	76
	3	5.57	60	5.44	34
	4	5.00	2	-	-
Jul	1	5.60	5	5.33	6
	2	5.85	34	6.05	20
	3	5.72	18	-	-
	4	6.00	1	6.50	2
Aug	1	-	-	6.00	2
	2	6.07	15	6.50	6
	3	6.42	26	6.36	11
	4	6.31	16	7.20	5
Sep	1	6.63	8	6.40	5
	2	-	-	-	-
	3	-	-	-	-
Total		5.88	303	5.58	276

Table 8.2-11. Mean total lengths (cm) and number of individuals measured of blueback herring (*Alosa aestivalis*) impinged weekly on large- and small-mesh screens at Unit 2, Calvert Cliffs Nuclear Power Plant, April-September 1981.

		Large Mesh		Small Mesh	
Month	Week	$\bar{x}$	n	$\bar{x}$	n
Apr	1	-	-	-	-
	2	9.67	3	9.00	2
	3	8.00	1	-	-
	4	-	-	9.00	1
May	1	5.33	3	-	-
	2	4.69	16	-	-
	3	-	-	-	-
	4	6.00	2	7.00	1
Jun	1	-	-	8.50	2
	2	6.00	24	7.50	2
	3	6.16	61	6.71	51
	4	6.25	61	6.51	57
Jul	1	-	-	-	-
	2	6.00	1	7.00	1
	3	-	-	-	-
	4	-	-	-	-
Aug	1	-	-	-	-
	2	-	-	6.00	1
	3	-	-	6.00	2
	4	-	-	-	-
Sep	1	6.00	2	6.25	4
	2	-	-	4.50	2
	3	-	-	-	-
Total		6.09	174	6.65	126

Table 8.2-12. Mean total lengths (cm) and number of individuals measured of oyster toadfish (*Opsanus tau*) impinged weekly on large- and small-mesh screens at Unit 2, Calvert Cliffs Nuclear Power Plant, April-September 1981.

Month	Week	Large Mesh $\bar{x}$	Large Mesh n	Small Mesh $\bar{x}$	Small Mesh n
Apr	1	-	-	-	-
	2	-	-	-	-
	3	-	-	-	-
	4	3.00	1	-	-
May	1	6.00	2	-	-
	2	5.00	2	-	-
	3	-	-	-	-
	4	-	-	-	-
Jun	1	-	-	-	-
	2	13.12	6	9.50	2
	3	11.69	35	10.78	23
	4	11.24	17	10.34	35
Jul	1	11.74	38	10.08	12
	2	11.82	176	11.68	50
	3	11.90	62	11.20	20
	4	10.00	5	8.00	1
Aug	1	8.50	2	11.33	3
	2	9.00	3	-	-
	3	10.00	3	9.33	3
	4	12.67	3	7.00	1
Sep	1	-	-	8.00	1
	2	-	-	-	-
	3	8.00	1	-	-
Total		11.62	356	10.82	151

Summary

Survival estimates were calculated for 31 species of fishes (57,717 individuals) collected in 1981. There were no consistent differences in survival between units (Tables 8.2-2 and 8.2-3). Analysis of lengths of dominant species between Royce and standard screens at Unit 2 showed no consistent patterns. However, for the entire year, there was a trend toward smaller individuals being impinged on the Royce screens. Survival rate of spot, oyster toadfish and winter flounder did not differ significantly for the two mesh sizes. Conversely, blueback herring had higher survival rates when impinged on the smaller-mesh screens but survival rates for bay anchovy were lower for individuals impinged on the smaller mesh screens. In general, survival rates were somewhat lower in 1981 than those in 1980.

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ZOOPLANKTON ENTRAINMENT STUDY

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Introduction

During the summer of 1981, studies were conducted at Calvert Cliffs Nuclear Power Plant (CCNPP) to examine effects on zooplankton entrained in the condenser cooling-water system of Unit 2. These studies were similar in design and purpose to entrainment studies conducted at Unit 2 from 1977 through 1980 (Sage and Bacheler, 1978; Olson and Sage, 1979; Newman, Sage and D'Apolito, 1980; Newman and Sage, 1981*a*) and were a continuation of investigations at Calvert Cliffs that have been conducted since 1974. In addition to the studies at Unit 2, these investigations have included preoperational studies in the fall of 1974 and operational studies at Unit 1 in 1975 and 1976 (Sage, 1976; Sage and Olson, 1977). Regulations for CCNPP operation were modified in 1979 to allow a maximum cross-condenser temperature increase (ΔT) of 6.7°C, instead of the previously allowed ΔT of 5.5°C. A primary objective of the entrainment studies in 1979, 1980 and 1981 was to assess any additional impact on entrained zooplankton from the increased ΔT.

Since organism survival is probably a function of plant-operating conditions and environmental and biological variables, studies were designed to examine zooplankton survival in as many different situations as budget and personnel constraints would permit. Based upon results of 1975-76 monthly (year round) studies, subsequent studies have been restricted to the summer months when maximum entrainment effects are anticipated. The 1981 study included two collection periods of 24-h duration in June and September and two collection periods of 48-h duration in July and August. The 1981 program was designed to determine daily variation in zooplankton densities and environmental conditions and secondarily to assess cyclic patterns within the 48-h periods.

Objectives of the zooplankton studies were: 1) to examine abundance and species and age composition of zooplankton entrained at Calvert Cliffs; 2) to determine the percentage of the different ages and types of zooplankton killed by entrainment and to determine the percent that survive plant passage, when survival is defined as mortality plus cropping loss; 3) to examine the factors contributing to entrainment effects, i.e., thermal stress and other environmental and/or plant-operating

conditions; and 4) to assess any additional impact on entrained organisms resulting from the increased waste-heat release.

Materials and Methods

Sampling Schedule

As in the four previous years (1977-1980), the 1981 entrainment studies used a time-series study design and analytical approach. Single, unreplicated samples were collected at the plant intake (IN) and discharge (DC) every 30 min through a 24-h or 48-h period according to the following schedule (EDST):

June 16, 0900 hours to 0830 hours, June 17
July 7, 0900 hours to 0830 hours, July 9
August 18, 0900 hours to 0400 hours, August 20
September 9, 0900 hours to 0830 hours, September 10

The August sampling period was terminated 2½ h early because of poor weather conditions. Collection at DC began 4 min after IN collection, the estimated time required for the cooling water to transit the system.

Sampling Locations

A schema of the plant and sampling locations for the studies at Unit 2 are shown in Figure 9-1. Sampling stations were the same as those used in the 1977-1980 studies. The intake station (IN) was behind the traveling screens, directly in the approach conduit to a circulating water pump serving Unit 2. Water here is committed to plant passage. At this station, samples from 1, 2 and 3 m from the bottom were combined to form a single composite sample integrating any vertical gradients that might exist in the water column. The Tunnel Access (TA) is an access port to the discharge conduit about midway between the plant and the offshore terminus. The Tunnel Access was not intended to be used as a zooplankton sampling site, but rather to provide a temperature reference for discharge-water temperatures at the terminus. The discharge sampling location (DC) was directly in the submerged plume as it issued from the discharge conduits serving Unit 2. Samples were collected from a boat anchored at the head of the plume. At DC, the water is turbulent and well-mixed; samples were collected from only a single depth (≅5 m) at the approximate center of the conduit.

Sampling Methods

Samples were pumped from depth using a low-volume 30.3 l/min diaphragm pump. The total sample volume was 20 liters, but to minimize effects of patchiness, collection of each sam-

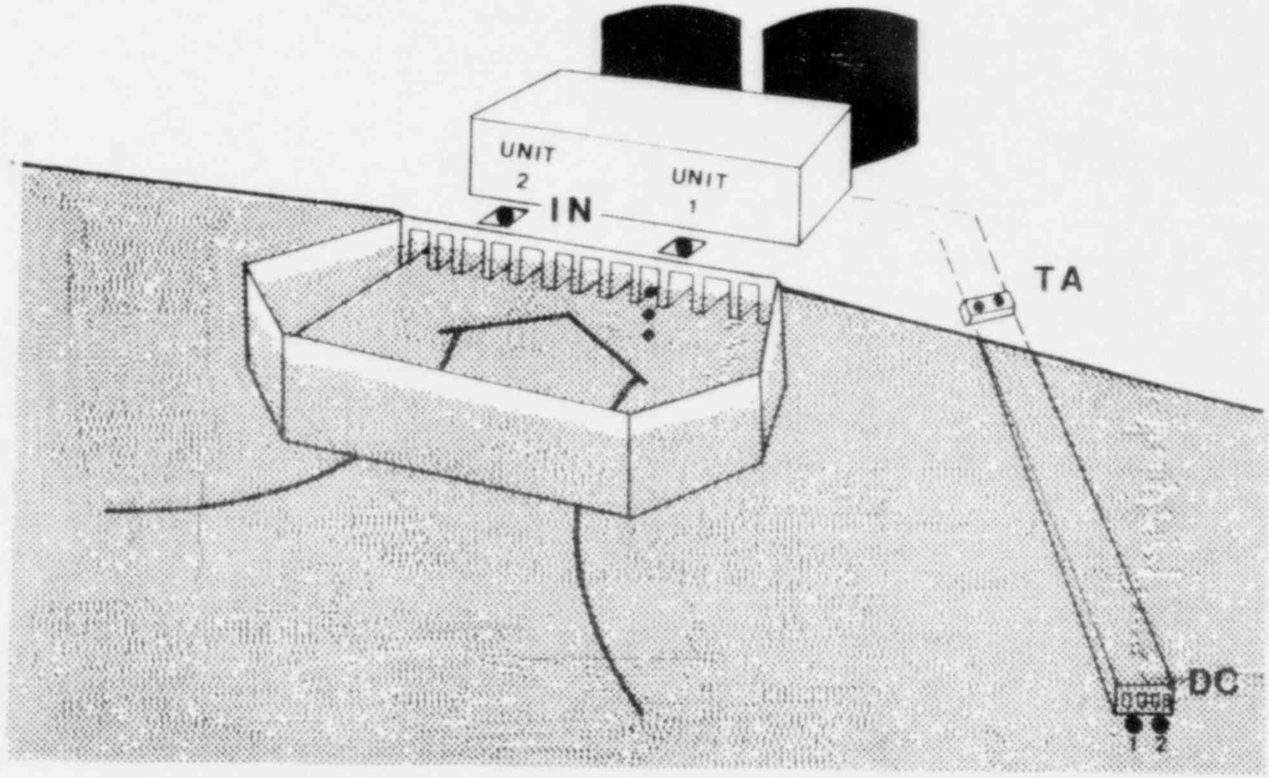

Figure 9-1. Schema of Calvert Cliffs Nuclear Power Plant on the Chesapeake Bay showing sampling locations for zooplankton entrainment studies in 1981. IN = Intake, TA = Tunnel Acess and DC = Discharge.

ple was prolonged in several ways. The pump outflow hoses were fitted with 2-way splitters with a septum angled to produce a 40/60 percent diversion of flow. Water from the 60% spigot was discarded; water from the 40% side was collected in 20-liter carboys. Further, carboys were filled only 1/3 at a time, with a 2-min interval between sample fractions. Total elapsed time in collecting each sample was approximately 6 min.

After collection, neutral-red vital dye (1:150,000) (Crippen and Perrier, 1974; Dressel, Heinle and Grote, 1972) was added to each sample, mixed thoroughly, and the samples were incubated at least 1 h at ambient temperature in shade or darkness. Each sample was then concentrated to a final volume of 50 ml using a 73-μm mesh plankton net. Samples were preserved in a basic solution containing buffered formalin to reduce the solubility of the vital dye. To achieve the proper color, 5N acetic acid was added just prior to analysis (Fleming and Coughlan, 1978).

Physico-chemical parameters were measured at the time each sample was collected. Salinity was measured with a Beckman Model RS5-3 salinometer and dissolved oxygen (DO) was measured with a YSI model 57 DO meter. Water temperature was measured by a hand-held thermometer calibrated in tenths of degrees.

Sample Analysis and Live/Dead Determination

In the laboratory, samples were acidified with acetic acid and an aliquot large enough to contain at least 200 organisms was withdrawn with a Hensen-Stempel pipette and transferred to a sorting wheel. Organisms were identified and counted by species and, where possible, by life stage (age class). Organisms were further designated as living or dead at the time of collection. Living dye-sensitive organisms metabolize vital dye and take on its color (Crippen and Perrier, 1974). Some organisms do not take up dye or do not take up dye within a practical incubation period, and therefore, vitality for those organisms cannot be consistently determined. In the Calvert Cliffs area, dye-sensitive components of the zooplankton are all life stages of calanoid copepods, cirriped (barnacle) nauplii, annelids, flatworms, nematodes and cladocerans.

Data Analyses

As in previous studies, consideration of the barnacle population residing in the plant cooling-water system was required when data were analyzed, since the number of cirriped nauplii recovered at the discharge frequently exceeds that collected at the intake. Total zooplankton densities and relative abundances of individual species, which are based on total zooplankton, were calculated exclusive of cirriped nau-

plii. Survival estimates for cirriped nauplii are inappropriate; however, general discussions of the community of entrainable zooplankton include this population. Analyses were performed on data for copepod nauplii, *Acartia* copepodites, *Acartia tonsa* adults, cirriped nauplii, all other less-abundant species grouped, all dye-sensitive organisms grouped minus cirriped nauplii, and total zooplankton minus cirriped nauplii.

The terms "% Alive" and " % Survival" are used in this report. "Percent Alive" is defined as the percentage of the total number of organisms which are alive in a sample. For example, if the total density of copepod nauplii at IN equals $1{,}000/m^3$, of which 900 are alive, then the % Alive equals 90. If the density of nauplii at DC equals $800/m^3$, of which 784 are alive, the % Alive at DC equals 98. The term "survival" is defined as the ratio of the normalized number of living organisms at DC to the normalized number alive at IN, i.e., # Alive DC (m^{-3})/# Alive IN (m^{-3}). (The number of living organisms at DC reflects cropping as well as mortality.) Expressed as a percent, the term becomes "% Survival". As used in the tables, the terms "% Alive" and "% Survival" represent mean values, calculated over each 24- or 48-h sampling period.

An estimate of mean survival was obtained for each dye-sensitive species or group for each sampling date by calculating the ratio of the mean density of living organisms at DC to the mean density of living organisms at IN for each entrainment study period.

Variances of the survival estimates were calculated (based on a method from Cochran (1977)) as follows:

$$\mathrm{Var}\ (\hat{R}) = 1/n.\mathrm{IN}^2[S^2_{DC}+\hat{R}^2.S_{IN}{}^2-2\hat{R}S_{IN-DC}],$$

where n is the number of samples taken during the sampling period, S^2_{IN} and S^2_{DC} are the respective variances at the intake and discharge, and S_{IN-DC} is the covariance. Estimated survival rates were computed at the 95 percent confidence interval.

To determine those environmental and plant-operation parameters which influence zooplankton survival, a stepwise linear regression technique was used (Draper and Smith, 1966). The dependent variable was the logit transformation of % Survival (Cox, 1970), while the non-transformed independent variables were mean total zooplankton density, ambient water temperature, dissolved oxygen, salinity, and ΔT.

Results

Physico-chemical parameters and plant operating conditions for sampling dates are summarized in Table 9-1. Temporal changes in hydrographic conditions are depicted in Figures 9-2

Table 9-1. Summary of plant operating conditions at Unit 2 and mean values for some physical-chemical parameters for each of four zooplankton entrainment studies conducted at Calvert Cliffs Nuclear Power Plant in 1981.

	June 14-17	Jul 7-9	Aug 19-21*	Sept 9-10
Gross Elec. Output (mw-h)	824	843	712	823
Intake temp (°C)	22.6	25.6	26.1	24.5
Discharge temp (°C)	28.3	30.9	32.1	30.6
ΔT (°C)	5.7	5.4	6.0	6.1
Salinity (°/oo)	16.4	15.1	17.5	19.7
DO (mg/l)	2.3 (0.8-4.0)	5.1 (3.2-8.6)	5.2 (3.6-6.2)	5.5 (3.8-6.3)
Air temp (°C)	29.0	27.7	21.6	N.A.

*Averages calculated through .0100 h on 8/21 where ΔT was reduced due to modified plant operation.
N.A. = Not available.

through 9-13. The mean cross-condenser temperature increase (ΔT) for each of the months during the 1981 entrainment ranged from 5.4 to 6.1°C, comparable to ΔT's in 1980 and slightly higher than those in 1978 and 1979. Ambient water temperatures ranged from 22.6° to 26.1°C, typical for this area of the Bay. Salinity generally increased through the study periods, ranging from 15.1 to 19.7 °/oo. Salinity was generally higher than previously recorded, particularly in 1978 and 1979. Dissolved oxygen (DO) was consistently low in June, averaging 2.3 mg/l. Averages for the other three study periods were greater than 5 mg/l.

A cumulative taxonomic list of species collected in the four sampling periods during 1981 is given in Table 9-2. Zooplankton composition was similar to that in previous entrainment studies (Newman and Sage, 1981*b*), although the presence and abundance of marine species denoted the increased salinity. Calanoid copepods were numerically the most abundant group from July to September, and of this group, *Acartia tonsa* was the predominant member. The three life stages of this species (nauplii, copepodites, and adults) made up more than 70% of the zooplankton abundance. In May or June there is usually a decrease in nauplii numbers, resulting from a seasonal shift from species present in winter to those present in the summer. Two calanoid copepods, *Eurytemora affinis* and *Acartia clausii*, are the most common in winter. While *Acartia tonsa* is present in low densities throughout the winter, it flourishes from mid-spring through late fall.

During the spring scarcity in calanoid species, an epibenthic harpacticoid, *Halectinosoma curticorne*, flourishes and can become relatively abundant. The most common barnacle, *Balanus improvisus*, and the polychaetes, *Scolecolepedes viridis* and *Nereis* sp., usually spawn during the spring and fall; at these times their larvae appear in the plankton in substantial numbers. Organisms less common in summer include the cyclopoid *Oithona similis* and the cladoceran *Podon polyphemoides*.

Figures 9-14 through 9-33 show densities of living organisms collected at the intake (IN) and discharge (DC) stations for each sampling interval. Survival of organisms from IN to DC is depicted, as well as the large, and frequently cyclic, density fluctuations which occurred over 24 or 48 h. Data for copepod nauplii, *Acartia* copepodites, *Acartia tonsa* adults, annelids, and all dye-sensitive species grouped are presented for each of the four sampling periods.

As previously stated, all life stages of calanoid copepods (primarily *Acartia tonsa*), annelid (polychaete) larvae, and cirriped (barnacle) nauplii are dye sensitive and composed more than 80% of the zooplankton community through the 1981 study period except for June. Data for these dominant groups are presented in Table 9-3. To facilitate comparisons, results are presented by each entrainment sampling period.

Table 9-2. Taxonomic list of zooplankton collected at the intake and discharge of the Calvert Cliffs Nuclear Power Plant, 1981, and ranked according to abundance.

	June 16 Rank	Jul 17 Rank	Aug 19 Rank	Sept 9 Rank
Rhabdocoela	7	10	16	20
Nematoda	3	15	14	9
Polychaeta				
Nereis sp.	9	8	17	6
Scolecolepedes viridis (Verrill)	4	4	8	4
Gastropoda	--	22	20	22
Pelecypoda	18	24	19	15
Cladocera				
Podon polyphemoides (Lenkarti)	--	13	5	18
Evadne nordmanni	--	--	11	17
Copepoda				
Copepod nauplii (primarily *Acartia tonsa*)	5	1	1	1
Acartia copepodites	6	2	2	2
Acartia tonsa (Dana) ♂	11	5	7	7
Acartia tonsa (Dana) ♀	10	3	6	5
Harpacticoid copepodites - unspeciated	16	21	*	21
Halectinosoma curticorne copepodites	--	25	15	--
Halectinosoma curticorne (Boeck)	1	12	13	*
Oithona copepodites	16	14	3	10
Oithona similis (Claus)	12	11	4	8
Saphirella sp.	8	9	12	11
Canthocamptus sp. copepodite	*	*	--	--
Canthocamptus sp.	14	17	*	*
Cletodes longicaudatus (Boeck)	--	--	--	22
Tachidius littoralis (Poppe)	*	*	--	--
Laophontidae copepodite	--	*	--	--
Laophontidae	18	*	*	21
Diaptomus pallidus	--	7	10	14
Pseudodiaptomus coronatus copepodite	--	--	*	16
Pseudodiaptomus coronatus (Williams)	--	*	*	12
Nitocra sp.	*	*	--	--
Eurytemora affinis (Poppe)	16	--	*	23
Halicyclops magniceps copepodite	19	--	--	--
Halicyclops magniceps (Lilljeborg)	19	19	--	22
Tropocyclops prasinus copepodite	--	20	--	--
Tropocyclops prasinus	--	19	--	19
Ergasilus sp.	13	18	--	*
Cirripedia				
Nauplii	2	6	9	3
Balanus larvae	16	16	18	13
Mysidacea				
Neomysis americana (Smith)	--	*	--	--
Amphipoda				
Corophidae	17	24	--	23
Decapoda				
Neopanope texana sayi (Smith)	15	23	20	*

--Absent
*Present in Discharge only.

Table 9-3. Mean densities, relative abundance and survival statistics for major zooplankton groups collected at intake (IN) and discharge (DC) stations during entrainment studies at Calvert Cliffs Nuclear Power Plant in 1981.

		Jun	Jul	Aug	Sept
Copepod nauplii					
N/m³	IN	542	48045	61840	15592
	DC	1080	7222	5723	3778
% of Total (minus cirriped)	IN	6.5	50.6	69.0	45.3
	DC	8.4	36.8	42.6	40.5
% Alive	IN	100.0	97.0	98.9	91.0
	DC	99.4	98.5	96.4	87.7
% Survival		>100.0	15.3	9.0	23.4
***Acartia* copepodites**					
N/m³	IN	303	34148	8611	7909
	DC	256	6091	1635	1592
% of Total (minus cirriped)	IN	3.6	36.0	9.6	23.0
	DC	2.0	31.1	12.2	17.1
% Alive	IN	93.4	96.0	96.7	88.4
	DC	97.3	97.7	94.1	88.6
% Survival		88.0	18.2	18.5	20.2
***Acartia tonsa* male**					
N/m³	IN	55	2295	1516	661
	DC	36	988	912	386
% of Total (minus cirriped)	IN	0.7	2.4	1.7	1.9
	DC	0.3	5.0	6.8	4.1
% Alive	IN	74.5	94.2	95.1	89.3
	DC	100.0	95.9	91.5	79.5
% Survival		87.8	43.8	57.8	52.0
***Acartia tonsa* female**					
N/m³	IN	67	3477	1697	2065
	DC	88	1165	986	1083
% of Total (minus cirriped)	IN	0.8	3.7	1.9	6.0
	DC	0.7	5.9	7.4	11.6
% Alive	IN	79.1	96.6	97.4	88.6
	DC	95.4	95.0	94.6	85.2
% Survival		>100.0	33.0	56.4	50.4
Polychaete					
N/m³	IN	1455	3412	1543	3328
	DC	1534	2371	1104	1780
% of Total (minus cirriped)	IN	17.4	3.6	1.7	9.7
	DC	11.9	12.1	8.2	19.1
% Alive	IN	100	99.8	99.2	96.1
	DC	100	99.6	99.0	98.8
% Survival		>100	69.4	71.4	55.0
Other species					
N/m³	IN	5948	3526	17614	4886
	DC	9902	1768	3060	710
% of Total (minus cirriped)	IN	71.0	3.7	19.7	14.2
	DC	76.8	9.0	22.8	7.6
Cirriped nauplii					
N/m³	IN	2579	1115	778	4452
	DC	41183	2964	903	5214
% Alive	IN	99.7	57.4	70.6	73.5
	DC	100.0	97.4	87.7	83.0
% Survival		>100	>100	>100	>100
Total minus cirriped nauplii					
N/m³	IN	8370	94903	92821	34441
	DC	12896	19605	13420	9329

June 16-17

Dissolved oxygen declined through the sampling period after 1430 hrs (sample # 12) from 4.0 mg/l to less than 1 mg/l (Fig. 9-4). Salinity fluctuated, but increased through the same time period from 15.8 to 17.6 ppt (Fig. 9-3). This inverse relationship usually typifies an upwelling of deeper bottom waters from further out in the Bay.

Survival estimates for the key groups in June were the highest of the four sampling priods. Survival for all dye-sensitive species combined was in excess of 100%. Copepod nauplii and *Acartia* copepodite survival estimates (Table 9-3) were considerably higher than those for June in previous years (cf. Tables 9-4 and 9-5) and were similar to adult survival (Table 9-3). The % Alive at IN and DC stations did not decrease during the episodes of low DO.

Dye-sensitive species combined represented less than 30% of the lowest total mean zooplankton abundance (8,370/m^3) during the 1981 study. Densities of copepod nauplii (542/m^3), *Acartia* copepodites (303/m^3) and *A. tonsa* adults (122/m^3) were the lowest observed in the five years of operational studies. The zooplankton community consisted primarily of a non-dye-sensitive species, *Halectinosoma curticorne* (46%). Densities for this species averaged 3,826/m^3. Cirriped nauplii were also abundant at the intake (2,579/m^3); densities at the discharge increased by 16 fold (Table 9-3). Other less abundant organisms were nematodes and *Scolecolepedes viridis*.

July 7-9

Dissolved oxygen exhibited three oscillations, ranging from 3.2 to 8.6 mg/l and was considered above stressful levels (Fig. 9-7). Salinity, ranging from 13.2 to 16.1 ppt, also fluctuated in a cyclic pattern but inversely to that of dissolved oxygen (Fig. 9-6). Ambient temperature decreased slightly during periods of low dissolved oxygen (Fig. 9-5). The mean ΔT was lowest in July (5.4°C) (Table 9-1).

Survival of all dye-sensitive combined (20%) declined considerably from June (Table 9-4) and was generally lower than previous years for the same month (Table 9-5). In addition, *A. tonsa* adult male survival (44%) was greater than adult female (33%) (Table 9-3). Entrainment survival increased with progressively older life stages of *A. tonsa*: nauplii, 15%; copepodite, 18%; adults, 39%.

Copepod nauplii, *Acartia* copepodites and *A. tonsa* adults represented more than 90% of the largest mean total abundance, 94,903/m^3 for 1981. *S. viridis* (4th ranked, Table 9-2) densities increased by ~1,000 to 2,663/m^3. The predominant species in June, *H. curticorne*, showed a marked decrease (312/m^3) and

Table 9-4. Survival estimates for several zooplankton groups collected during entrainment studies at Calvert Cliffs Nuclear Power Plant in 1981. Percent survival = (# alive at DC/# alive at IN) x 100. Percent survival not defined where # alive at DC > # alive at IN, i.e., % survival > 100.

% Survival (95% C.I.):	June	July	August	September
Copepod nauplii	≥100 -	15 (14-17)	9 (8-10)	23 (19-28)
Acartia copepodites	88 (62->100)	18 (16-20)	18 (16-21)	20 (16-24)
Acartia tonsa ♀	≥100	33 (27-39)	56 (47-66)	50 (41-60)
Acartia tonsa ♂	88 (32->100)	44 (35-52)	58 (45-71)	52 (38-66)
Acartia tonsa adults	98 (73->100)	37 (32-43)	57 (49-65)	51 (44-57)
Polychaeta	≥100	69 (59-79)	70 (60-80)	54 (47-61)
All dye-sensitive spp.	≥100	20 (19-22)	15 (14-16)	29 (25-33)

Table 9-5. Survival estimates for several zooplankton groups collected during entrainment studies at Calvert Cliffs Nuclear Power Plant in 1977 (Sage and Racheler, 1978), 1978 (Olson and Sage, 1979), 1979 (Newman, Sage and D'Apolito, 1980) and 1980 (Newman and Sage, 1981). Percent survival = (# alive at DC/# alive at IN) x 100. Percent survival not defined where # alive at DC > # alive at IN; i.e., % survival > 100. (See text for calculation of 95% confidence interval for estimated survival).

I. % Survival (95% C.I.):	6/7/77	6/28/77	6/13/78		6/5/79		6/4/80
Copepod nauplii	46 (41-51)	71 (65-77)	24 (16-31)		27 (22-32)		52 (46-58)
Acartia copepodites	50 (45-55)	67 (61-72)	19 (15-22)		26 (20-32)		85 (70-99)
Acartia tonsa adults	97 (76-100)	88 (64-100)	30 (26-35)		--		--
Polychaeta	66 (58-74)	86 (75-97)	59 (49-70)		49 (38-59)		≥100 -
All dye-sensitive spp.	53 (49-57)	71 (66-77)	28 (24-32)		34 (29-39)		58 (52-64)
II. % Survival (95% C.I.):	7/12/77		7/11/78	7/13/78	7/10/79	7/12/79	7/8/80
Copepod nauplii	≥100 -		33 (28-37)	34 (30-38)	23 (20-27)	21 (19-23)	24 (20-28)
Acartia copepodites	≥100 -		47 (38-57)	49 (40-58)	27 (24-31)	24 (22-26)	37 (32-41)
Acartia tonsa adults	≥100 -		--	70 (52-87)	51 (39-63)	66 (48-84)	≥100 -
Polychaeta	≥100 -		85 (63-100)	80 (64-96)	59 (46-71)	52 (43-62)	69 (61-78)
All dye-sensitive spp.	≥100 -		38 (33-43)	42 (37-47)	28 (26-31)	24 (22-25)	49 (44-53)
III. % Survival (95% C.I.):	8/9/77		8/8/78	8/10/78	8/14/79	8/16/79	8/14/80
Copepod nauplii	38 (33-43)		30 (26-35)	22 (19-24)	16 (14-18)	45 (39-51)	32 (29-36)
Acartia copepodites	40 (37-44)		46 (40-53)	38 (34-43)	21 (18-24)	41 (37-46)	39 (35-42)
Acartia tonsa adults	82 (75-90)		88 (76-100)	≥100 -	46 (29-64)	≥100 -	≥100 -
Polychaeta	≥100 -		93 (76-100)	≥100 -	73 (57-89)	≥100 -	≥100 -
All dye-sensitive spp.	45 (41-49)		47 (41-52)	30 (26-33)	19 (17-21)	47 (42-52)	39 (36-42)
IV. % Survival (95% C.I.):	9/13/77		9/12/78		9/18/79		9/3/80
Copepod nauplii	49 (42-56)		24 (21-27)		22 (18-24)		26 (24-28)
Acartia copepodites	46 (40-52)		27 (23-30)		27 (24-30)		29 (27-31)
Acartia tonsa adults	≥100 -		56 (43-69)		69 (56-81)		69 (59-78)
Polychaeta	≥100 -		≥100 -		82 (59-100)		≥100 -
All dye-sensitive spp.	54 (47-60)		31 (27-34)		25 (23-78)		27 (26-29)

was 12th ranked overall. Other less common species were *Diaptomus pallidus*, *Nereis* sp. and *Saphirella* sp. Two species, *Tropocyclops prasinus* copepodite and adult, and *Ergasilus* sp. collected during this sampling period, had not been observed since 1977.

August 18-20

Weather conditions hampered sampling efforts in the last 24 hours, finally causing termination at 0400 hrs on the 20th. In addition, the plant operation of Unit 2 was modified, reducing ΔT by 0100 h, August 20. The ΔT averaged 6.0°C prior to reduced plant output and thereafter averaged 3.8°C (Fig. 9-8). Average intake (26.1°C) and discharge (32.1°C) temperatures were the highest determined for 1981 (Table 9-1). These respective temperatures are approximately 1° to 2°C lower than the highest average temperatures in 1980. Dissolved oxygen ranged from 3.6 to 6.2 mg/l. Salinity increased by approximately 2 ppt (to 17.5 ppt) from the July sampling period (Table 9-1).

Survival of the all dye-sensitive group was poor (15%), reflecting the lowest survival of copepod nauplii (9%) in the 1981 study. This survival estimate was an exceptionally low value; prior to 1981 the lowest value was 16% in August 1979 (Table 9-5). *Acartia* copepodite survival, 18.5%, was exceptionally low also. Conversely, survival estimates of *A. tonsa* adults (57%) and polychaetes (71%) increased from July and were the highest estimates except for June. *A. tonsa* male survival was slightly better than female, 58% versus 56%.

The all dye-sensitive species constituted a large portion (79%) of the total mean abundance (92,821/m^3). Copepod nauplii densities, 61,840/m^3, were the highest of the 1981 sampling periods and alone represented 67% of the total mean abundance. Other species present were *Oithona* copepodites and *Oithona similis* adults and the marine cladoceran *Podon polyphemoides*. *Evadne nordmanni*, a cladoceran collected in this study period, had not been observed in prior zooplankton studies.

September 9-10

Mean salinity in September (19.7 ppt) was the highest average for a sampling period from 1977 to 1981. Salinity increased after 0230 h (sample #36), and a corresponding decline occurred in dissolved oxygen and ambient temperature (Figs. 9-11 to 9-13). The relationship of these three parameters indicate an upwelling of deeper bottom waters from further out in the Bay. ΔT averaged 6.1°C, the highest of the 1981 study.

Overall survival improved from July and August, as indicated by the increase in survival of all of the dye-sensitive groups (Table 9-4). Entrainment survival for the key species and groups was low, but comparable to that found in prior studies in September (Tables 9-4 and 9-5). Atypically, copepod nauplii survival (23%) was slightly greater than *Acartia* copepodite (20%). *A. tonsa* adult survival (51%) decreased slightly from August, but remained higher than the two juvenile stages (Table 9-4). Male *A. tonsa* survival was 2% higher than female. The % Alive for the *Acartia* life stages was low in comparison to the other three study periods, generally less than 90% (Table 9-3).

The total mean abundance declined by 63% from August to 34,441/m^3; 76% of this total comprised the three life stages of *A. tonsa*. Other less common species were polychaetes, *S. viridis* (2,661/m^3) and *Nereis* sp. (667/m^3). Barnacle nauplii were also abundant (4,452/m^3).

Results of the linear regression analysis of the data for copepod nauplii, *Acartia* copepodites, *A. tonsa* females and males, *A. tonsa* adults, and all dye-sensitive groups combined are presented in Table 9-6. It was determined that ΔT had no significant effect on the survival of any of the groups analyzed. Copepod nauplii and all dye-sensitive combined (primarily copepod nauplii) showed a significant ($p<0.01$) decrease in survival with increasing ambient temperatures.

Discussion

Species composition of the zooplankton collected in the 1981 entrainment study was neither unusual nor unique to the Chesapeake Bay area (Heinle, 1966; Herman et al., 1968; Olson and Sage, 1978). Species and relative abundances were similar to previous entrainment studies (1977-1980) conducted at CCNPP. There were, however, a few notable exceptions, particularly in June. Abundances of all life stages of *A. tonsa* (nauplii, copepodites and adults) were the lowest recorded from 1977 to 1981. Densities in the remaining three study periods were considered normal.

Average salinity in 1980 and 1981 ranged between 11.7-19.7 ppt and was notably higher than in the 1978 and 1979 studies when salinity ranged between 8.9-12.8 ppt. A shift in species composition resulting from higher salinities was expected and observed, although small. The marine cladoceran *Podon polyphemoides*, absent in 1978 and 1979, ranked fifth in abundance in August 1981. In addition, another marine cladoceran, *Evadne nordmanni*, which had not been collected in previous studies, was present in small numbers in 1981. Two copepod species, *Tropocyclops prasinus* and *Ergasilus* sp., last collected in 1977 (Sage and Bacheler, 1978), were also present in the 1981 study.

Table 9-6. Summary of linear regression analysis determining significant effects of ambient water temperature, salinity, dissolved oxygen and total zooplankton density on survival of copepod nauplii, *Acartia* copepodites, *Acartia tonsa* females, males, separate and combined, and all dye-sensitive combined during June-September 1981 entrainment studies at the Calvert Cliffs Nuclear Power Plant.

Dependent Variable	y-intercept	Independent Variables: IN Temp.	Sal.	DO	Total Zooplankton	DF v_1, v_2	F
Copepod nauplii	14.16	-0.63				1,245	126.06*
Acartia copepodites	-8.21	0.17	0.11			2,255	5.56*
Acartia tonsa ♀	-35.79	1.19	0.41	-0.36		3,204	38.76*
Acartia tonsa ♂	-18.55	0.77	0.25		0.0001	3,176	24.88*
Acartia tonsa adults	-19.51	0.65	0.27	-0.36		3,218	11.06*
All dye-sensitive	12.03	-0.41	-0.08	-0.16	-0.0001	4,243	78.13*

*$p < 0.01$

Zooplankton densities fluctuated hourly and daily and appeared to be influenced primarily by tidal action and upwelling of deeper bottom waters from further out in the Bay. Upwelling events are characterized by increasing salinity, with a corresponding decline in ambient water temperature and dissolved oxygen. This relationship was most clearly exemplified in the July sampling period. Compare the decrease in intake dissolved oxygen, (upwelling events) (Fig. 9-7, Samples 5, 29, 37, 81), amd density peaks of *A. tonsa* adults (Fig. 9-19) and copepod nauplii (Fig. 9-21).

Survival estimates for all dye-sensitive species combined were notably higher in June (>100%) than for the other three study periods. All three life stages were exceptionally low in density and appeared in the samples sporadically. When abundances are low and patchiness is great, it is more difficult to sample the same group of zooplankton at intake and discharge because of the great mixing of waters during transit through the cooling system. This problem has generally involved only *A. tonsa* adults, which are seldom abundant in June (Table 9-5).

Survival estimates for the all dye-sensitive species group in July (20%) and August (15%) were notably lower than in previous studies during these months. Based on the % Alive in IN samples throughout the study, the zooplankton population did not appear to have been abnormally stressed or weakened by adverse hydrographic conditions prior to entrainment. Ambient water temperatures ranged from 22.6°C to 26.1°C and were similar to those of the previous year (1980) when estimated survival was higher. Moreover, ambient temperatures never reached the laboratory-determined upper thermal limit (32° to 35°C) of the predominant zooplankton, *A. tonsa* (Heinle, 1969). Dissolved oxygen was considered to be above potentially stressful levels (>3 mg/l) in July and August (Bakker et al., 1977). Zooplankton survival has not been noticeably reduced in previous entrainment studies by episodes of low dissolved oxygen (Newman and Sage, 1981*a*). However, the consequences of imposing the additional stress of entrainment on organisms which have experienced low dissolved-oxygen concentrations is not fully known.

Effects from any other environmental factor would have also been reflected in increased mortality in the nearfield zooplankton community. Incidence of mortality at IN was low (high % Alive), however, and was less than 6% in July and August. Furthermore, mortality in IN samples was higher in September when all dye-sensitive survival increased (Table 9-3).

Sellner and Kachur (in press) noted during 1981 phytoplankton entrainment studies conducted concurrently with the zooplankton studies that phytoplankton cell densities were exceptionally low compared to densities in previous studies (Olson and Sellner, 1981). Moreover, mean phytoplankton densi-

ties were essentially the same in August (3,956/ml) and September (3,963/ml), while total mean zooplankton densities were 2.7 times greater in August than in September (Table 9-3).

A reduced food supply might be considered to be a contributing cause to the low estimated survival rate; however, this hypothesis is not totally consistent with our observations. Such an effect would have been reflected in an increased incidence of mortality at both intake and discharge. However, increased cropping was observed in discharge samples.

Moreover, food requirements for zooplankton (primarily *A. tonsa*) can be approximated (Appendix A) and compared with food available from the phytoplankton present. Based on densities of the respective life stages, required total carbon was calculated to be 25,399 $\mu g\text{-}C/m^3$, 10,078 $\mu g\text{-}C/m^3$, and 7,796 $\mu g\text{-}C/m^3$ for July, August and September, respectively. Available carbon from existing phytoplankton densities was approximated from chlorophyll *a* concentrations using conservative proportions (Parsons and Takahashi, 1973). Estimated carbon available during each zooplankton sampling period was 289,310 $\mu g\text{-}C/m^3$ (July), 220,340 $\mu g\text{-}C/m^3$ (August), and 120,060 $\mu g\text{-}C/m^3$ (September). These values are roughly 11 to 22 times greater than the required total carbon budgets of the predominant zooplankter, *A. tonsa*. Therefore, the zooplankton population was apparently not limited by the carbon resources available.

The cross-condenser temperature increase, ΔT, (5.4°C to 6.1°C) was similar to that in 1980, when survival estimates were higher and within expected ranges (Newman and Sage, 1981*a*). In August and September 1981, when ΔT's were highest, % Alive in discharge samples corresponded with % Alive in intake samples, indicating that the cross-condenser temperature increase resulted in little mortality. Effects attributable to ΔT have been minimal in previous studies (Newman and Sage, 1981*b*).

Sampling error, which could cause low survival estimates, was not considered to be a contributing factor. If there were a problem with sampling procedures, such as equipment, survival estimates for all of the dye-sensitive groups would have been uniformly low during one sampling period. This was not the case. The estimated survival of each life stage of *A. tonsa* was the lowest determined for any of the entrainment studies (1977 to present) (Tables 9-4 and 9-5), but not necessarily within the same sampling period. Estimated survival of copepod nauplii was lowest (9%) in August. *Acartia* copepodite survival was lowest in July and August (15%), while lowest survival of *A. tonsa* adults occurred in July (34%). It has been demonstrated that the undersampling biases attributed to the low volume pumps (8 gal/min) used in these studies cannot account for the observed reduction in zooplankton densities at CCNPP (Jacobs and Kuo, 1981). Nets, which can be a potential problem, were washed, examined for deterioration and randomly as-

signed to IN and DC stations prior to each sampling period. Zooplankton densities did not change drastically beyond expected natural fluctuations when crew shifts occurred at 12-h intervals (Sample # 50 and 71; Figs. 9-14 to 9-33), which would have indicated human error.

Field notes indicate more difficulty than usual in matching TA and DC temperatures. An unusually large amount of mixing of ambient and discharge waters at the terminus would only serve to increase survival, however, not lower it.

Vital dye was also considered as a possible source of error. However, numbers of organisms absorbing the dye (% Alive) were high, indicating that the dye was effective. Moreover, assuming the dye was defective, survival estimates were recalculated using total densities; survival was still low (e.g., August *Acartia* copepodites: [DC $1635/m^3/8611/m^3$]x100 = 19%).

As previously discussed (see Data Analyses, Methods Section) the obverse of organisms surviving entrainment is organisms lost during entrainment. These losses result from cropping or death. The primary effect of entrainment at CCNPP is cropping; mortality has been consistently low during entrainment studies. Cropping is thought to be caused by physical damage from mechanical abrasion and hydraulic shear forces. Organisms passing through the cooling system are apparently either ruptured and disintegrate or they survive entrainment intact.

The impact of cropping is species and age-class specific. Some organisms are little affected, such as polychaete larvae and the harpacticoid, *Halectinosoma curticorne*. As in previous studies, organisms most affected were copepod nauplii, *Acartia* copepodites and, to a much less extent, *Acartia tonsa* adults. These disparate survival rates may be seen by comparing the difference between IN and DC densities shown in Figures 9-19 through 9-22. This selective cropping response has been consistent throughout recent years and is believed to result from differences in the shape and rigidity of the exoskeleton of the three copepod age classes.

A. tonsa adults were sexed to determine whether cropping was preferential by sex. Females were found to have a lower mean % survival than males (July 10% lower, August and September 2%; Table 9-4), suggesting that females are preferentially reduced. However, the difference is small and these data are not sufficient to be conclusive.

Many copepods have a decrease in ultimate adult size as ambient temperatures increase through the season (Deevey, 1960; McLaren, 1963; Lock and McLaren, 1970; Marshall and Orr, 1972). The predominant zooplankter, *A. tonsa*, exhibits this characteristic in laboratory growth experiments (Heinle, 1966). ANSP

personnel have also noted progressively smaller adult *A. tonsa* in samples as the season progresses.

During growth, *A. tonsa* passes through a series of twelve molts, from nauplii through copepodite to a final adult stage. At a given temperature inter-molt duration is constant; duration decreases with increasing temperature (Miller, Johnson and Heinle, 1977). This species matures from egg to first egg-producing adult in 7 or 13 days at 25.5° or 15.5°C, respectively (Heinle, 1966). Therefore, with increasing ambient temperatures *A. tonsa* matures faster but achieves a smaller body size. It is possible that organisms growing more quickly at higher ambient temperatures have thinner and less durable exoskeletons and therefore, are more susceptible to shear stress during transit through a cooling system. The effect on molting stages of nauplii and copepodites would be even greater as the cylindrical form of the adult "shell" is thought to be more resistant to stress.

Fragments of these organisms would be expected to be recovered at the discharge in proportions relative to the number of organisms collected at the intake unless they disintegrate to very small particles. In studies conducted by the State of Maryland, fragments were not found in quantities sufficient to account for the cropping rate observed in entrainment studies (Bradley, 1980).

The increased ΔT in 1981 was analyzed to determine any additional impact on the zooplankton community. Mean ΔT's ranged from 5.4°C to 6.1°C for the four sampling periods, similar to mean ΔT's in 1980. The maximum ΔT of 6.7°C did not last long enough to obtain sufficient data for analysis; therefore, analysis was restricted to data obtained when ΔT was less than 6.1°C. A stepwise linear regression analysis determined that ΔT did not significantly affect survival of *A. tonsa* life stages or all dye-sensitive species combined (Table 9-6). This analysis indicated that ΔT alone, at the elevations observed in the 1981 study, did not adversely affect survival of entrained zooplankton. This finding is consistent with previous studies conducted at CCNPP (Newman and Sage, 1981*b*). Deaths attributable to thermal stress (IN % Alive minus DC % Alive) were low, ranging between 0% and 9.8%. The low mortality from passage through the plant is not surprising, in view of the relatively short exposure time (~4 min) to the low cross-condenser increase in water temperature (<6.7°C). Once-through cooling systems with longer exposure times and/or higher ΔT's typically produce greater mortalities, especially if chlorine is applied to the cooling water system (Icanberry, 1974; Davies and Jensen, 1975); no biocides are used in the cooling water system at CCNPP.

Survival of copepod nauplii and all dye-sensitive combined (primarily copepod nauplii) was inversely related to ambient temperature and were the only groups that had a significant

decrease in survival related to ambient temperature increases (Table 9-6). This relationship was strongly influenced by conditions surrounding the August entrainment (highest ambient temperature and lowest survival). As previously discussed, ambient temperatures were not unusual and were unlikely to have been the sole factor in the reduced copepod nauplii survival. Curiously, linear regression showed that *Acartia* copepodite and *A. tonsa* adult survival increased with higher ambient temperatures. Biologically, the opposite would have been expected. The sporadic densities in June precluded the pairing of several intake and discharge samples, excluding them from the analysis and, therefore, under representing survival in June.

Estimated percent survival for entrained zooplankton declined with seasonally increasing densities; this is consistent with previous findings. This inverse relationship is not necessarily solely the result of biological factors, but is partially a mathematical function resulting from the calculation of the survival estimates (Newman, Sage, and D'Apolito, 1980). The extent of the bias has not been investigated. The biological cause of the inverse relationship of density and survival is probably a sum of an underlying physiological response of these organisms, but this response is not understood.

Fluctuations in survival estimates correspond to monthly, daily, and hourly periodicities in abundance. Survival appears to be negatively influenced by a complex interaction of ΔT, maximum ambient temperatures and zooplankton densities (Newman and Sage, 1981*b*). *Acartia tonsa*, the major constituent of the summer assemblage, exists in water temperatures approaching their upper thermal tolerance of 32-35°C (Heinle, 1969; Gonzales, 1974). The nauplii and copepodite stages probably have a lower thermal tolerance, assuming they follow the patterns of other invertebrates whose juvenile stages are more sensitive to thermal stress (Jensen et al., 1969; Kinne, 1970). Heinle (1969) has suggested that the zooplankton community at this season is already thermally stressed. The combination of maximum ambient water temperature and ΔT elevate discharge temperatures to those approaching the maximum thermal tolerance limit. This relationship is depicted in Figure 9-34, a 3-dimensional plot of naupliar survival against ΔT and discharge temperature---observe that lower survival corresponds with higher discharge temperature (>30°C) and not with higher ΔT's. The length of exposure is probably not enough to allow a direct heat-shock effect; however, the additional stress may impair the organism, increasing its susceptibility to the rigors of entrainment.

Conclusions

Results of the 1981 zooplankton entrainment study at the Calvert Cliffs Nuclear Power Plant were generally similar to results of prior years (1977-1980). Although species and age

composition were typical of this area of the Chesapeake Bay, there was a perceptible shift in spcies composition, with an increase in numbers and abundances of marine species which was attributed to the sustained higher salinities. The most abundant species in June was a harpacticoid, *Halectinosoma curticorne*. From July through September the three life stages of *Acartia tonsa*, adults, copepodites and nauplii, were predominant.

The primary effect of entrainment upon zooplankton survival is a reduction in numbers of organisms (cropping), determined by the ratio of alive organisms entering the plant to those recovered alive in the effluent. As observed in prior studies of dye-sensitive organisms, copepod nauplii and the copepodite stage of *Acartia tonsa* experienced the greatest losses. Cropping was specific to species and age class through time; this finding was consistent with results of previous studies. It has been hypothesized in previous studies (1977 to 1980) that the loss of organisms is the result of physical damage from mechanical and hydraulic forces during transit through the cooling system, but to date this hypothesis has not been confirmed.

Survival estimates for the dye-sensitive species were unusually low in July and August. Data for selected hydrographic parameters, sampling error, and power-plant operations were examined as possible causes of the disparate values but were not considered to be the responsible factors. Reasons for the lower survival estimates are not known.

The cross-condenser thermal increase (ΔT) ranged between 5.4°C and 6.1°C, similar to that in 1980. Within these ranges, ΔT did not adversely affect estimated survival of entrained zooplankton at Calvert Cliffs Nuclear Power Plant. However, when high ambient water temperature and ΔT combine to exceed 30°C, the temperature of the entrained waters approaches the thermal tolerance of the predominant species, *A. tonsa*, and is believed to weaken the organism, particularly the juvenile stages, increasing susceptibility to rigors of entrainment.

Reduced zooplankton survival is correlated with maximum zooplankton densities. This apparent relationship may be an artifact due to the method of calculating survival estimates from ratios and/or ancillary to an underlying physiological response to seasonally high ambient temperatures and increased densities.

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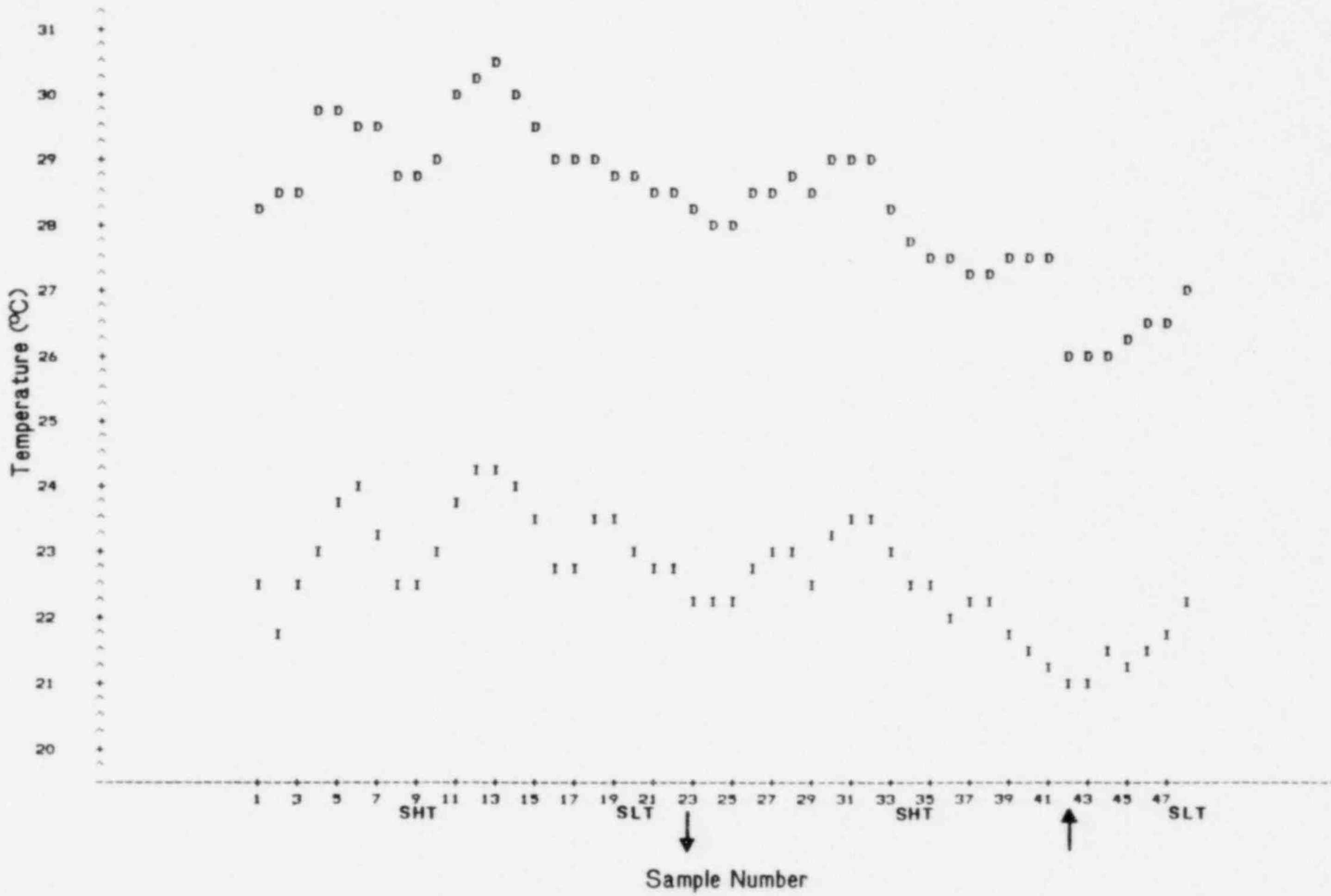

Figure 9-2. Water temperature (°C) at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant measured at time of zooplankton sample collection on June 16-17. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓).

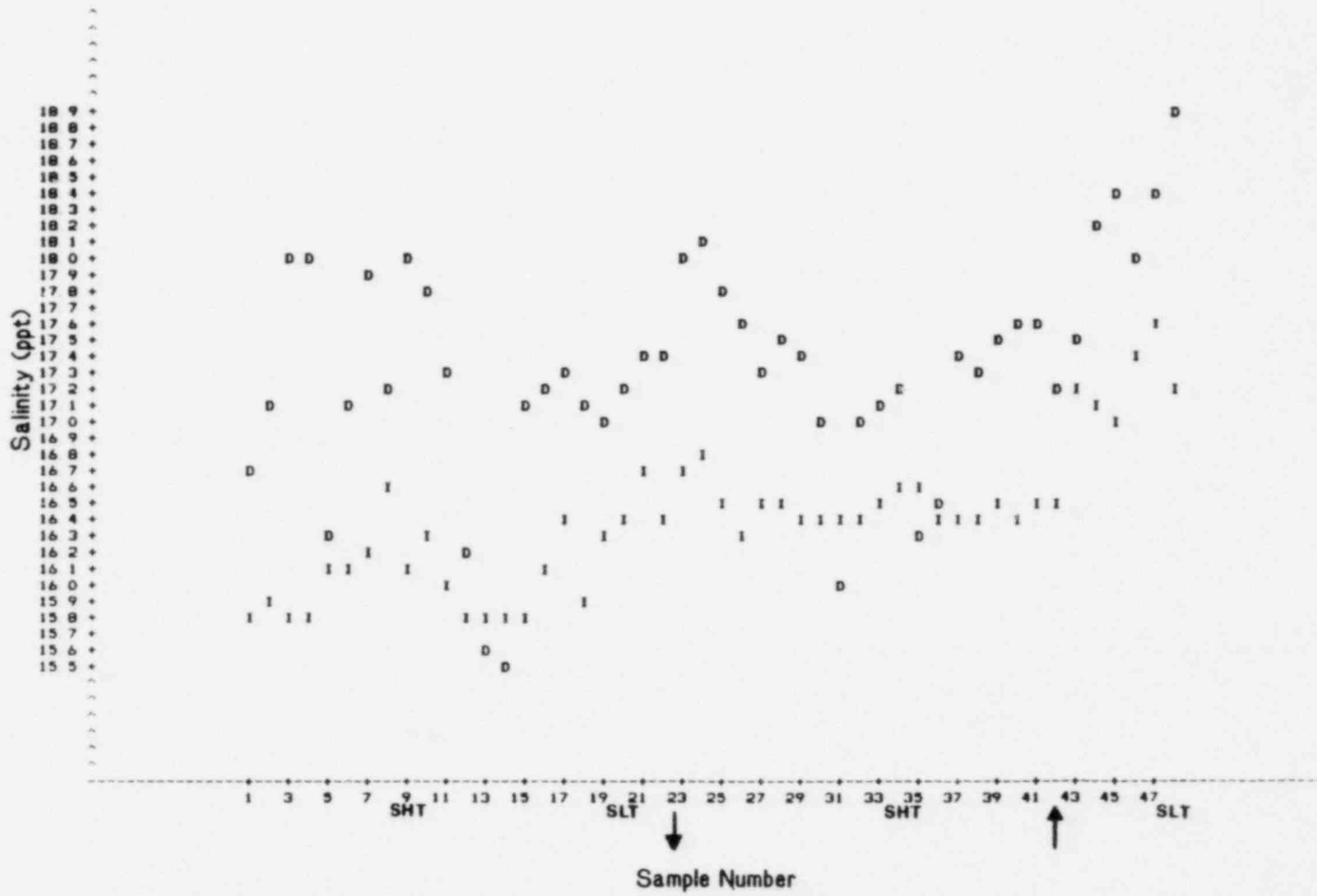

Figure 9-3. Salinity (ppt) at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant measured at time of zooplankton sample collection on June 16-17. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓).

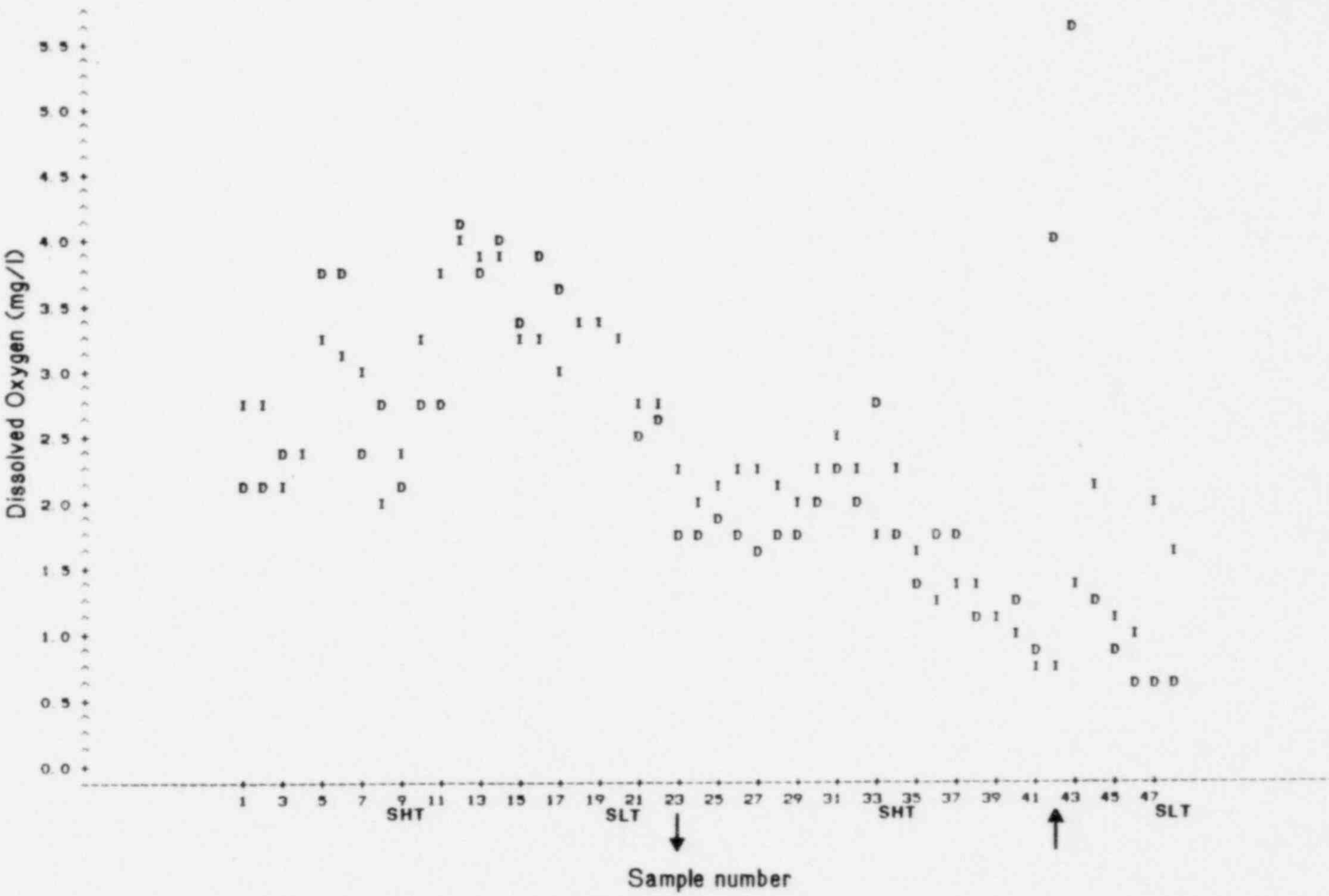

Figure 9-4. Dissolved oxygen (mg/l) at Intake (I) and Discharge (D) at Calvert Cliffs Nulcear Power Plant measured at time of zooplankton sample collection on June 16-17. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓).

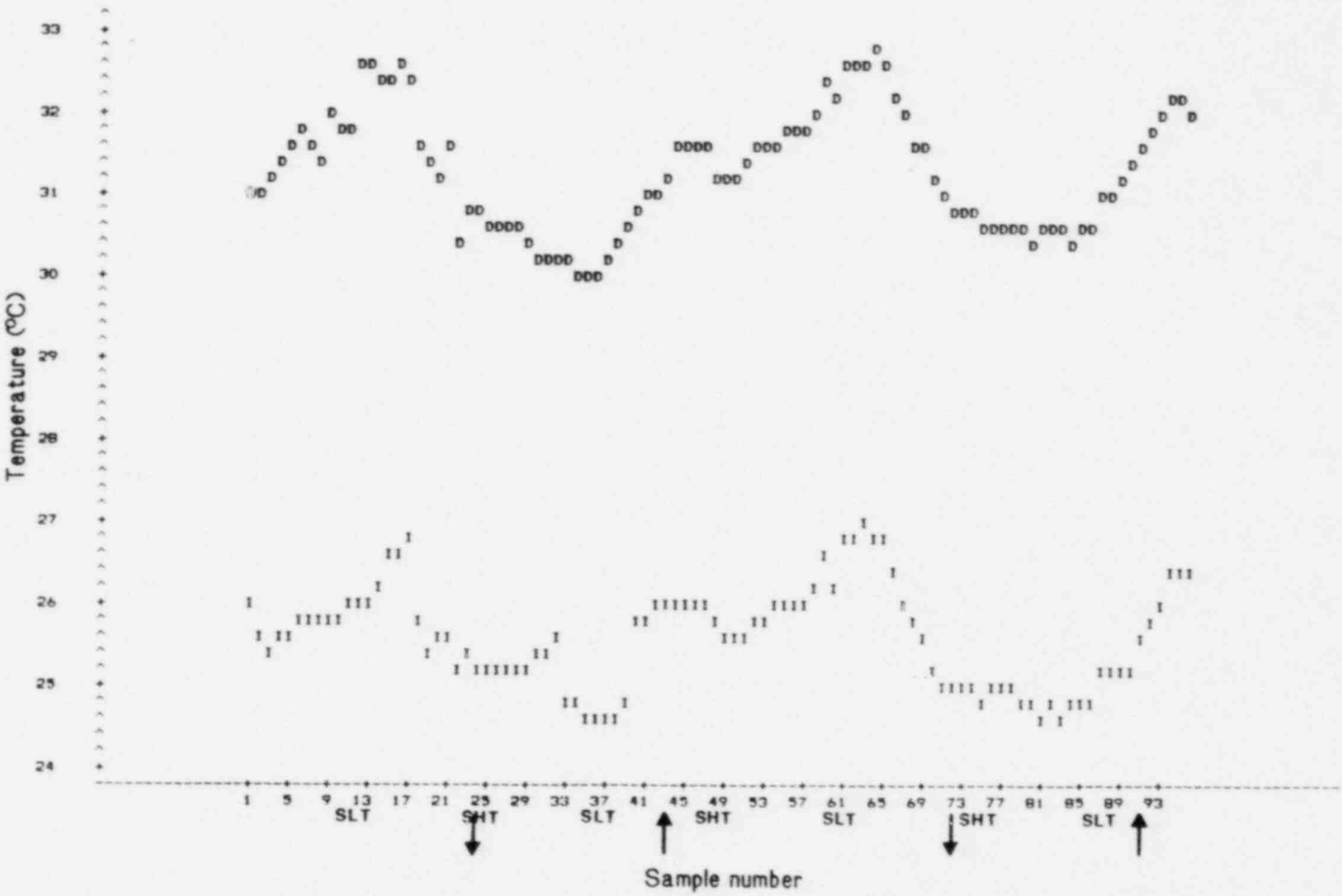

Figure 9-5. Water temperature (^{0}C) at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant measured at time of zooplankton sample collection on July 7-9. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓).

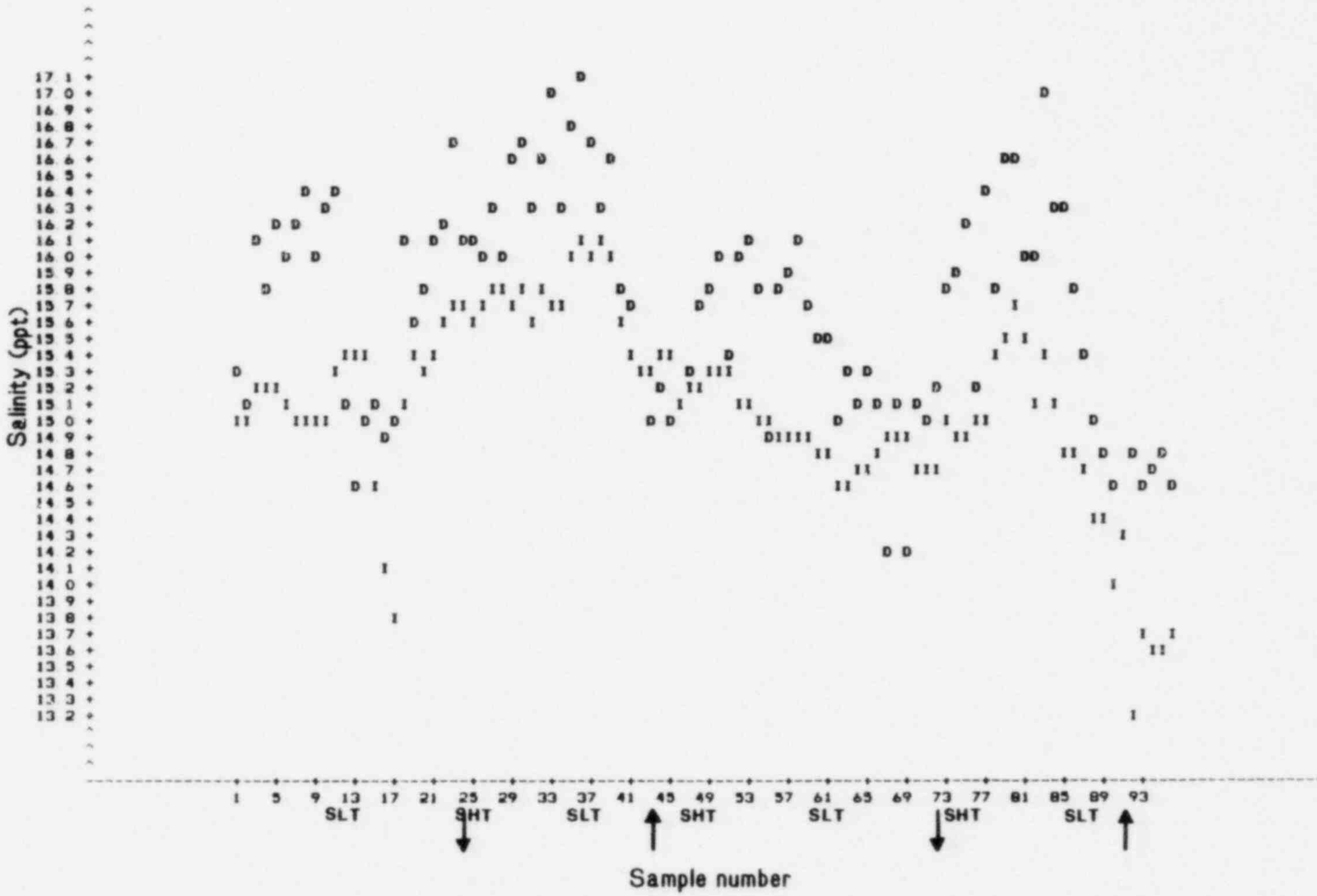

Figure 9-6. Salinity (ppt) at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant measured at time of zooplankton sample collection on July 7-9. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓).

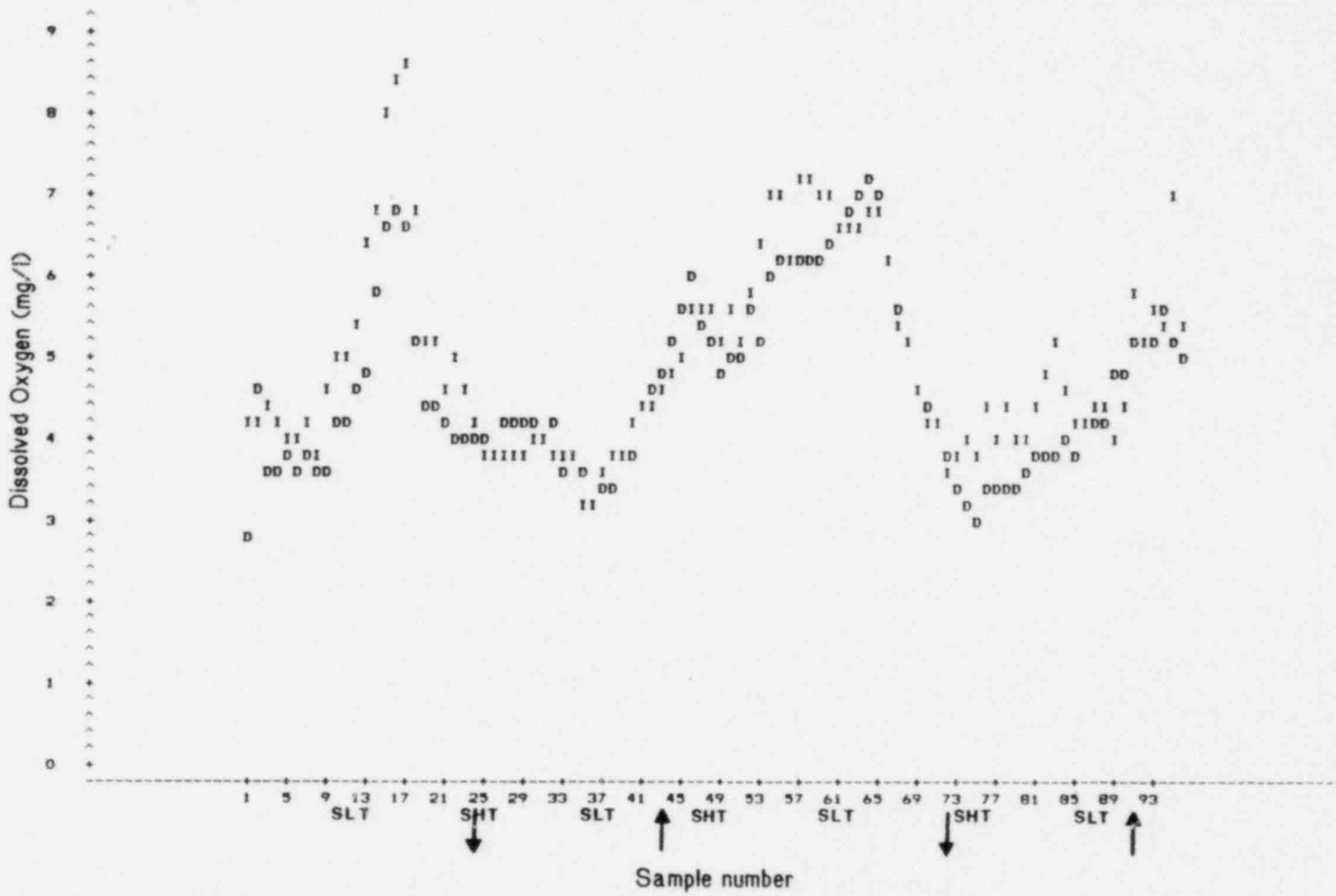

Figure 9-7. Dissolved oxygen (mg/l) at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant measured at time of zooplankton sample collection on July 7-9. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓).

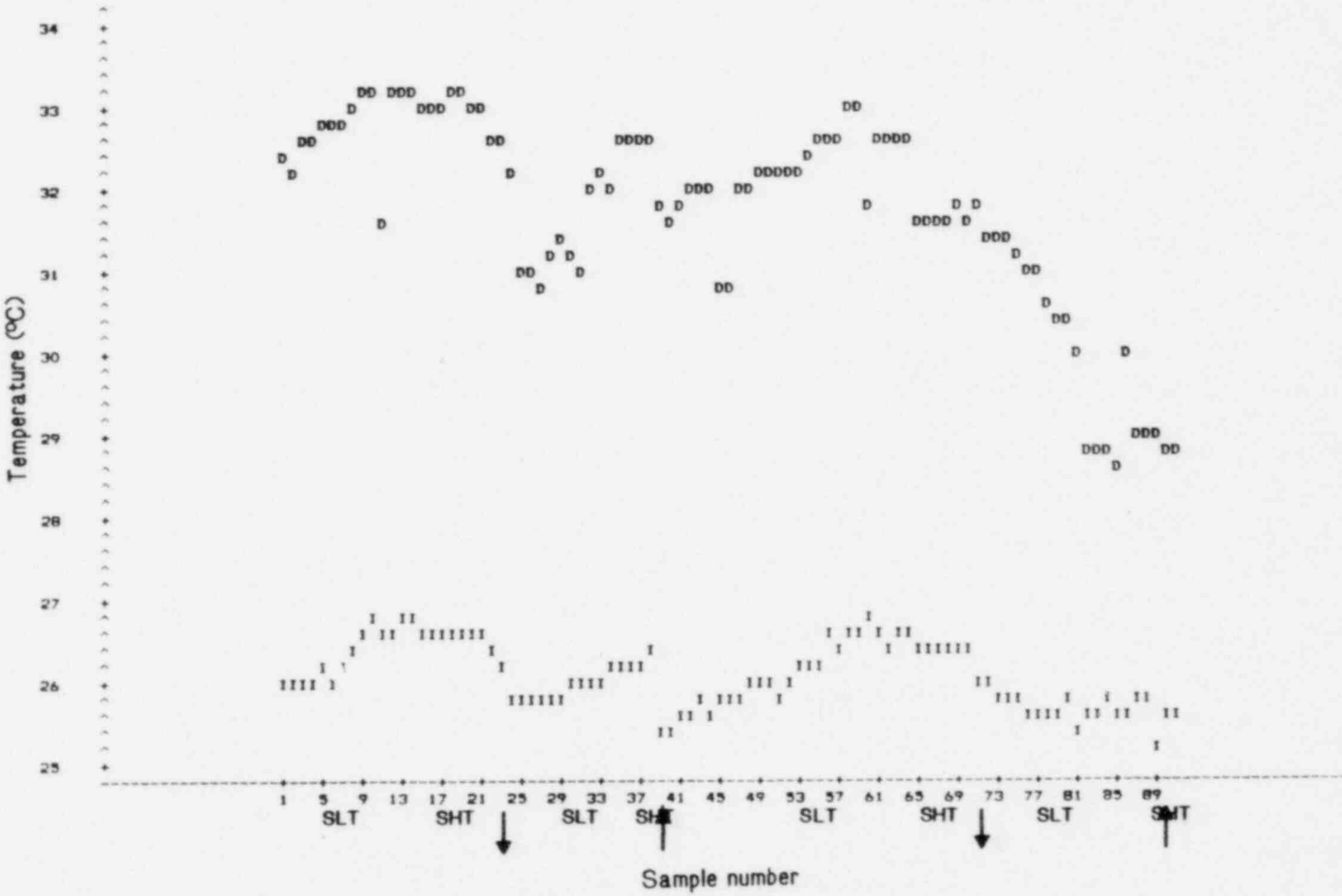

Figure 9-8. Water temperature (°C) at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant measured at time of zooplankton sample collection on August 18-20. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓).

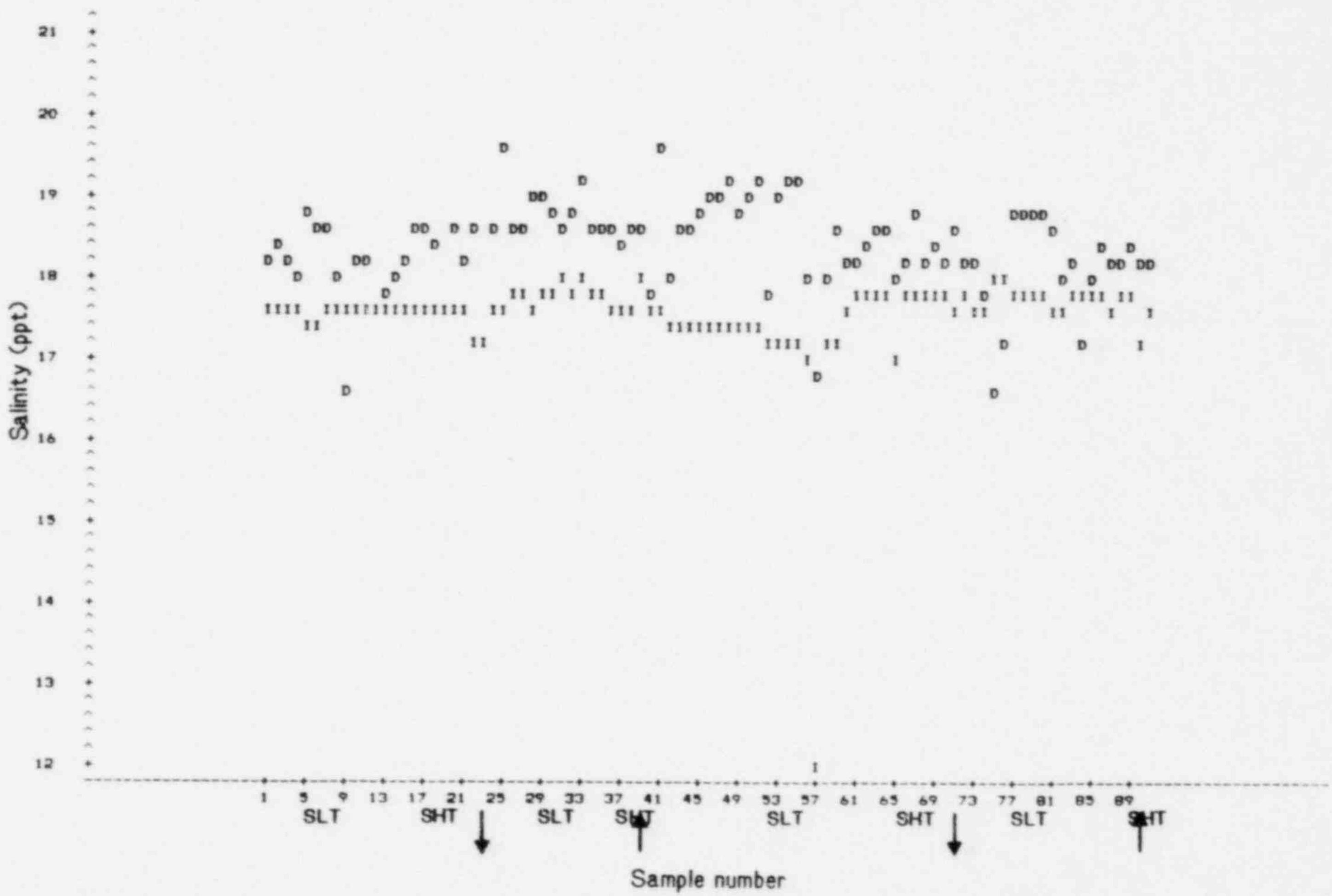

Figure 9-9. Salinity (ppt) at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant measured at time of zooplankton sample collection on August 18-20. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓).

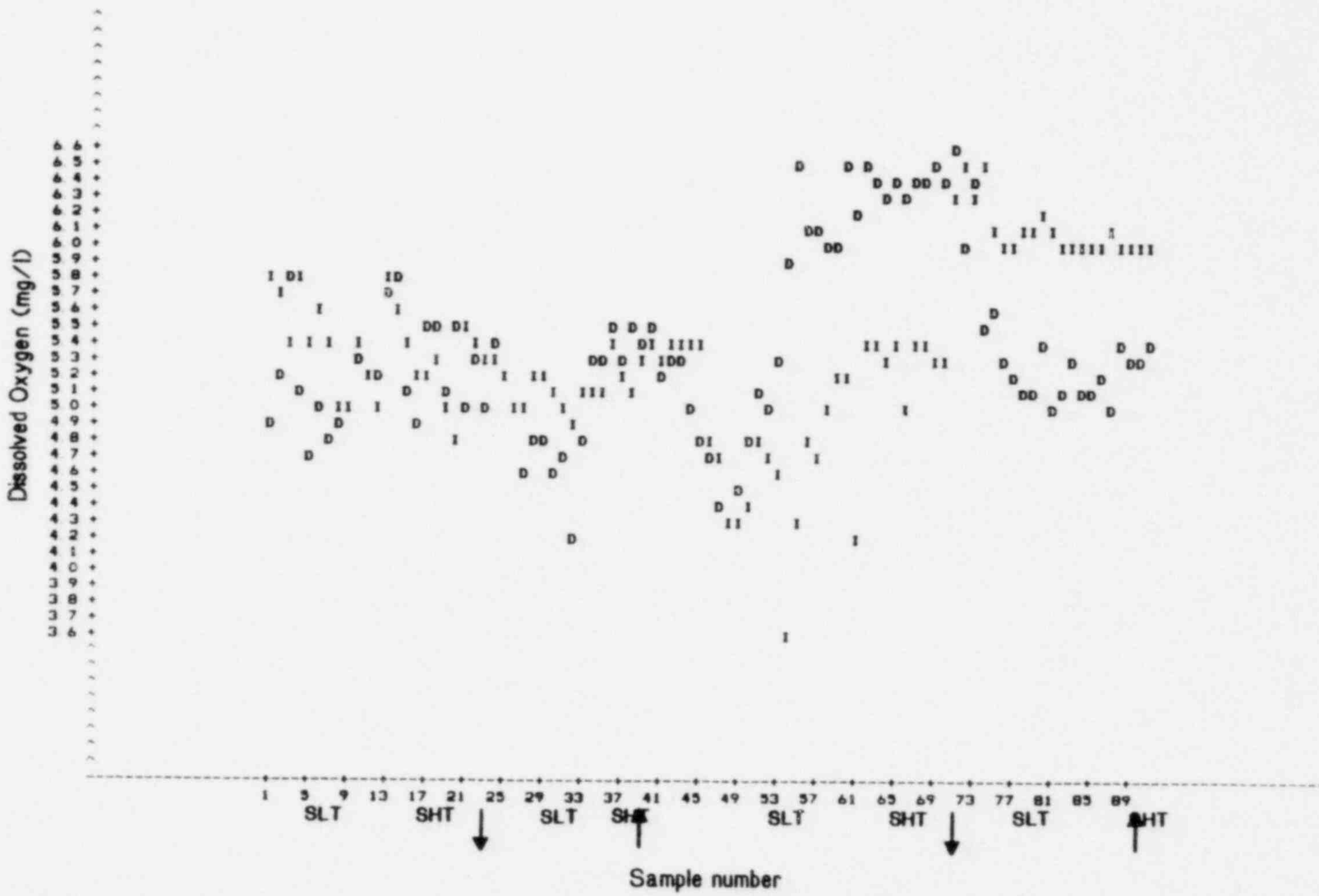

Figure 9-10. Dissolved oxygen (mg/l) at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant measured at time of zooplankton sample collection on August 18-20. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓).

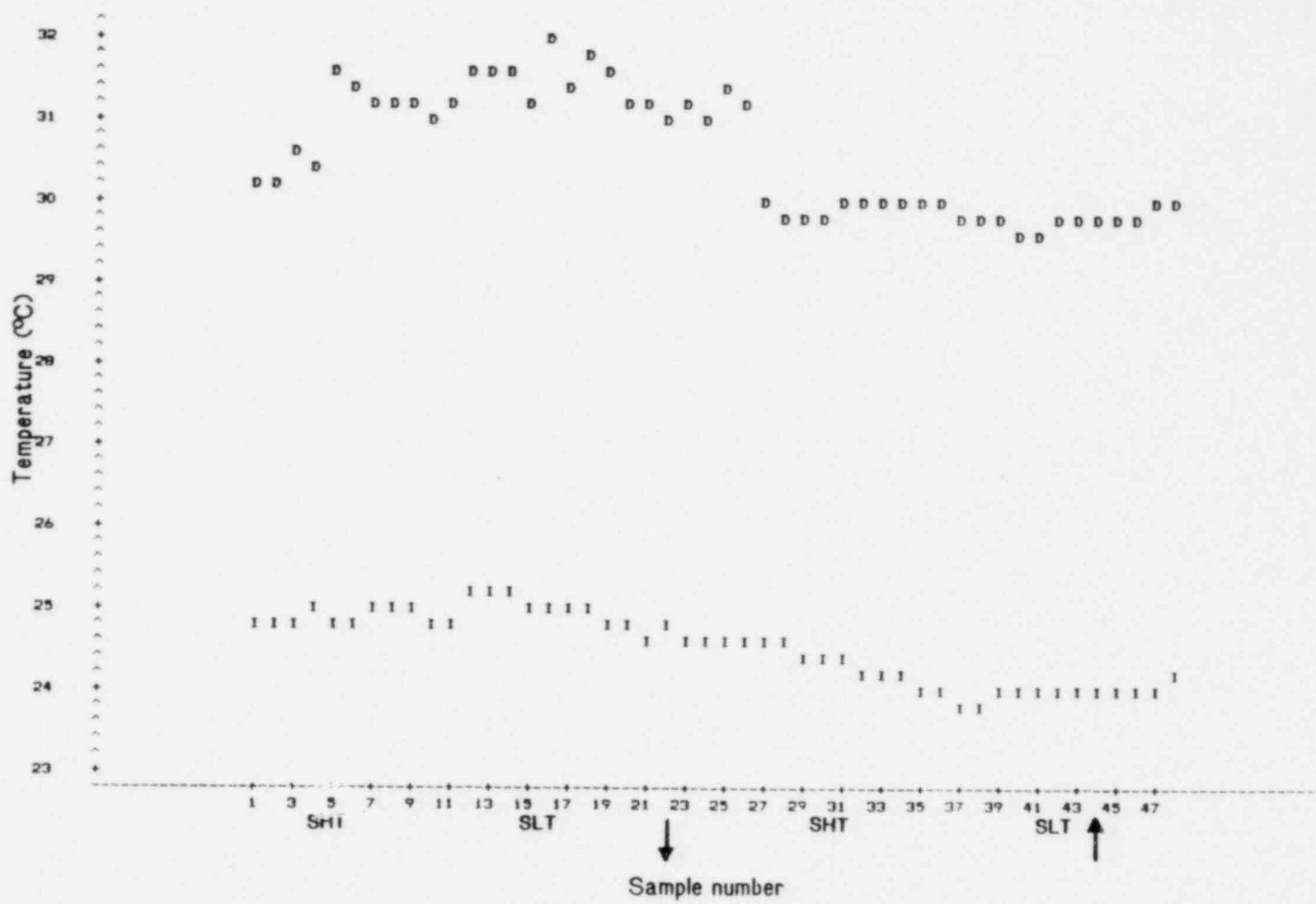

Figure 9-11. Water temperature (°C) at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant measured at time of zooplankton sample collection on September 9-10. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓).

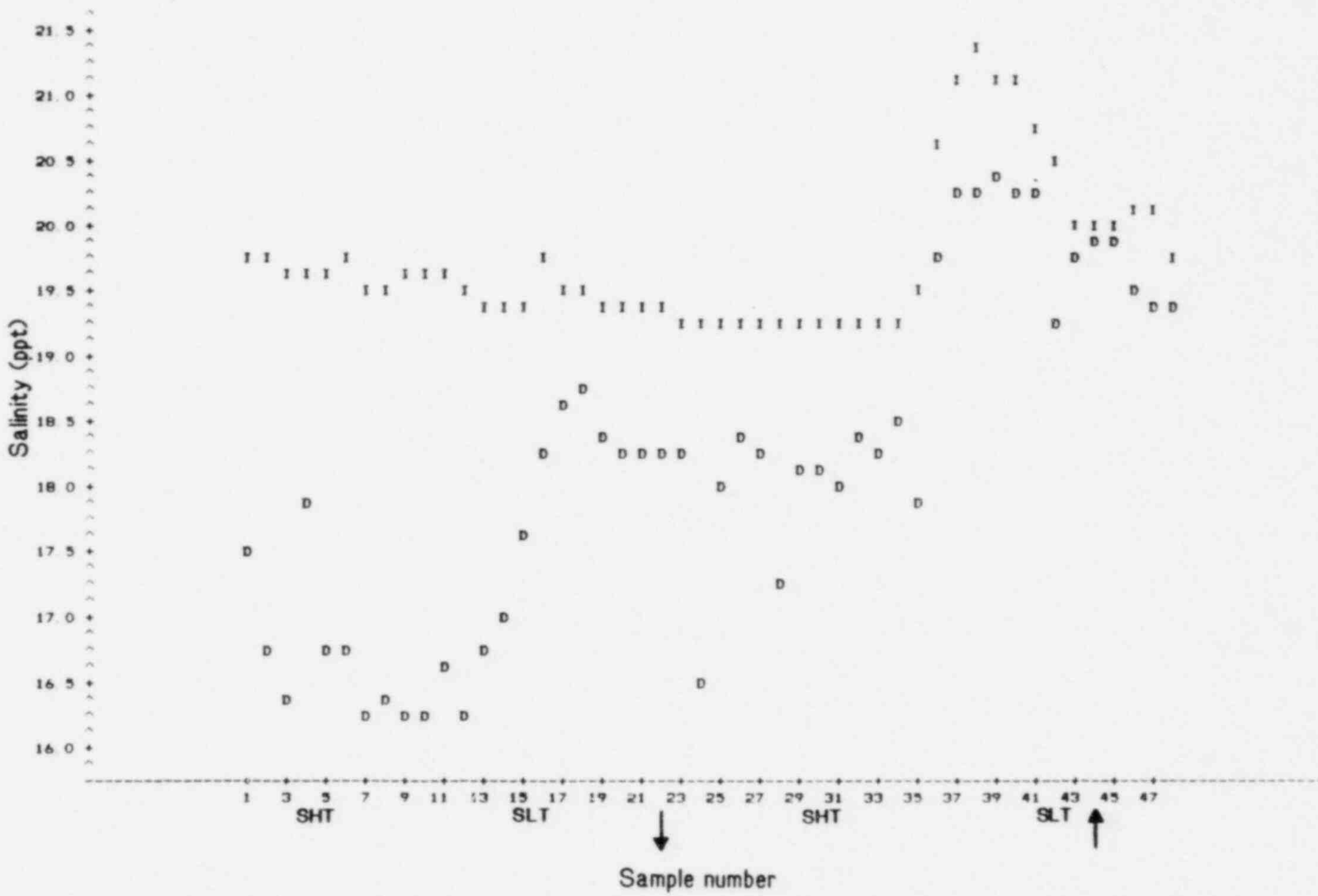

Figure 9-12. Salinity (ppt) at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant measured at time of zooplankton sample collection on September 9-10. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓).

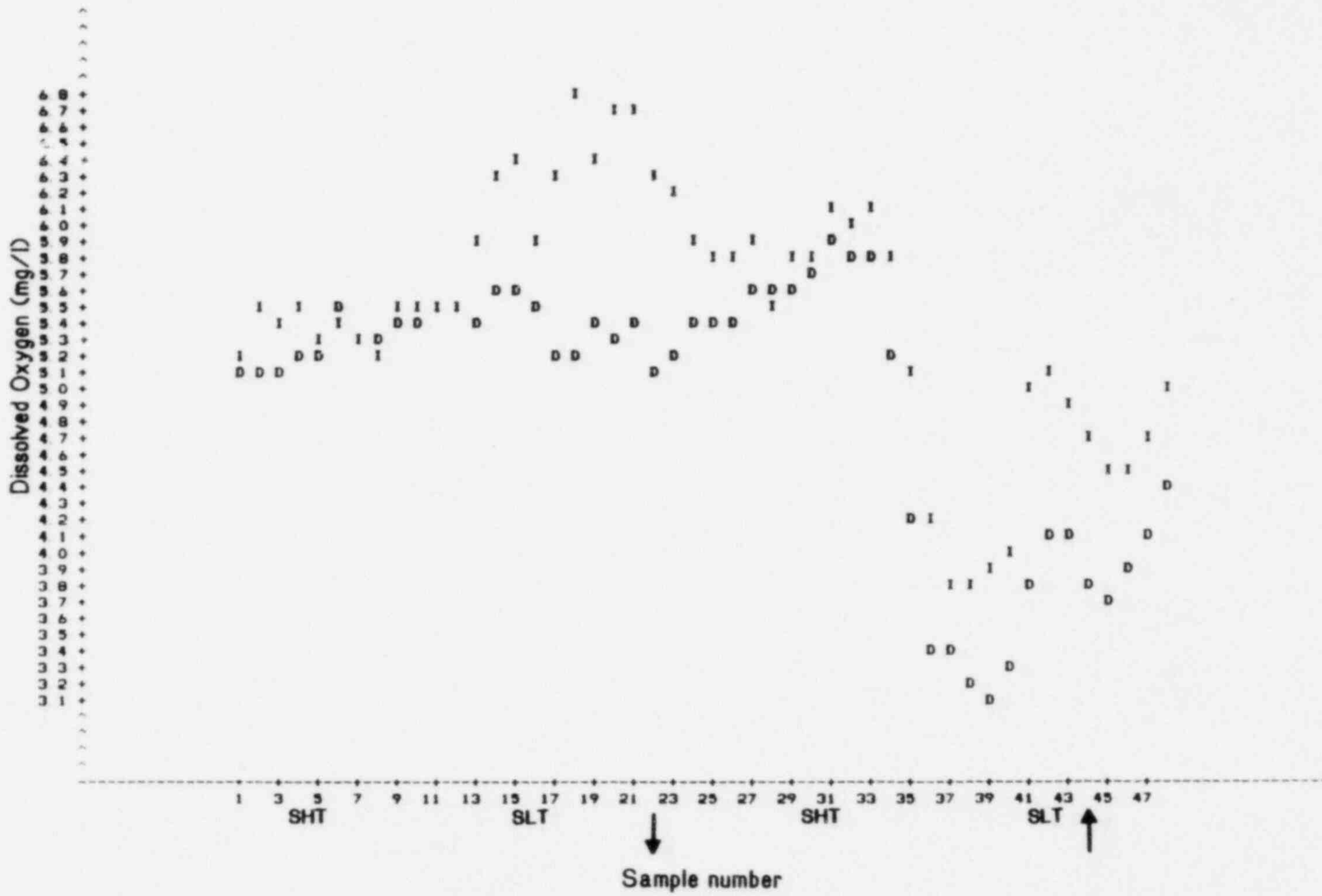

Figure 9-13. Dissolved oxygen (mg/l) at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant measured at time of zooplankton sample collection on September 9-10. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun Positions are indicated as sunrise (↑) and sunset (↓).

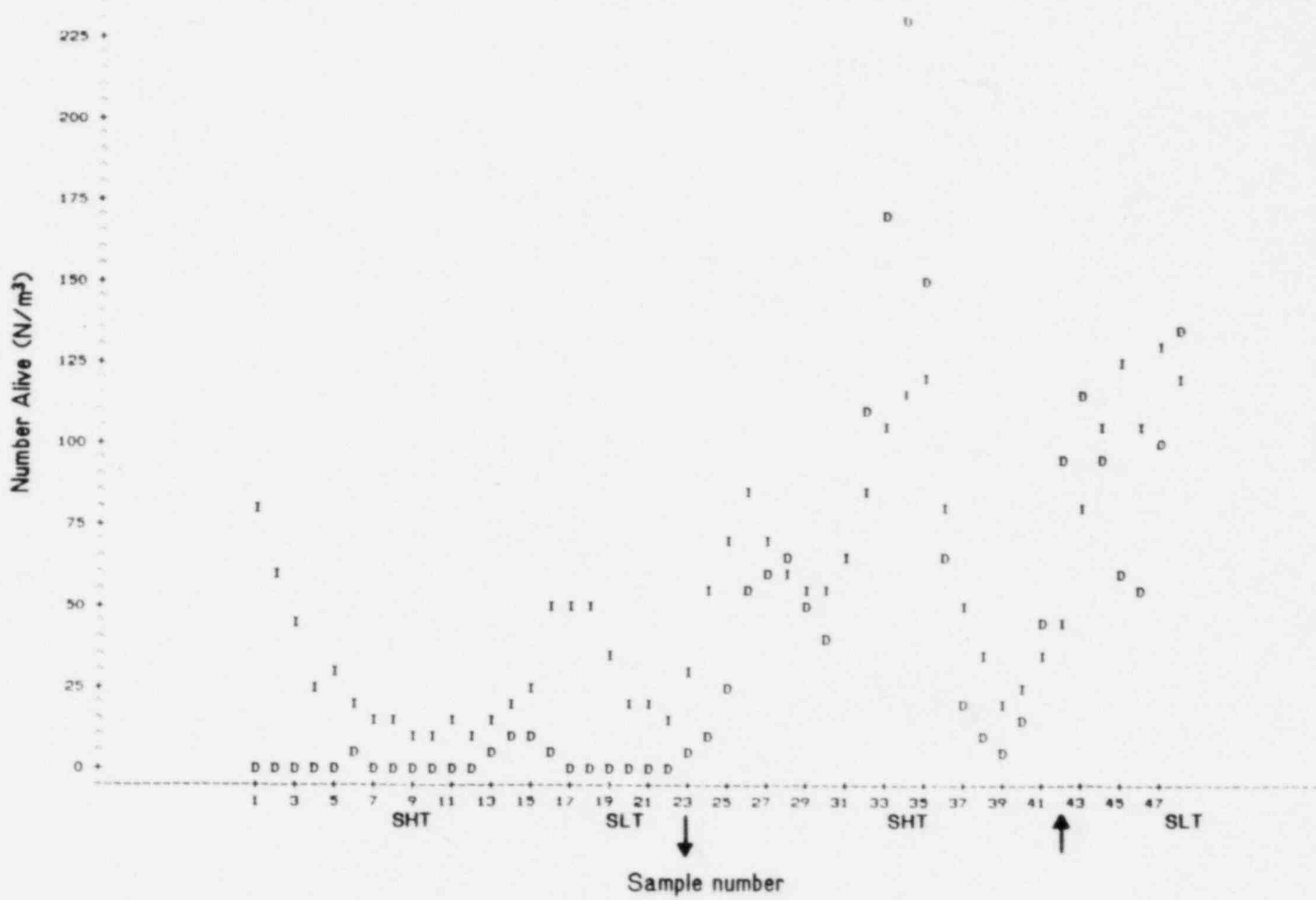

Figure 9-14. Density (N/m^3) of living *Acartia tonsa* adults in samples collected every 30 min on June 16-17 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant. Tiedes are indicated as slack hight tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

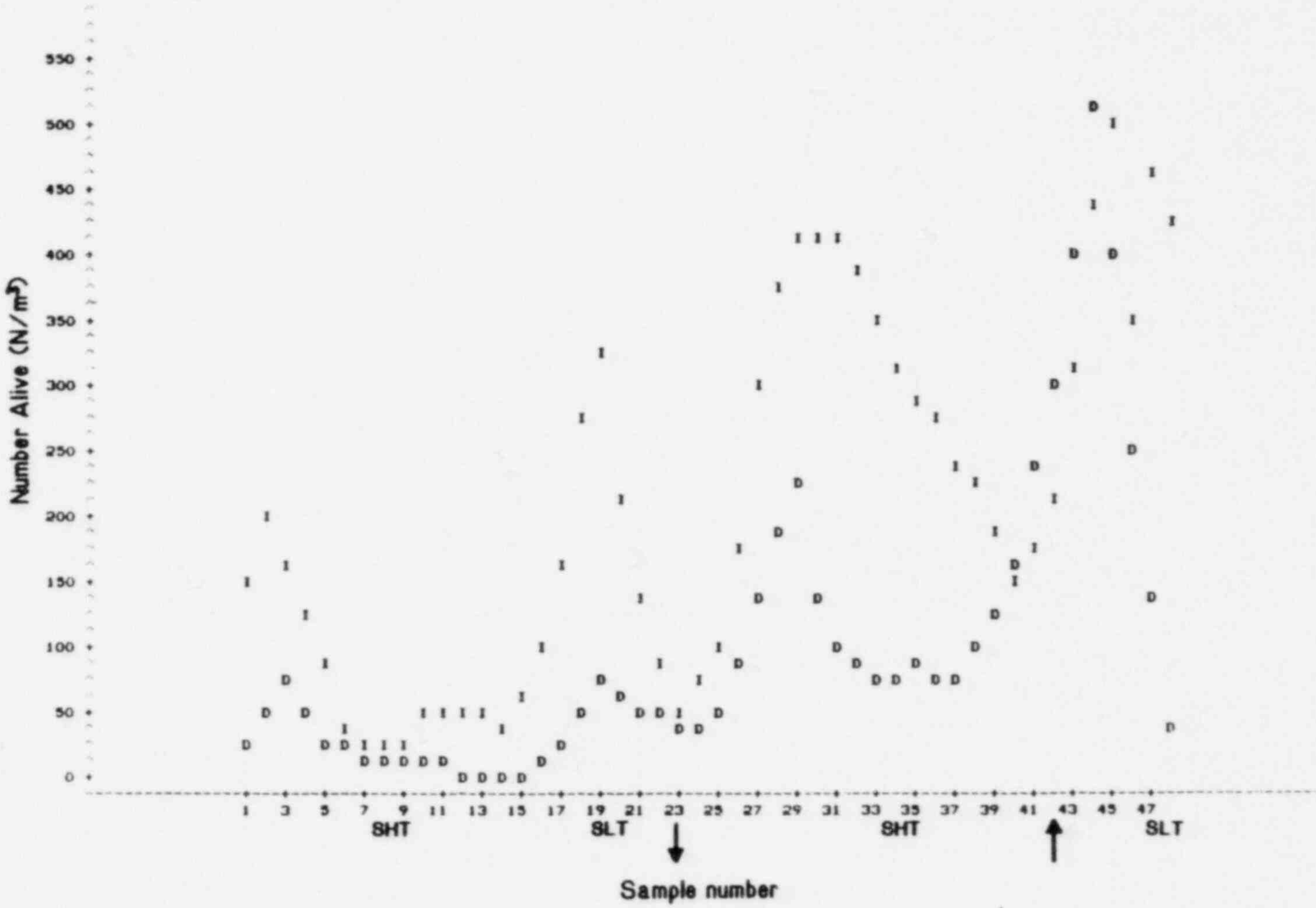

Figure 9-15. Density (N/m^3) of living *Acartia* copepodites in samples collected every 30 min on June 16-17 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant. Tides are indicated as slack high tide (SHR) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

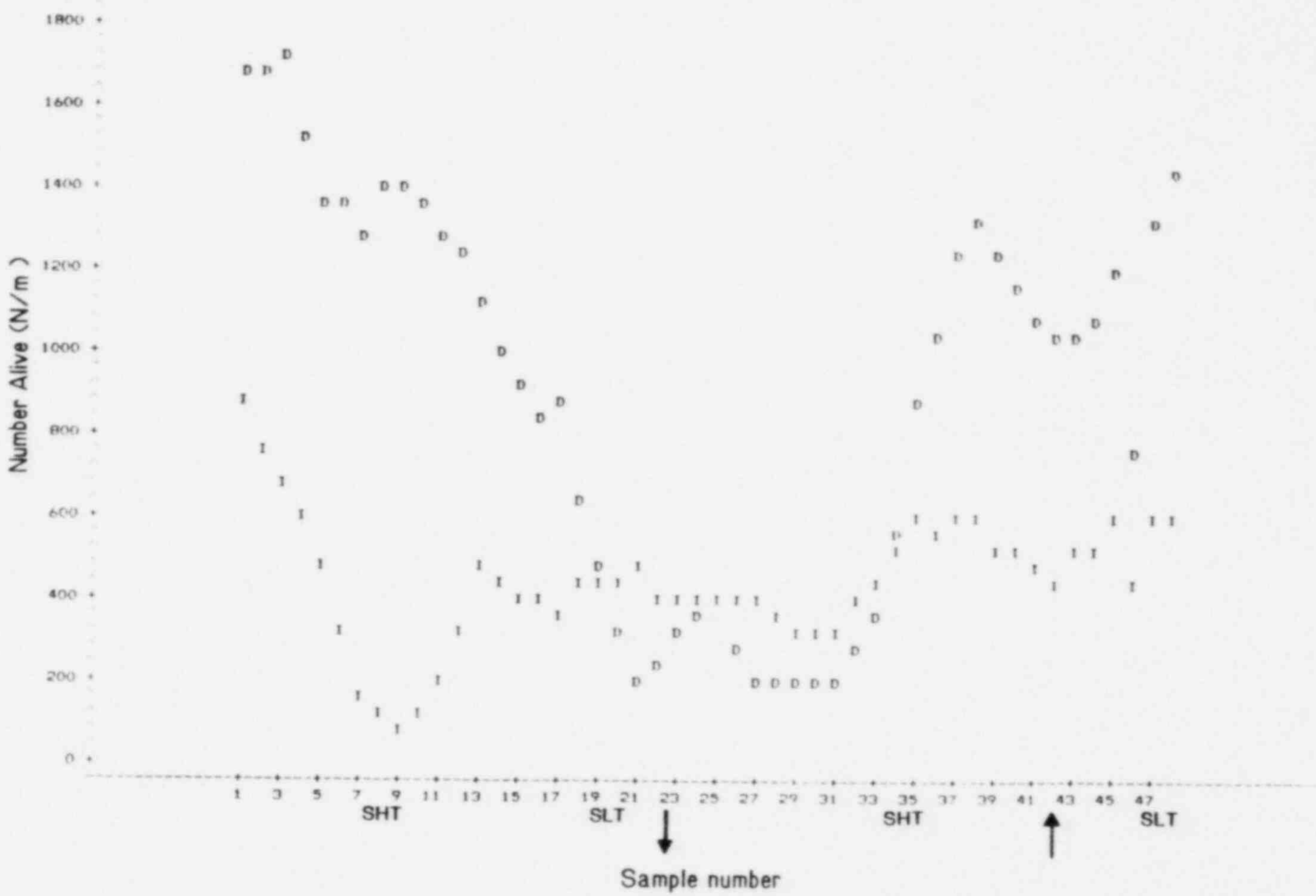

Figure 9-16. Density (N/m^3) of living Copepod nauplii in samples collected every 30 min on June 16-17 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

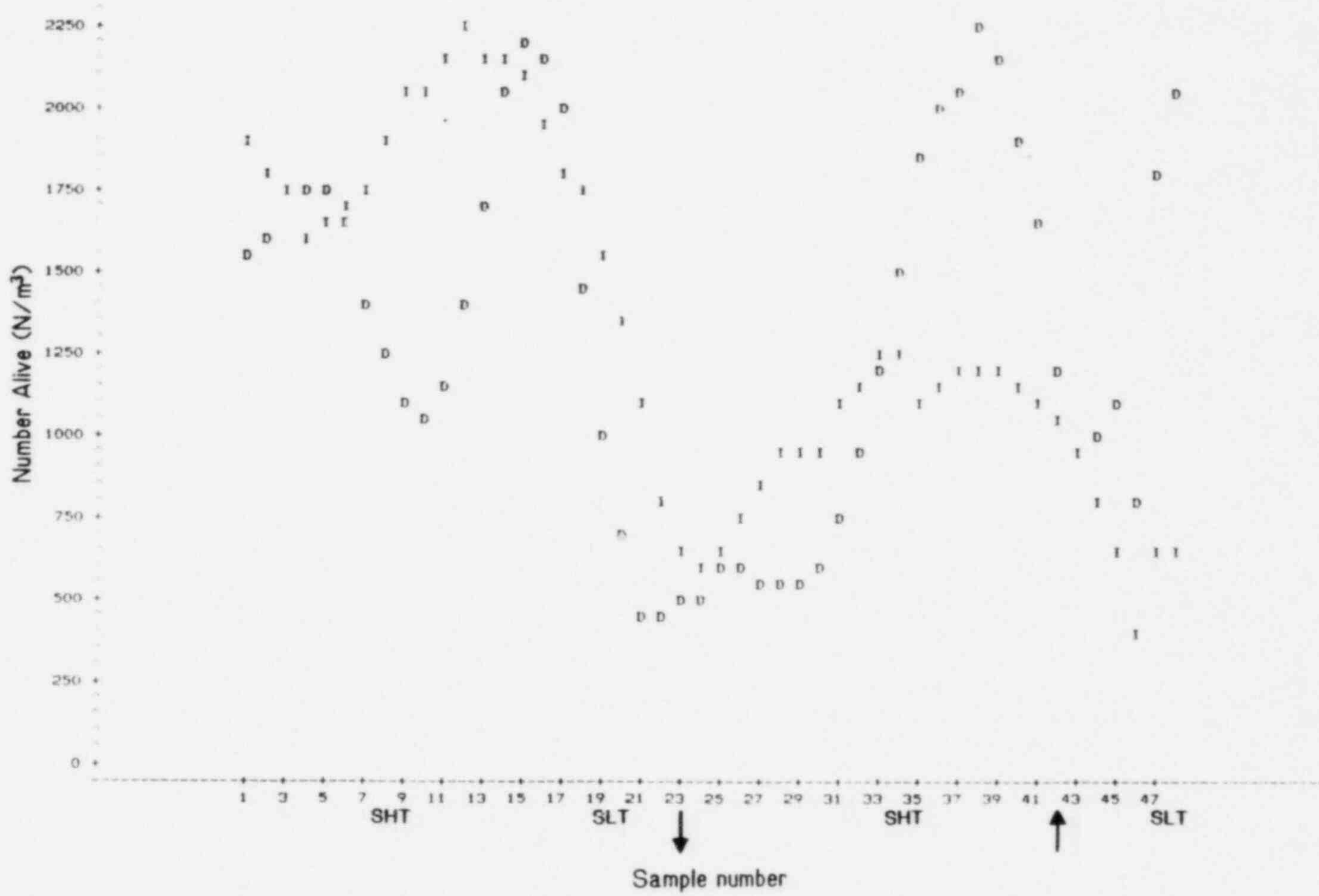

Figure 9-17. Density (N/m³) of living Polychaete larvae in samples collected every 30 min on June 16-17 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plqnt. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

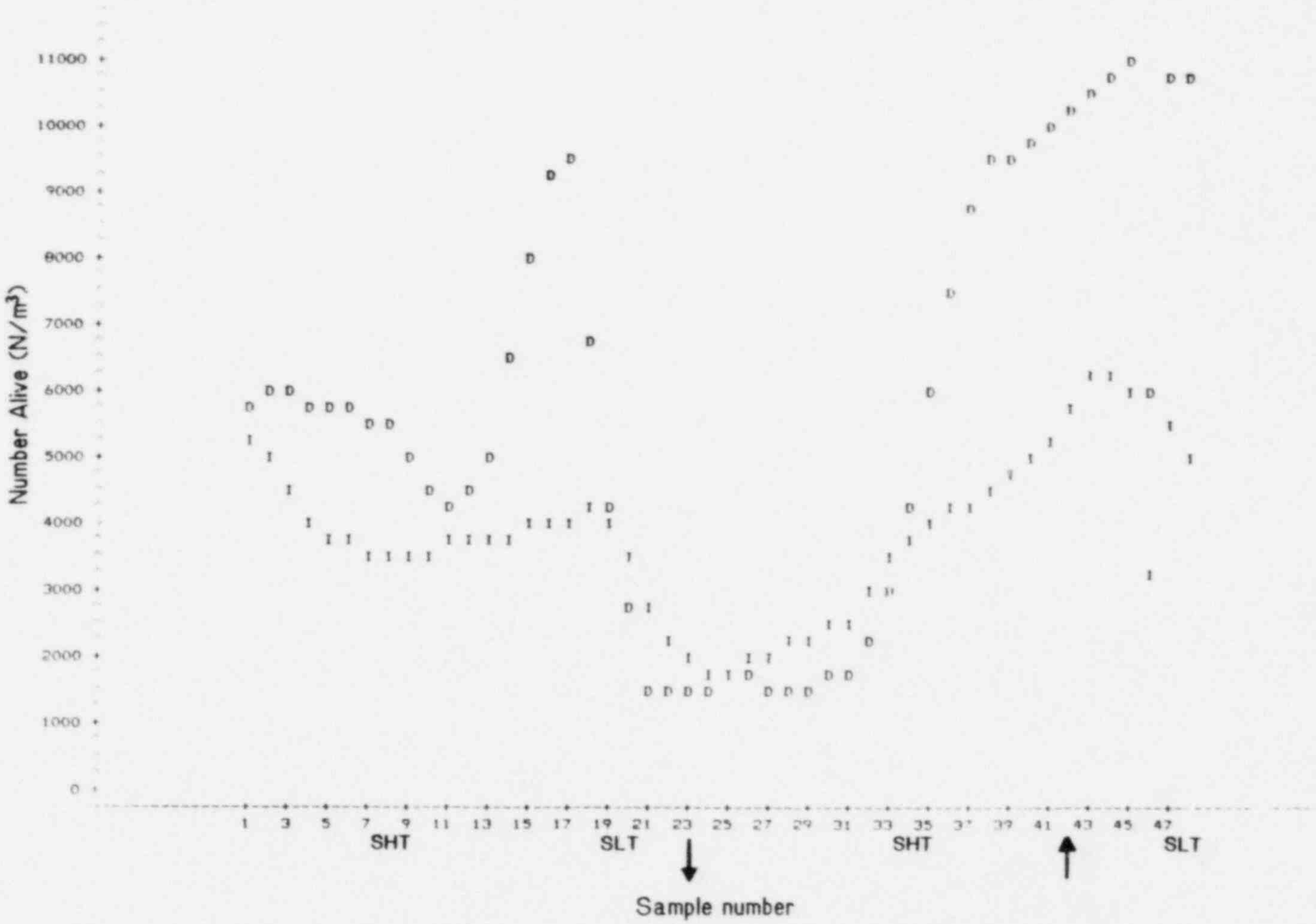

Figure 9-18. Density (N/m^3) of living all dye-sensitive species in samples collected every 30 min on June 16-17 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

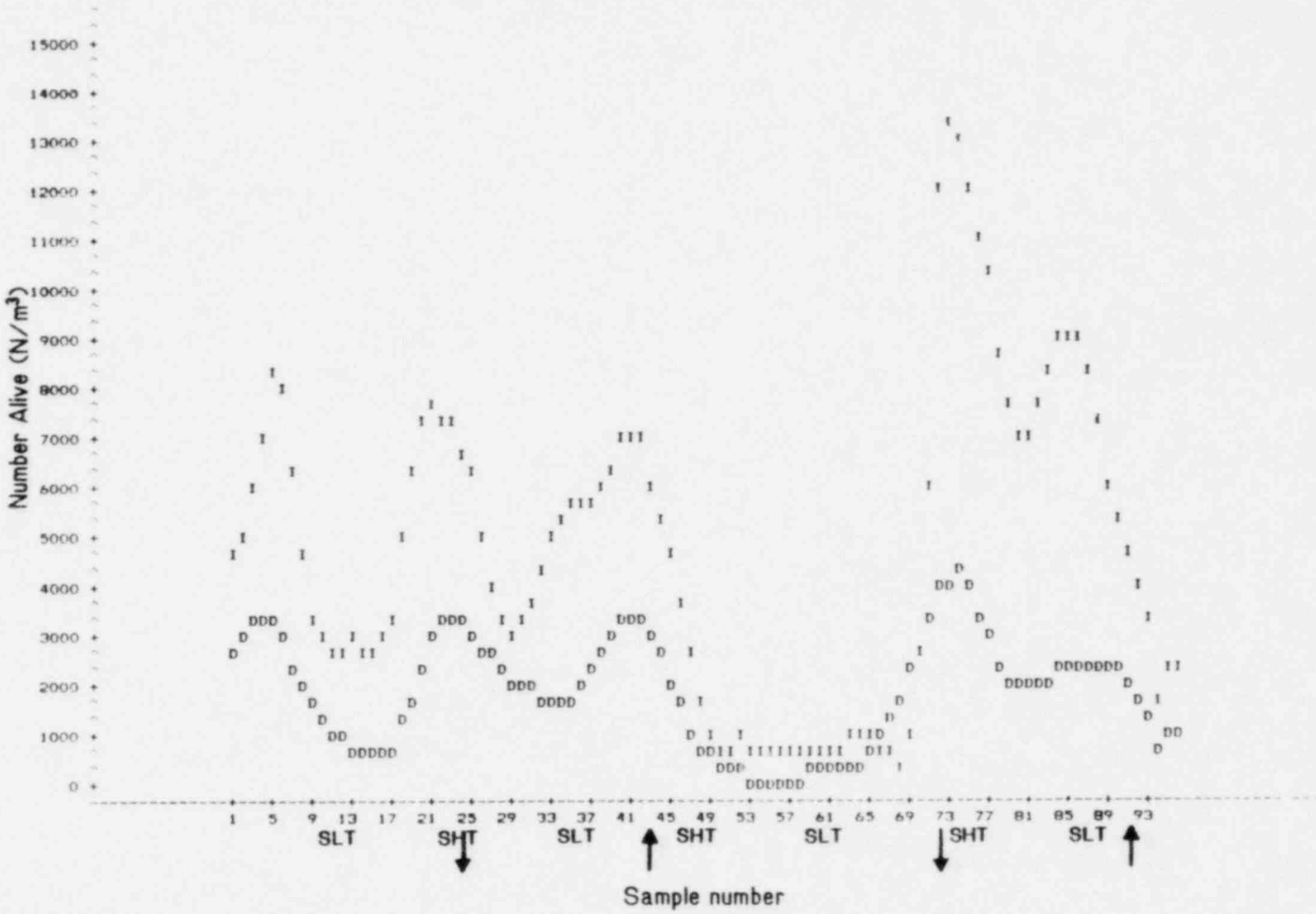

Figure 9-19. Density (N/m^3) of living *Acartia tonsa* adults in samples collected every 30 min on July 7-9 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

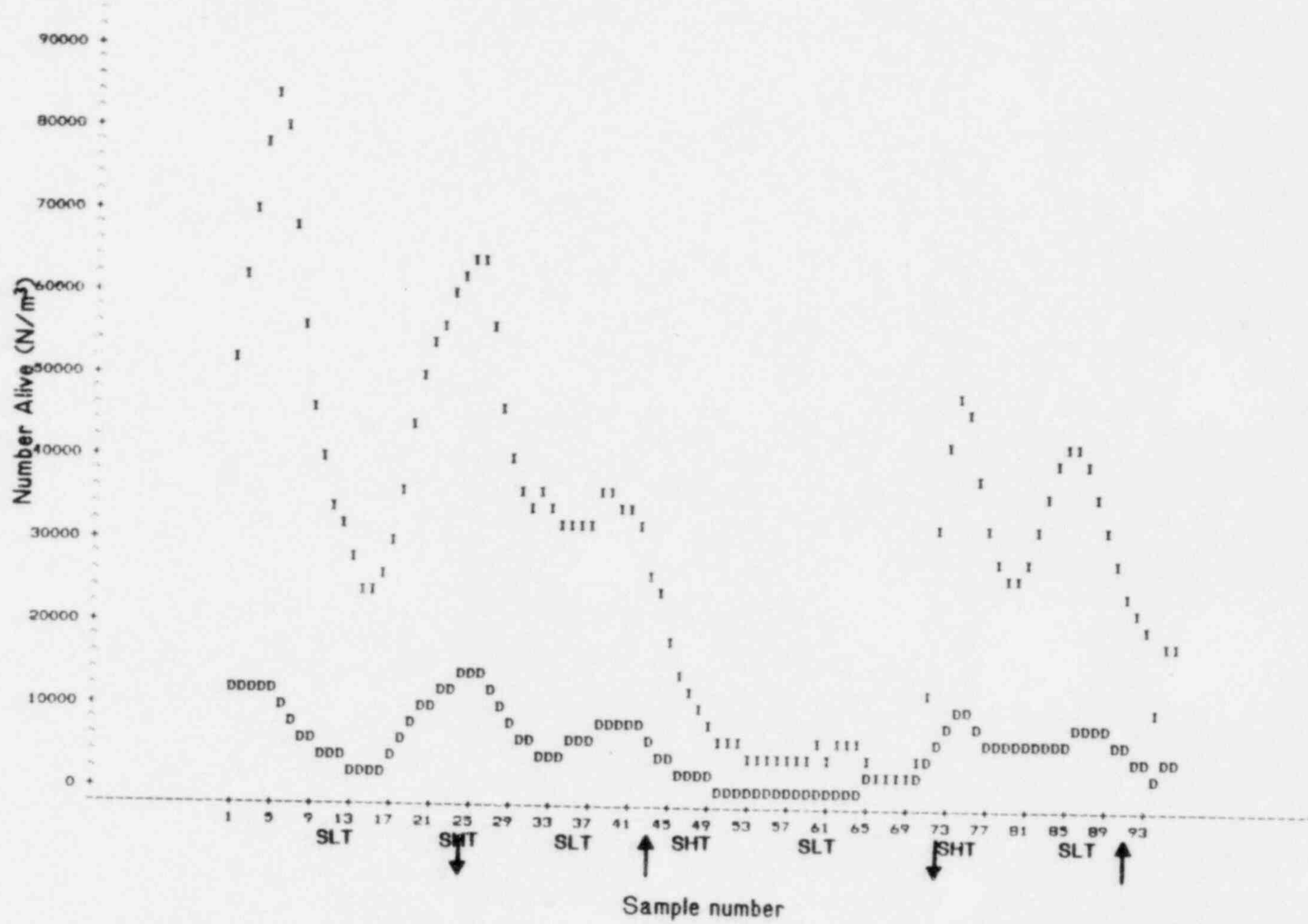

Figure 9-20. Density (N/m^3) of living *Acartia* copepodites in samples collected every 30 min on July 7-9 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

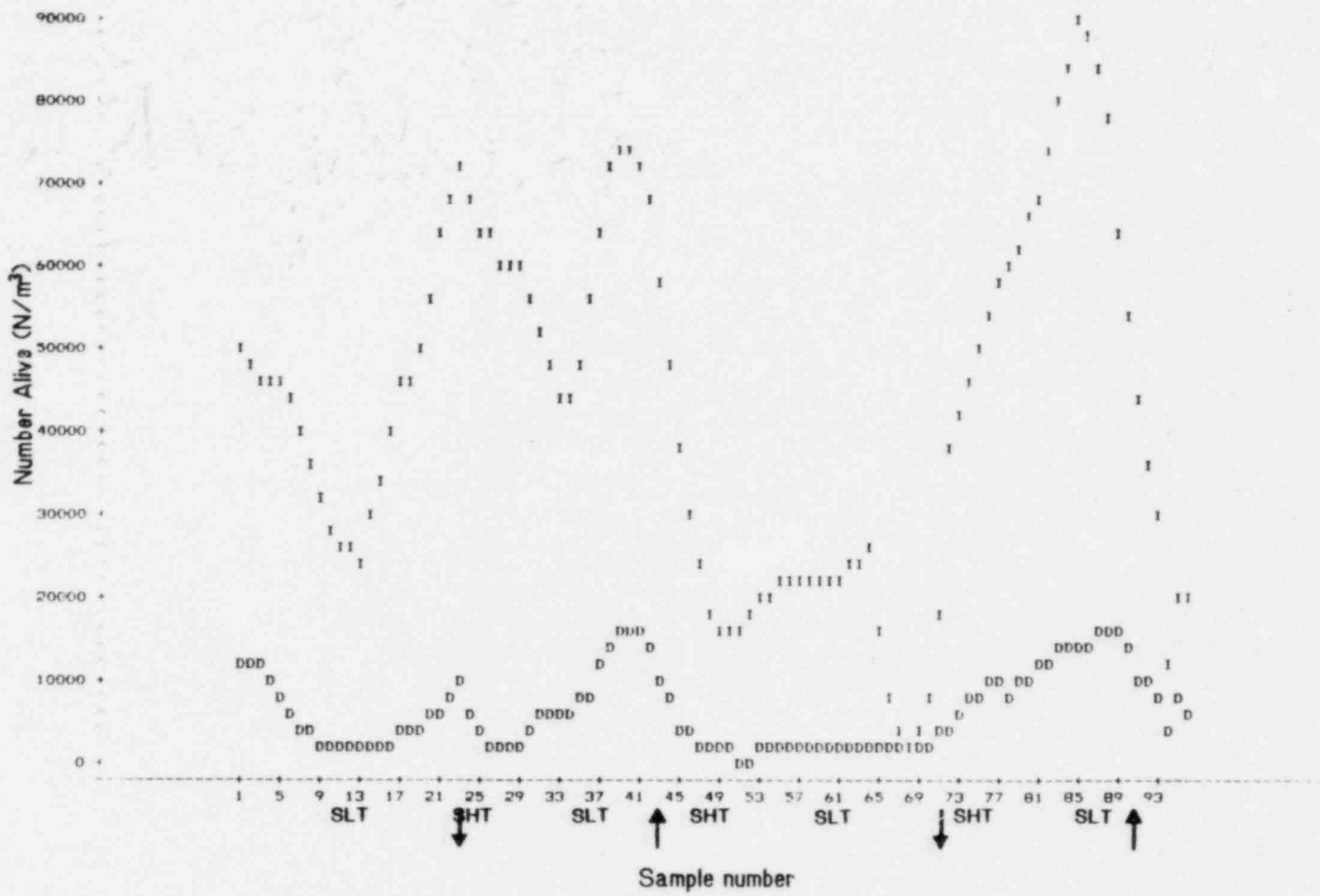

Figure 9-21. Density (N/m^3) of living Copepod nauplii in samples collected every 30 min on July 7-9 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

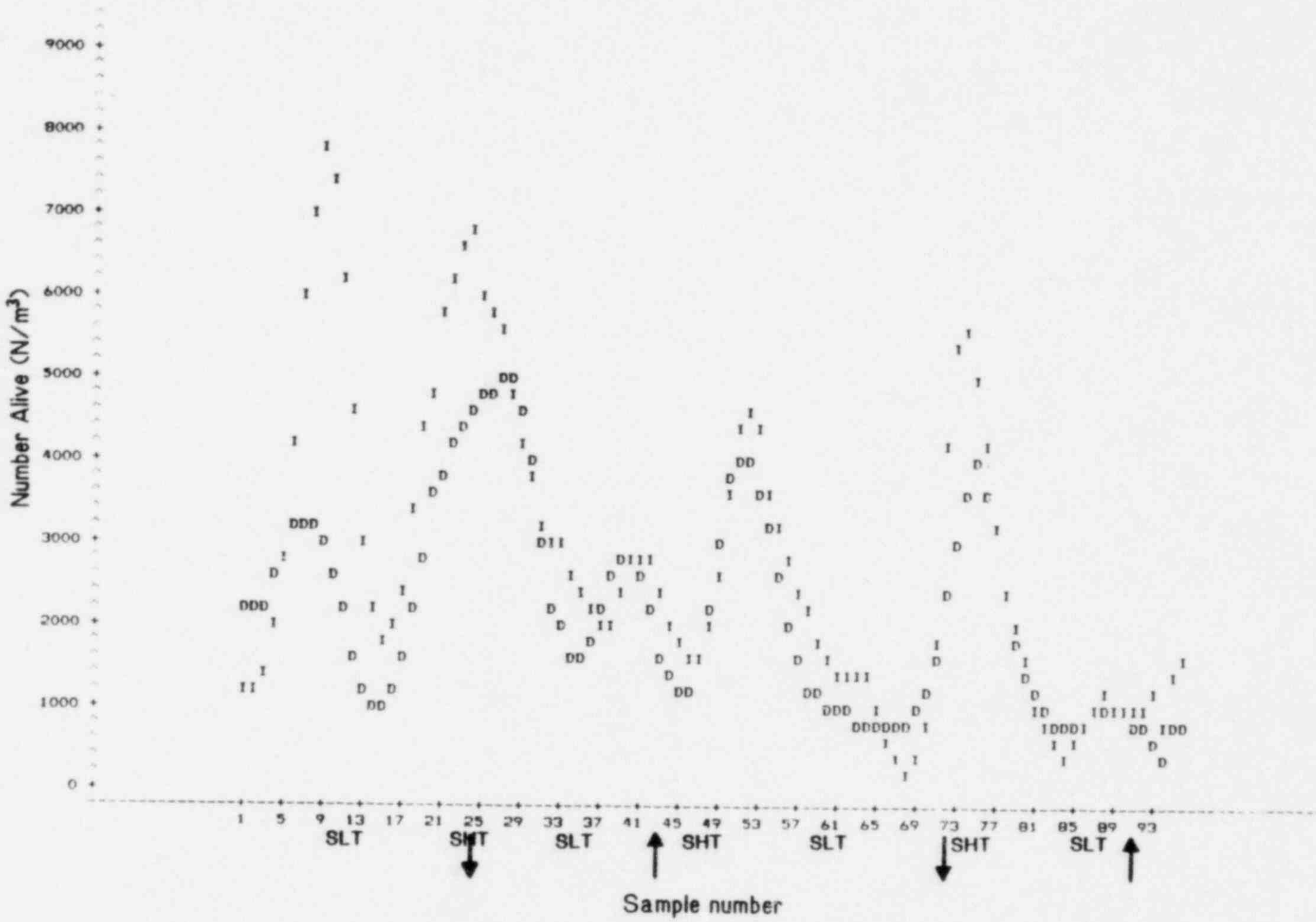

Figure 9-22. Density (N/m^3) of living Polychaete larvae in samples collected every 30 min on July 7-9 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

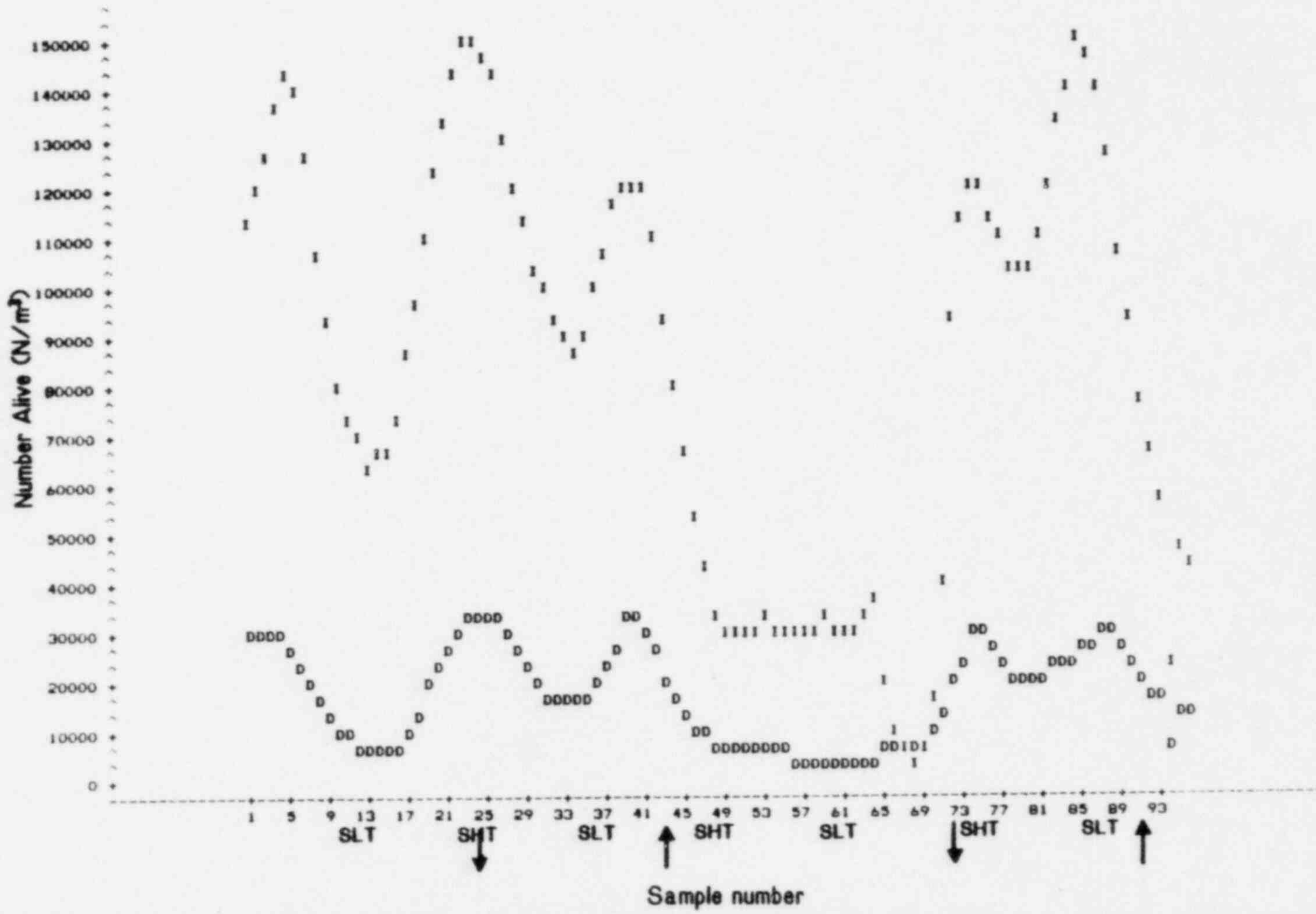

Figure 9-23. Density (N/m³) of living all dye-sensitive species in samples collected every 30 min on July 7-9 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant. Tides are indicated as slack high tide (SHT) and slack low tide SLT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

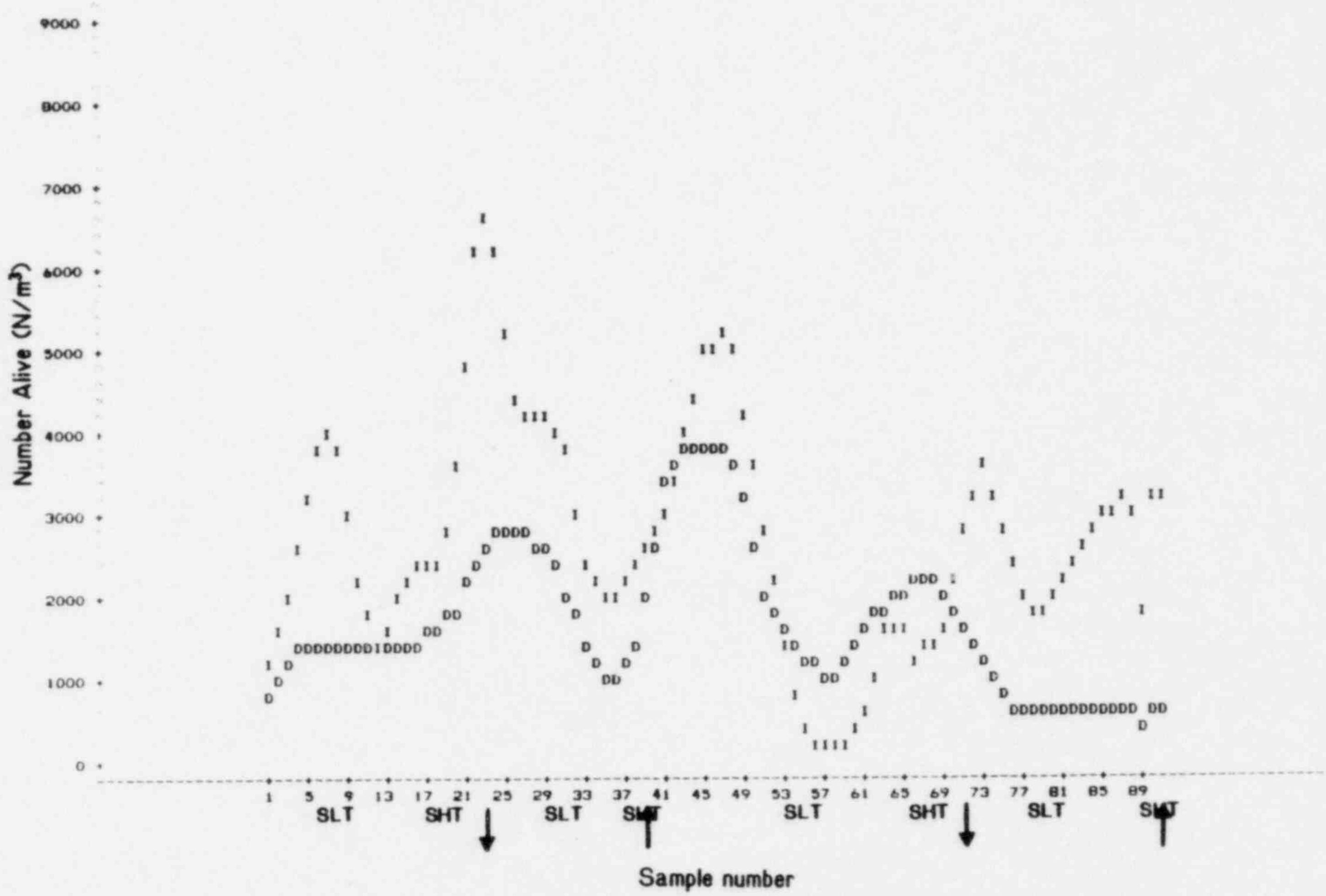

Figure 9-24. Density (N/m^3) of living *Acartia tonsa* adults in samples collected every 30 min on August 18-20 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

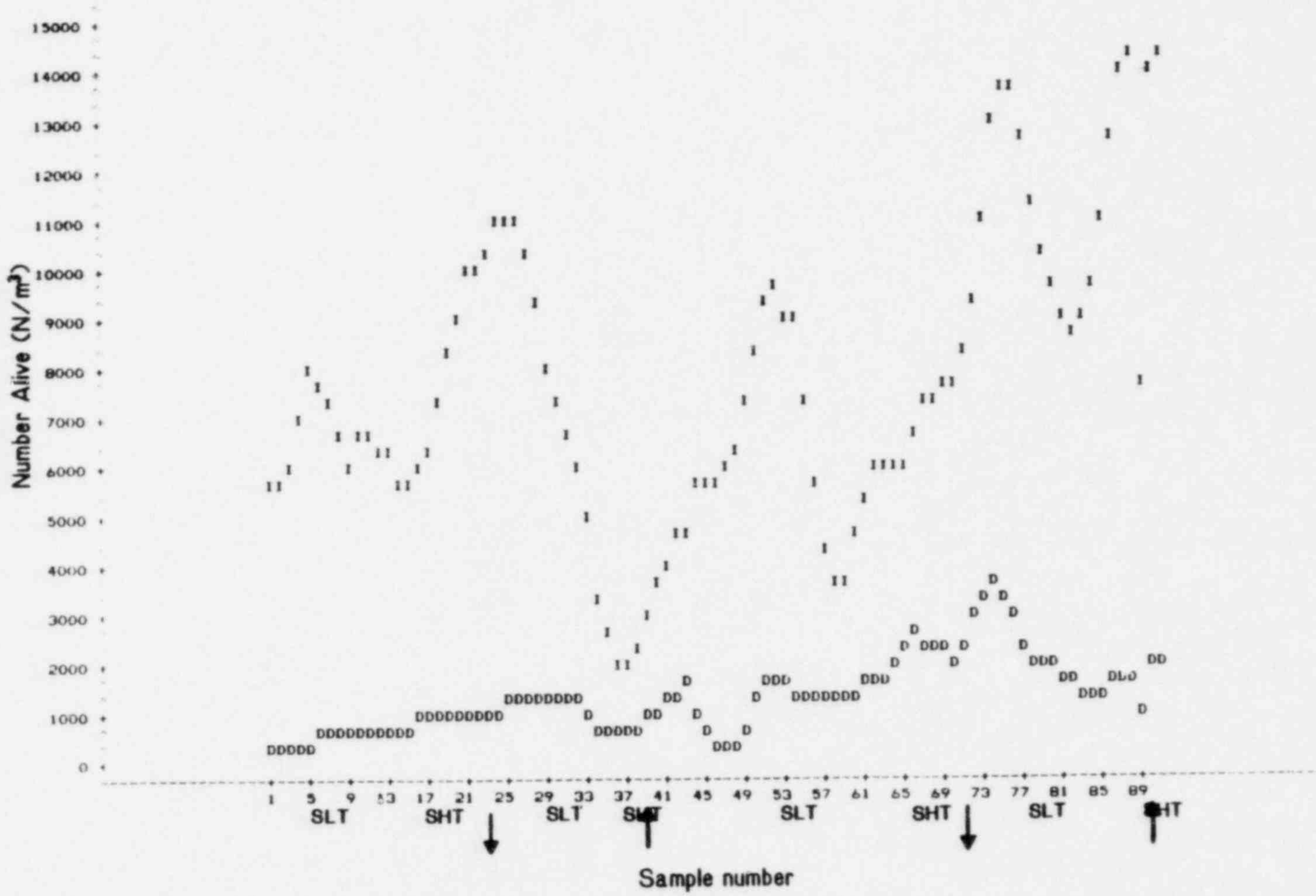

Figure 9-25. Density (N/m^3) of living *Acartia* copepodites in samples collected every 30 min on August 18-20 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

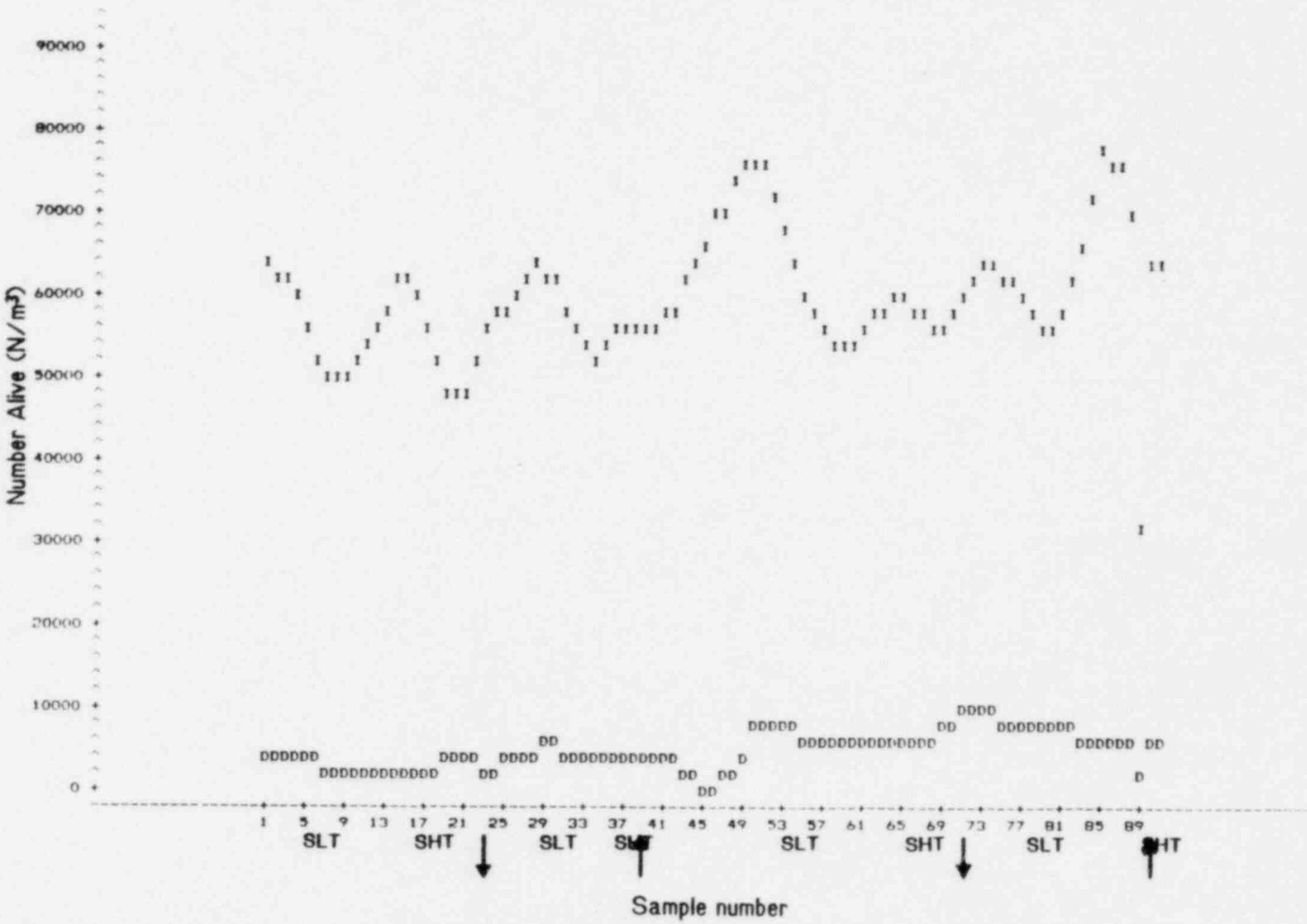

Figure 9-26. Density (N/m^3) of living Copepod nauplii in samples collected every 30 min on August 18-20 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

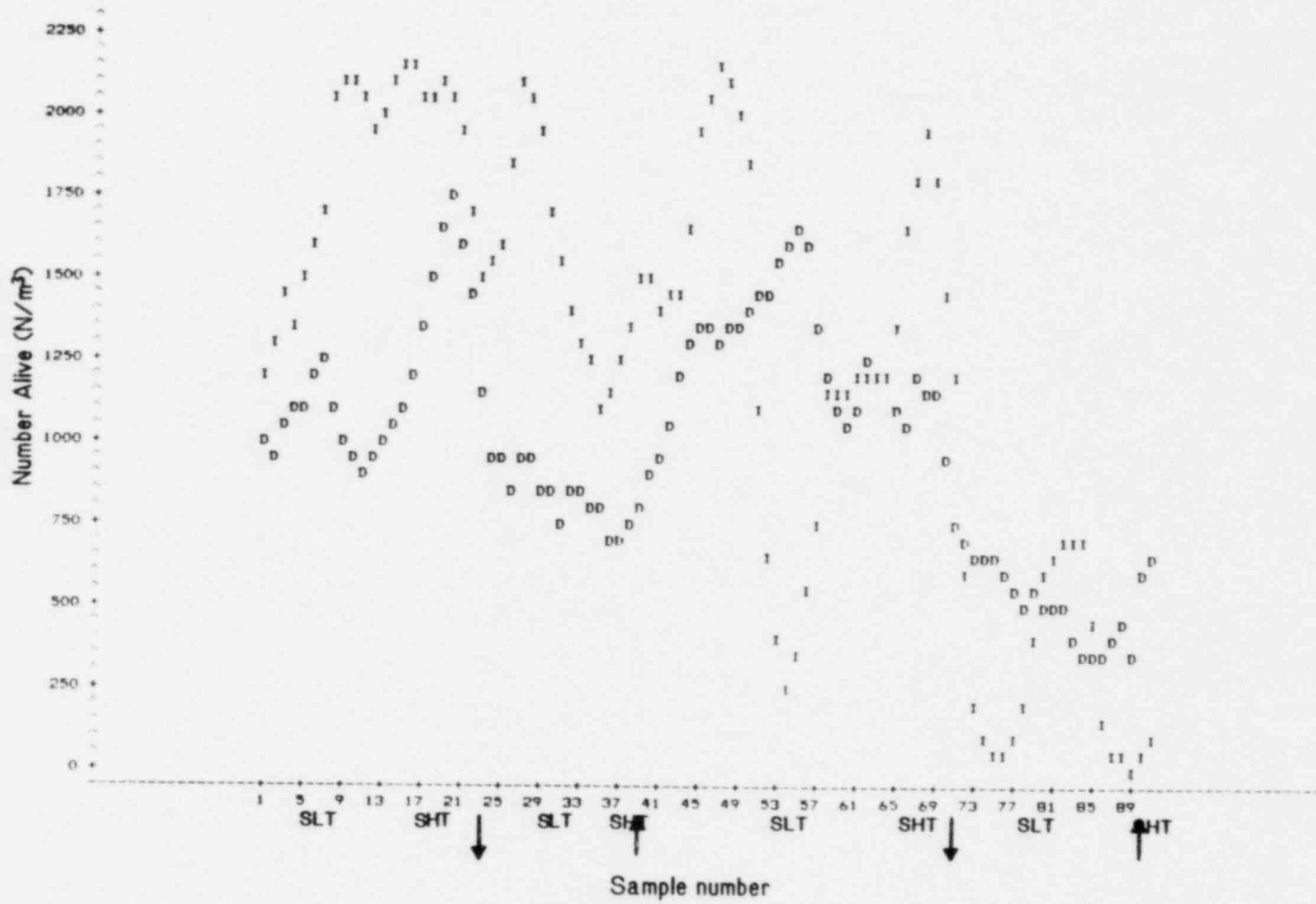

Figure 9-27. Density (N/m³) of living Polychaete larvae in samples collected every 30 min on August 18-20 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

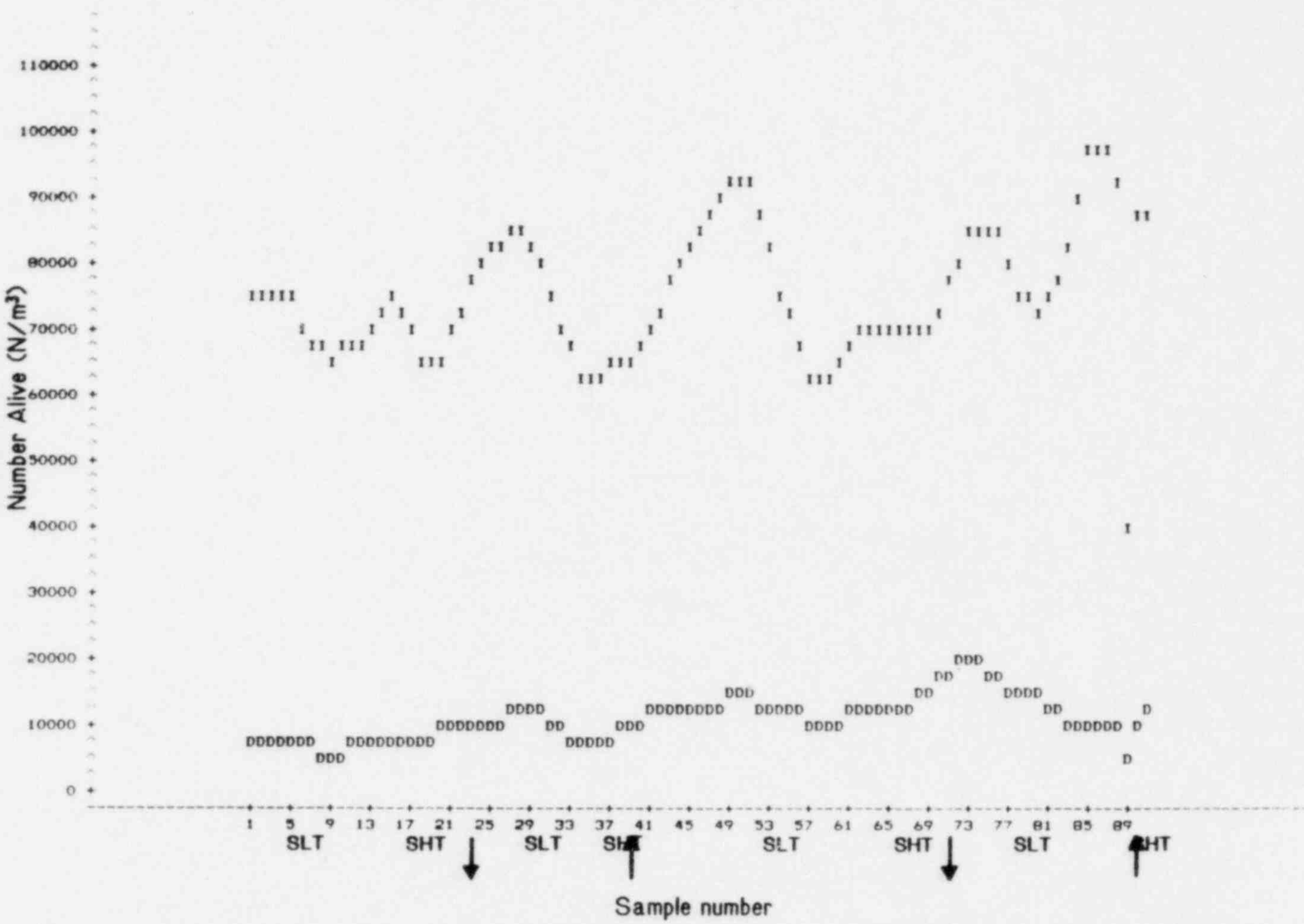

Figure 9-28. Density (N/m^3) of living all dye-sensitive species in samples collected every 30 min on August 18-20 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

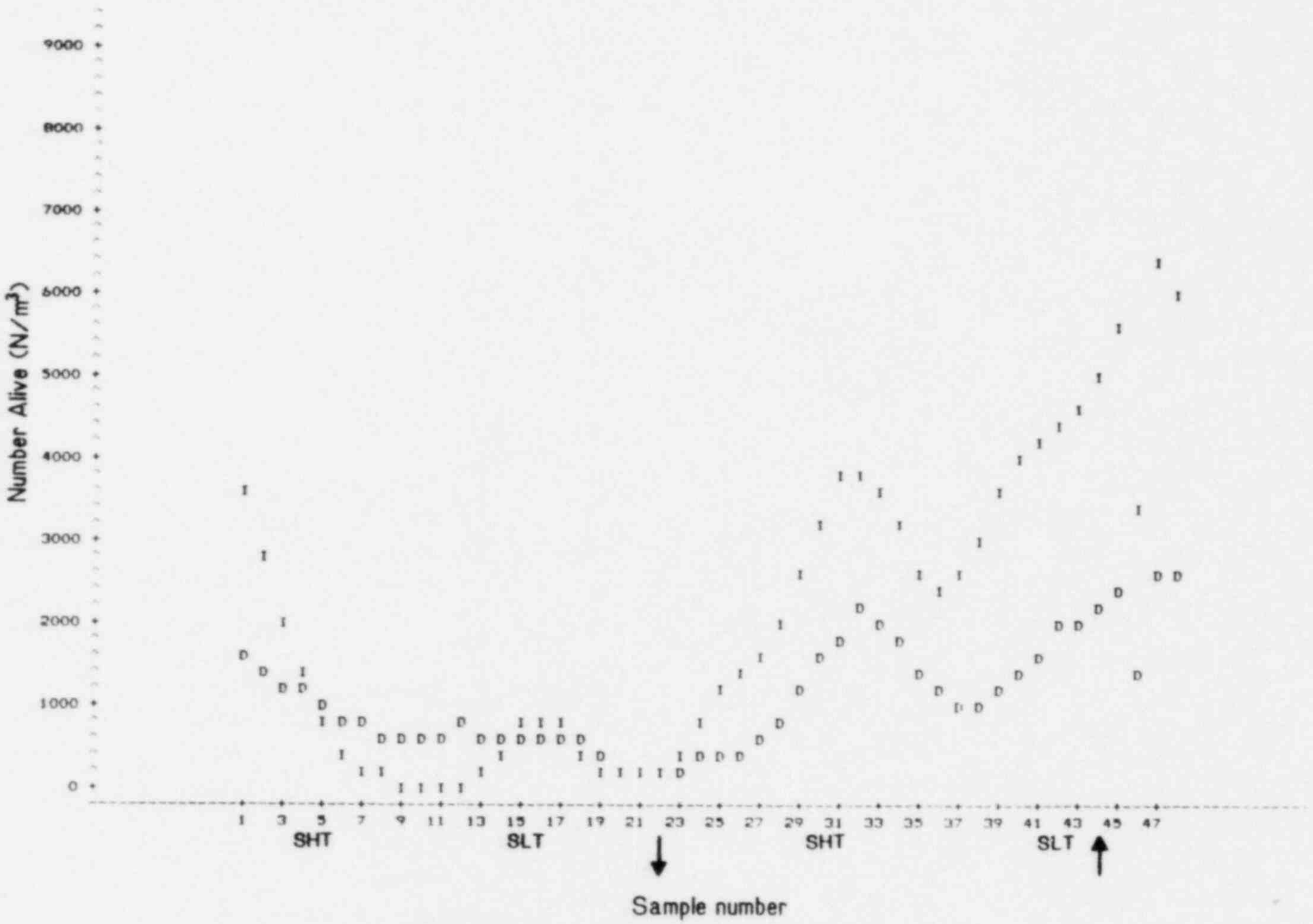

Figure 9-29. Density (n/m^3) of living *Acartia tonsa* adults in samples collected every 30 min on September 9-10 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant. Tides are indicated as slack high tide (SHT) and slack low tide (SHT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

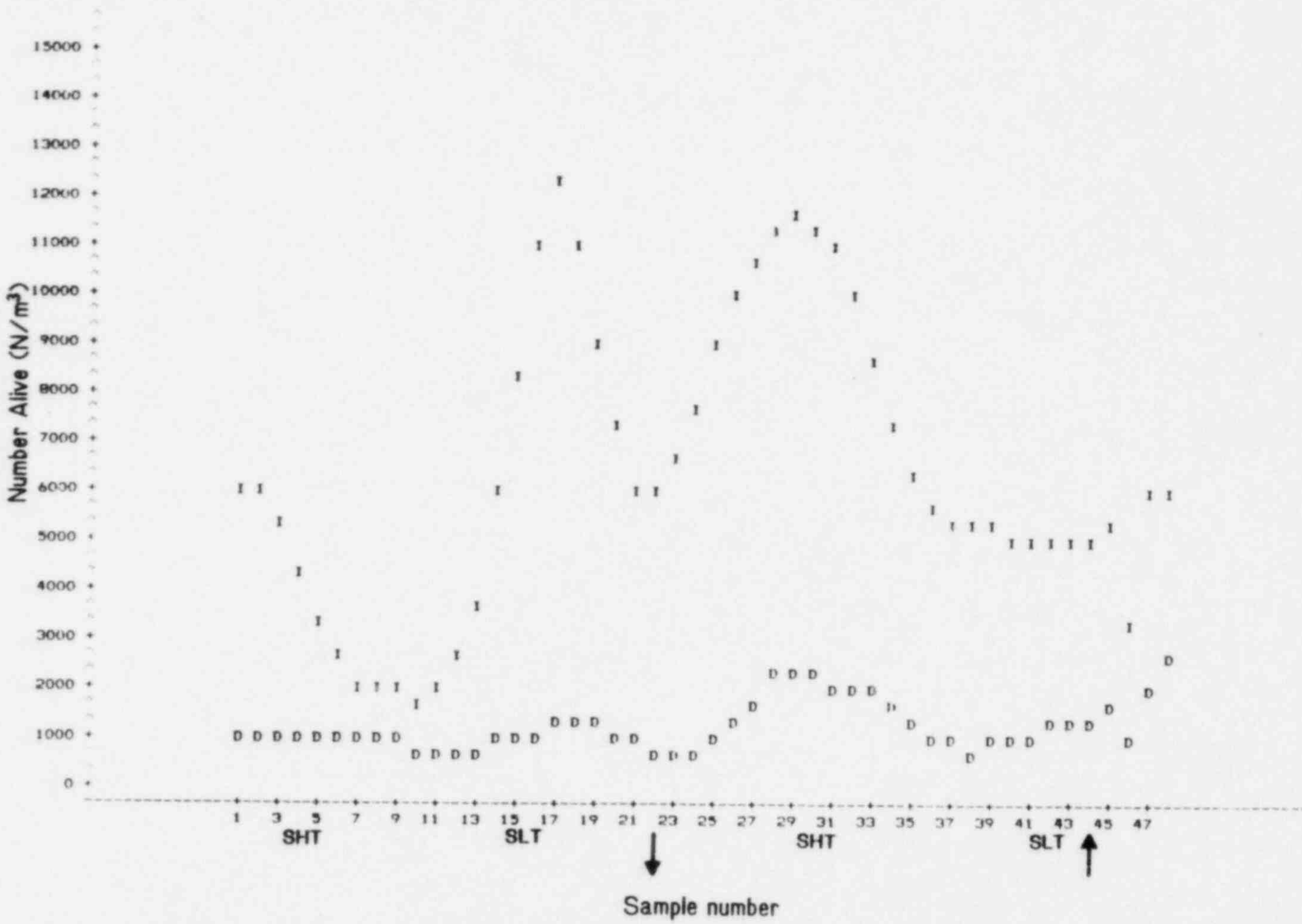

Figure 9-30 Density (N/m^3) of living *Acartia* copepodites in samples collected every 30 min on September 9-10 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant. Tides are indicated as slack high tide (SLT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

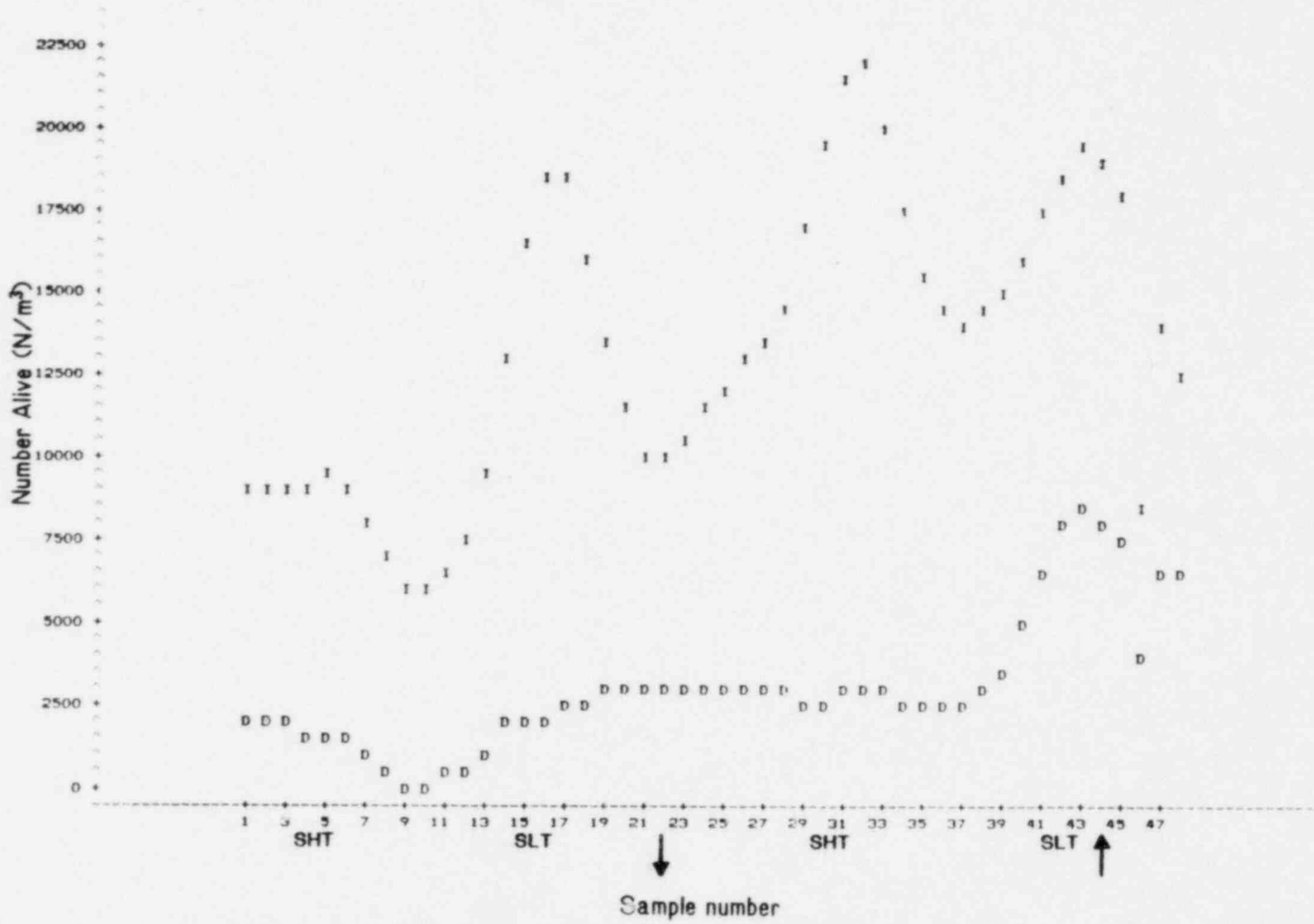

Figure 9-31. Density (N/M^3) of living Copepod nauplii in samples collected every 30 min on September 9-10 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

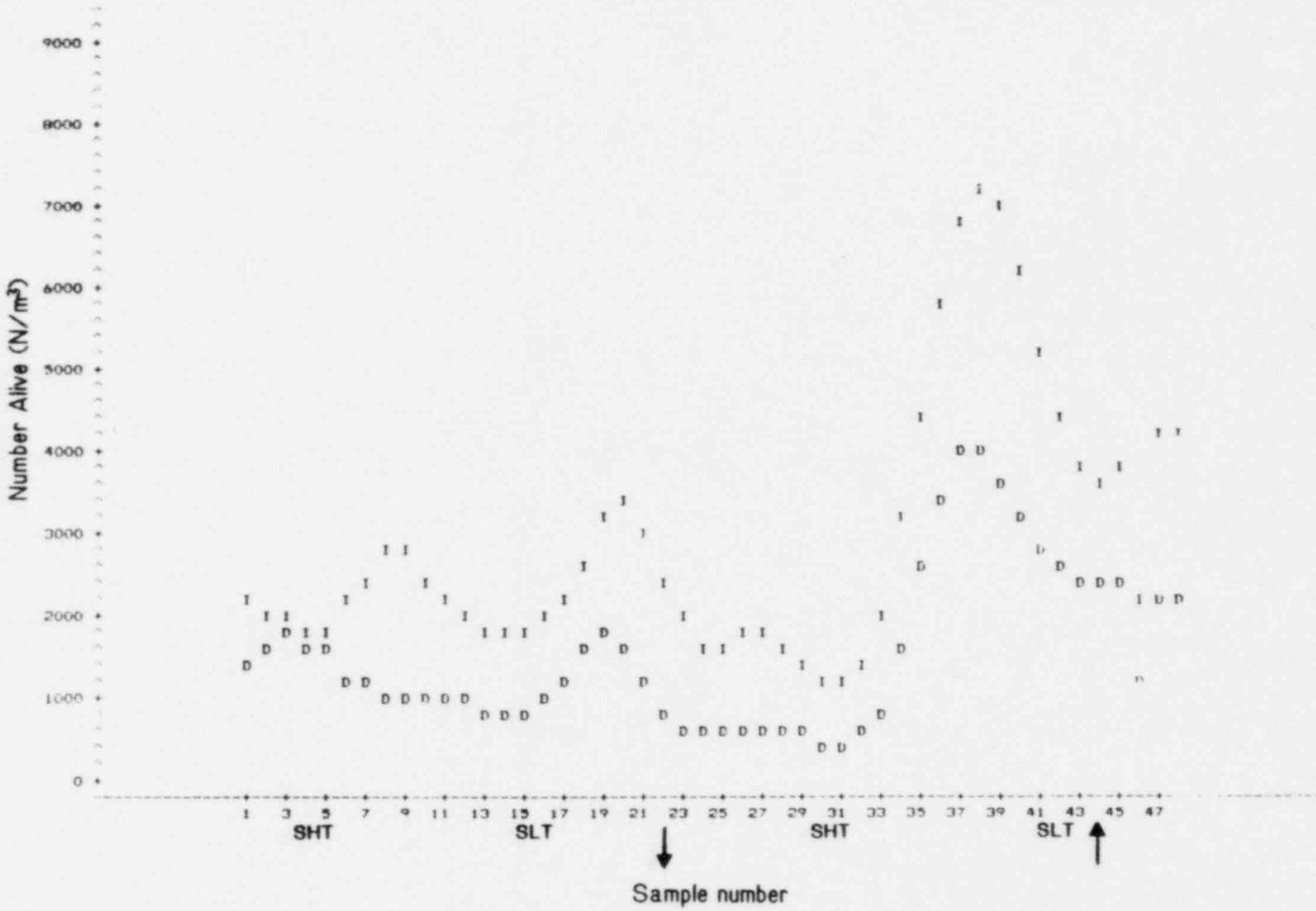

Figure 9-32. Density (N/m³) of living Polychaete larvae in samples collected every 30 min on September 9-10 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

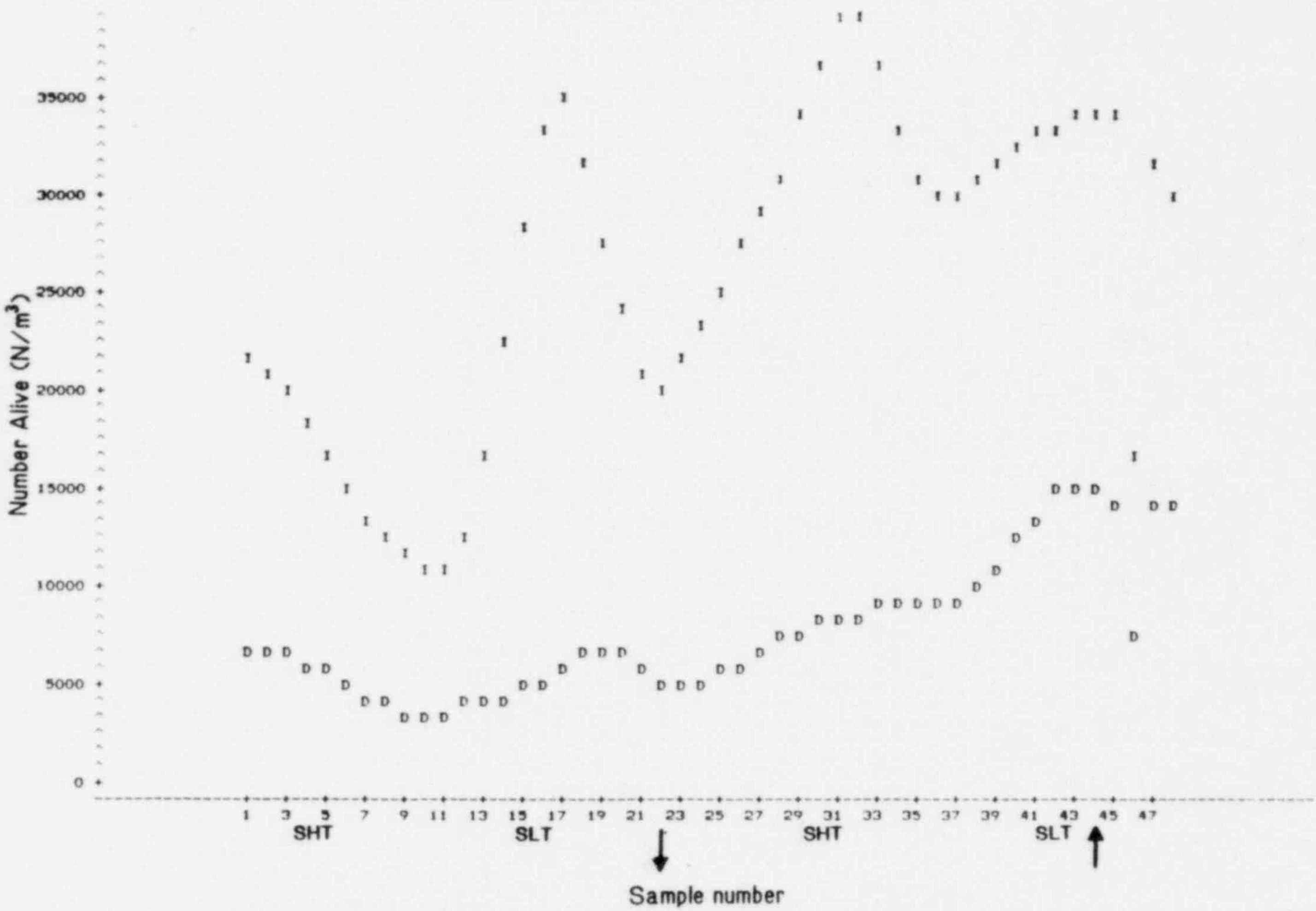

Figure 9-33. Density (N/m³) of living all dye-sensitive species in samples collected every 30 min on September 9-10 at Intake (I) and Discharge (D) at Calvert Cliffs Nuclear Power Plant. Tides are indicated as slack high tide (SHT) and slack low tide (SLT). Sun positions are indicated as sunrise (↑) and sunset (↓). A 7-point smoothing function was used to transform the data.

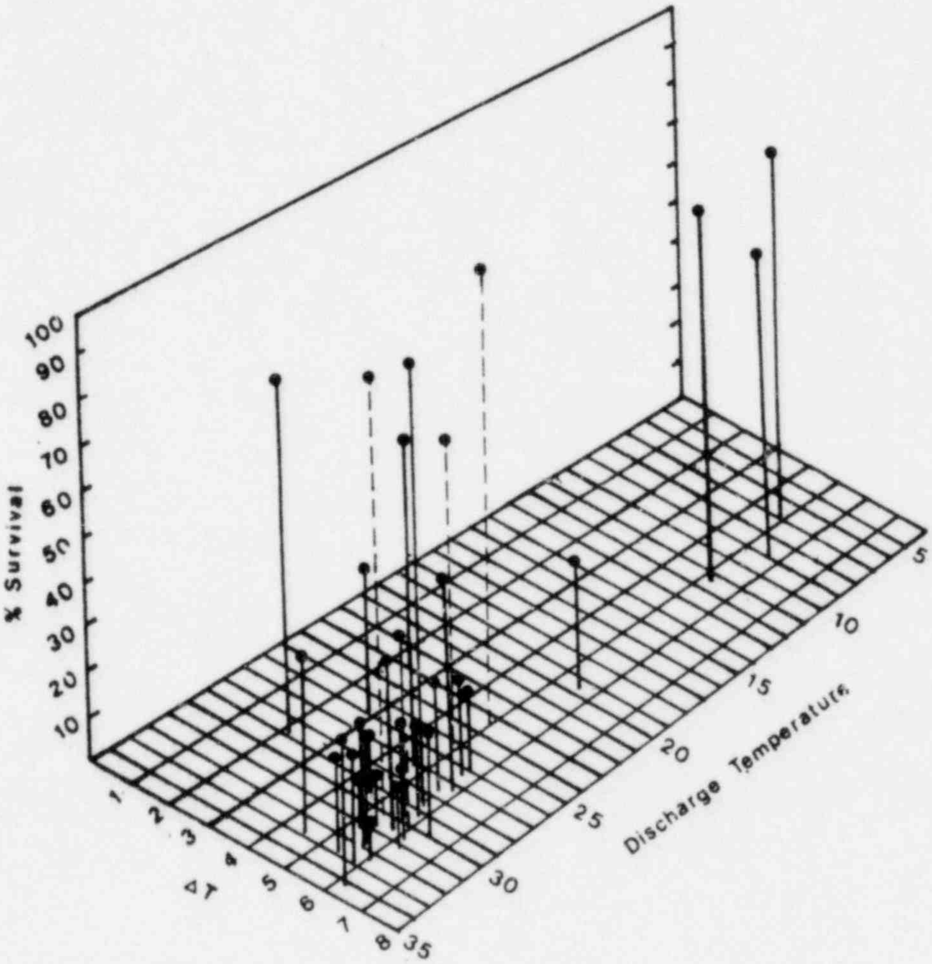

Figure 9-34. Three dimensional plot of copepod naupliar survival versus discharge temperature and ΔT (°C) of cooling water. Values are 24-h or 48-h averages from zooplankton entrainment studies conducted at Calvert Cliffs Nuclear Power Plant from 1976 through 1981. (Dotted lines indicate questionable survival estimates.)

APPENDIX A

Food requirements in the form of carbon for each *Acartia tonsa* life stage were determined as follows. Dry weight for individual life stages of *A. tonsa* was calculated according to Miller, Johnson, and Heinle (1977). All nauplii were assumed to be N IV, and all copepodites to be C III. The carbon content of each life stage was determined from dry weight by multiplying by a factor of 0.5 (Heinle, 1966). Carbon content was then multiplied by 0.5 to obtain carbon consumption (Paffenhöfer and Harris, 1976). Estimated food requirements for *A. tonsa* are:

Stage	Dry weight (μg)		Transformation factor*		μg-C/individual
Nauplii	0.14	x	0.25	=	0.035
Copepodite	2.00	x	0.25	=	0.500
Adult ♂	3.70	x	0.25	=	0.925
Adult ♀	5.20	x	0.25	=	1.300

*0.5 x 0.5 = 0.25

Using 1981 zooplankton densities (Table 9-3) and the above carbon requirements, total carbon necessary to maintain the *A. tonsa* population was calculated:

Stage	N/m^3		μg-C/individual		$\mu g\text{-}C/m^3$
July					
Nauplii	48,045	x	0.035	=	1,681.6
Copepodite	34,148	x	0.500	=	17,074.0
Adult ♂	2,295	x	0.925	=	2,122.9
Adult ♀	3,477	x	1.300	=	4,520.1
				Total	25,398.6
August					
Nauplii	61,840	x	0.035	=	2,164.4
Copepodite	8,611	x	0.500	=	4,305.5
Adult ♂	1,516	x	0.925	=	1,402.3
Adult ♀	1,697	x	1.300	=	2,206.1
				Total	10,078.3
September					
Nauplii	15,592	x	0.035	=	545.7
Copepodite	7,909	x	0.500	=	3,954.5
Adult ♂	661	x	0.925	=	611.4
Adult ♀	2,065	x	1.300	=	2,684.5
				Total	7,796.1

The amount of carbon available was determined from amounts of chlorophyll *a* calculated for phytoplankton samples during 1981 phytoplankton entrainment studies (Sellner and Kachur, in press). Carbon:chlorophyll *a* ratios can range from 23 to 79 (for examples see Parsons and Takahashi, 1973, p. 47). Using the conservative ratio of 23 (representing the minimal amount

of carbon) available carbon can be calculated during each zooplankton entrainment sampling period as follows:

	μg-Chl*a*/m²†		Ratio		μg-C/m³
July	12,970	x	23	=	298,310
August	9,580	x	23	=	220,340
September	5,220	x	23	=	120,060

†Mean chlorophyll *a* determind for each phytoplankton entrainment sampling period in 1981 (Sellner and Kachur, in press).