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ECOLOGICAL STUDIES FOR THE OYSTER CREEK GENERATING STATION

Progress Report for the Period September 1977-August 1978

FINFISH, SHELLFISH, AND PLANKTON

Donald J. Danila, Charles B. Milstein,
and Associates

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For
JERSEY CENTRAL POWER AND LIGHT COMPANY

ICHTHYOLOGICAL ASSOCIATES, INC.

April 1979

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For

JERSEY CENTRAL POWER AND LIGHT COMPANY

ICHTHYOLOGICAL ASSOCIATES, INC.

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April 1979

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TABLE OF CONTENTS

LIST OF TABLES

Table Page

Table		Page

LIST OF FIGURES

Figure | Page

Figure		Page

Figure | Page

Figure | Page

INTRODUCTION

The Oyster Creek Generating Station (OCGS) of Jersey Central Power and Light Co. is a 620 MWe boiling water reactor which has been in commercial operation since December 1969. It is located 3.2 km inland from Barnegat Bay in Lacey Township, New Jersey. Oyster Creek and the South Branch of Forked River have been modified as a discharge and intake canal, respectively (Fig. 1). When OCGS is in operation, the flow in the South Branch of Forked River is always upstream toward OCGS, and the flow in Oyster Creek is always downstream toward Barnegat Bay. Tidal range at the mouth of Oyster Creek is 0.15 m (U. S. Atomic Energy Commission, AEC 1974).

Barnegat Bay is a relatively large (surface area 16,714 ha), shallow (average depth 1.5 m) estuary (AEC 1974). The eastern Bay contains extensive shoal areas (depth 0.2 to 0.9 m); the central and western Bay is deeper and ranges from 1.2 to 3.7 m (National Oceanic and Atmospheric Administration, NOAA 1976). Interchange of water between the Atlantic Ocean and the Bay is limited and occurs through Barnegat Inlet which is narrow (Makai 1973, Carpenter 1963). Normal tidal range in Barnegat Bay is 0.3 m (Makai 1973).

Several studies of Barnegat Bay and OCGS have been conducted prior to those undertaken by Ichthyological Associates, Inc. (I.A.). Makai (1973) reported on the physicochemical parameters of upper Barnegat Bay, and Halgren (1973) conducted a study on the recreational usage of the upper Bay.

Wurtz (1969), Marcellus (1972), and McClain (1973) reported on the fishes of the Bay. Wurtz (1972) reported preliminary findings on impingement of fishes and crabs at OCGS. He also (1965, 1971) conducted brief studies of zooplankton and ichthyoplankton in limited portions of the Bay, and Sandine (1973) studied the condition of microzooplankton entrained at OCGS. Rutgers University investigated various aspects of the benthic invertebrates and benthic algae (Loveland et al. 1966-1972, 1974); this work was reviewed by Vouglitois (1976). An extensive evaluation of the impact of OCGS on the fin- and shellfish in Barnegat Bay was made by JCP&L (1978).

Since 8 September 1975, I.A. has conducted studies to help determine and assess the biological impact of OCGS and its discharges and made general ecological surveys of Barnegat Bay, Oyster Creek, and Forked River. Data collected from September 1975 through August 1976 and September 1976 through August 1977 were reported by Tatham et al. (1977a, b; 1978a, b). This document summarizes information obtained during the entire third year of study, from September 1977 through August 1978. Data from individual collections of the impingement and entrainment sampling programs and from fin- and shellfish collections made at selected stations in Barnegat Bay from September 1977 through March 1978 were presented by I.A. (1979) and from April through August 1978 by Danila et al. (1979); these data may be obtained at cost.

Impingement and fisheries studies emphasized fin- and shellfish designated as important by the U. S. Environmental Protection Agency (EPA) and the U. S. Nuclear Regulatory Commission (NRC). These were the Atlantic menhaden, bay anchovy, Atlantic silverside, threespine stickleback, northern pipefish, striped bass, bluefish, weakfish, northern kingfish, summer flounder, winter flounder, northern puffer, sand shrimp, and blue crab. The life history of most of these species was reported by Tatham et al. (1977a, 1978a). The common and scientific names of all vertebrates and invertebrates taken by the impingement and fisheries programs are given in Tables 1 through 3.

Emphasis in the plankton program was also placed on forms designated as important species by the NRC or the EPA. Important macrozooplankton were the ctenophores *Mnemiopsis leidyi* and *Beroe* spp., the arrowworms *Sagitta elegans* and *Sagitta* spp., the sand shrimp *Crangon septemspinosa*, grass shrimp *Palaemonetes* spp., the mysids *Neomysis americana* and *Mysidopsis bigelowi*, polychaete epitokes and individuals less than 1 mm, and blue crab zoeae and megalopae. Important ichthyoplankton included the eggs and larvae of the Atlantic menhaden, bay anchovy, threespine stickleback, northern pipefish, striped bass, bluefish, weakfish, northern kingfish, summer flounder, winter flounder, and northern puffer.

WATER QUALITY

Keith W. Hoch

Introduction

Water temperature, salinity, pH, dissolved oxygen, and water clarity were taken with each biological collection from September 1977 through August 1978. These data were used to describe the physicochemical regime at four stations in western Barnegat Bay (Fig. 1) and at the circulating-water intake to OCGS.

Materials and Methods

Water temperature and dissolved oxygen were measured with a YSI dissolved oxygen meter (Model 57A), and salinity with an American Optical hand refractometer. The pH was determined with either a Photovolt pH meter (Model 126A) or a Corning pH meter (Model 610A). Water transparency for most biological collections taken during the day, except for those made by seine, was measured with a 20-cm Secchi disc. Procedures for use and calibration of these instruments were presented previously (I.A. 1975).

Surface and bottom water chemistries were taken with trawl, impingement, and entrainment collections. Water chemistry samples taken with impingement and entrainment samples were collected during or near the end of the sampling period. In the Bay, water chemistries were taken between replicate collections. Bottom water samples were obtained with either a 1.7 or 5-liter Niskin bottle; only surface water chemistry was taken with seine collections. Because water at the OCGS discharge was thoroughly mixed, only surface water chemistry was taken with entrainment collections at the discharge. Surface water chemistry was taken for all impingement collections. Bottom water chemistry was determined to be similar to the surface at the OCGS intake based on data collected during previous years; therefore, bottom water samples were taken only on the first and last collection of each impingement sampling period.

Results and Discussion

Mean monthly water temperature, salinity, pH, dissolved oxygen concentration, and Secchi disc measurements were determined for three areas: the Bay, which includes stations at the mouth of Cedar Creek, Forked River, Oyster Creek, and Double Creek; the OCGS intake; and the OCGS discharge.

The physicochemical data examined for stations at the mouth of Cedar Creek, Forked River, Oyster Creek, and Double Creek were limited to that taken during fisheries collections, usually during 2 days each month. No samples were taken at Cedar Creek and Double Creek during February due to ice cover.

Daily records of intake and discharge water temperatures taken by JCP&L were used to calculate the mean monthly increase in the temperature of water circulated through OCGS (delta T) rather than water temperatures taken during 4 or 5 days of entrainment sampling during a month.

Water Temperature

The coldest mean monthly surface and bottom temperature (-0.8 and -1.0 C, respectively) were recorded at the mouth of Forked River in January (Table 4). Tatham (1977) also recorded the coldest water temperature in Barnegat Bay (-1.5 C) during January. The warmest surface and bottom temperatures were always found at the mouth of Oyster Creek and were maximum in August (29.5, 29.7 C). When OCGS was in operation, the difference in mean monthly surface and bottom water temperatures between Oyster Creek and thermally unaffected stations was greatest during February (7.6, 9.9 C). The difference in mean monthly surface and bottom water temperatures at the mouth of Oyster Creek averaged 3.7 C (range of 1.7 to 7.6 C) and 4.6 C (1.8 to 9.9 C), respectively, warmer than the combined mean temperature at the other three stations (Table 4).

Differences between mean monthly surface and bottom temperatures were substantial at all Bay stations from March through May. The mean surface temperature at these stations averaged 2.9 C warmer than the bottom temperature. Makai (1973), Tatham (1977), and Kurtz and Swiecicki (1978) all reported similar findings. Temperature stratification was less common and occasionally reversed during other months.

The largest mean monthly delta T (Table 5) from September through August occurred during September (12.3 C) and the smallest in August (8.6 C). The mean yearly delta T when OCGS operated in

1977-78 (10.8 C) was slightly higher than either 1976-77 (9.4 C) or 1975-76 (9.2 C). The lowest mean monthly intake (1.3 C) and discharge (12.1 C) temperatures occurred in February, while the maximum mean monthly temperature was found at the intake (26.1 C) in August and at the discharge (34.8 C) in September.

Salinity

The mean yearly salinities (Table 6) at the mouth of Cedar Creek (15.3 ppt), Forked River (19.6), Oyster Creek (18.2) and Double Creek (21.3) were similar to salinities for these stations reported by Tatham (1977) and Kurtz and Swiecicki (1978). The total precipitation at OCGS (D. R. Weigle, personal communication) was considerably greater in 1977-78 (140.0 cm) than in 1976-77 (95.3) or 1975-76 (89.9). The greater precipitation probably contributed to the lower salinities found from September 1977 through August 1978.

The highest mean monthly salinities were usually found at Double Creek (10 of 11 months), which is the southernmost station and closest to Barnegat Inlet (Table 6). The lowest mean monthly salinities were generally recorded at Cedar Creek (10 of 11 months), the northernmost station. Mean monthly salinities at the mouth of Forked River were slightly higher than those at the mouth of Oyster Creek in 10 of 11 months. The freshwater input of Cedar Creek and from the three branches of Forked River and from Oyster Creek probably caused the lower salinities taken at Cedar Creek and

Oyster Creek.

The mean monthly salinity at the OCGS intake ranged from 16.8 ppt in July to 24.1 ppt in September (Table 7). The mean yearly surface salinity at the OCGS intake was 19.5 ppt. This was less than the 23.8 ppt reported by Kurtz and Swiecicki (1978) for 1976-77.

pH

The mean monthly pH ranged from 7.4 at Cedar Creek in October to 8.3 at Double Creek in June (Table 8). The mean yearly pH was similar among stations with the values of 7.9 at Oyster Creek and Cedar Creek and 8.0 at Double Creek and Forked River. No seasonal trends in pH were apparent, but the bottom pH values were generally slightly higher than those at the surface.

The mean yearly pH was 7.8 for both surface and bottom samples, which was slightly more acidic than the 8.0 determined by Kurtz and Swiecicki (1978).

Dissolved Oxygen

The mean monthly dissolved oxygen concentrations at all stations ranged from 6.5 ppm in April to 13.4 ppm in February (Table 9). The mean yearly dissolved oxygen concentrations among the Bay stations were similar at the surface (range 9.0 to 9.4 ppm) and bottom (8.8 to 9.8).

The seasonal variation in dissolved oxygen concentrations was similar to those reported by Tatham (1977) and Kurtz and Swiecicki

(1978). The highest mean values occurred in January and February (12.1 and 13.4 ppm) and in general declined to the lowest values in August and September (7.7 and 7.1 ppm). No seasonal trends were apparent between surface and bottom dissolved oxygen values.

Water Clarity

The greatest mean monthly Secchi disc reading was generally found at Double Creek (8 of 11 months). However, similar mean yearly readings were found at all Bay stations (Table 10) with the largest values at Double Creek (125 cm) and the smallest at Cedar Creek (114). Water clarity generally increased, from 89 cm in November to a maximum of 195 cm in March, and then decreased to 80 cm in July and August. During the 2 previous years, similar seasonal trends were found. Mountford (1971) reported that water transparency decreased during the summer as a result of phytoplankton blooms and increased in the fall and spring due to nutrient depletion and low chlorophyll concentrations.

IMPINGEMENT OF FISHES AND MACROINVERTEBRATES ON THE TRAVELING SCREENS

Gerald J. Miller

Introduction

Since September 1975, Ichthyological Associates, Inc. has studied the effect of the impingement of organisms on the vertical traveling screens which protect the intake to the OCGS circulating-water system. Impingement data have been reported from 8 September 1975 through 3 September 1977 (Miller 1977, 1978). Data presented here are a continuation of those studies and include collections from 4 September 1977 through 2 September 1978. The objectives of these studies were to determine the species composition and abundance of organisms impinged on the OCGS screens and their survival rate when returned to Barnegat Bay. An evaluation of these losses on the populations in Barnegat Bay was discussed by JCP&L (1978).

Materials and Methods

Samples of impinged organisms were taken from the sluiceway after the last traveling screen and from the sluiceway pit (Fig. 2). A 45.7 x 50.8 x 61.0-cm wire basket (10.7-mm mesh) was used to collect organisms from the sluiceway (Sta. 8) to determine their condition. A 101.6 x 101.6 x 121.9-cm wire basket (10.7-mm mesh) was used to collect organisms from the sluiceway pit.

Samples were usually taken two nights a week during two periods; period 3 was from sunset to 6 h after sunset and period 4 was from 6 h after sunset to sunrise. After the screens were washed at the beginning of the sampling period, the pit sampler was lowered into place. Subsequently, the screens washed automatically either every 2 h or when the pressure differential across the screens reached a critical level. Automatic screen washes usually involved about two complete rotations of the screens and lasted for approximately 20 min. Screen washes triggered either manually or by differential pressure lasted from 10 to 11 min.

After the screens had washed for 1 min, the sluiceway sampler was inserted. After 1 min or less, depending on the abundance of organisms, it was removed and the organisms were placed on a 3.9-m^2 sorting table. The sluiceway sampler was replaced, and the procedure repeated until a maximum of six, 1-min samples was taken during the screen wash. For 20-min screen washes, the sluiceway sampler was used only during the first 11 min of the wash.

Collections from the sluiceway sampler were rapidly processed on the sorting table. Fishes were placed into water in insulated coolers, and crabs were placed into 10-liter plastic buckets. The condition (live/dead/damaged) of the organisms was determined 5 to 10 min after the last sluiceway sample was taken. Live denoted a specimen which had no apparent damage and which was swimming normally. Damaged specimens were alive (opercular movement in fishes) but had external damage or abnormal behavior. Dead fishes showed no opercular movement, and dead invertebrates showed no movement of either appendages or mouthparts. Condition samples were taken during periods 3 and 4 from September 1977 through March 1978, but were taken only during period 3 from April through September 1978.

Organisms washed from the screen and not collected in the sluiceway sampler passed into the pit sampler. At the end of the screen wash, this sampler was removed and the specimens were processed. The number and weight of abundant species were estimated volumetrically in the following manner. After all other species were removed from the sample, the remaining debris and abundant organisms were thoroughly mixed and a known volume removed. The number and weight of abundant species in this subsample were determined and were used to estimate the number and weight of these species in the total sample. Physicochemical parameters were recorded with each collection.

When the screens washed frequently or continuously, it was not always possible to collect all impinged organisms because the screen wash would have overflowed the pit sampler. To avoid this, the pit sampler was removed before it overflowed, and some portion of the screen wash was missed. If this occurred, the portion of the screen wash that was sampled was used to estimate the total number and weight of organisms impinged during that period.

For a week, estimated impingement during a period (W_a) was calculated by the formula:

$$W_a = \frac{P_a \cdot 7}{s}$$

P_a = actual or extrapolated number or weight of specimens impinged in a period during a week.

s = number of times a period was sampled during the week.

The sum of the estimated weekly impingement at night during each of the two periods was the total weekly impingement estimate at night. A Hewlett-Packard 9830A programmable calculator was used for data compilation and statistical analyses.

Stratified sampling with optimal allocation (Snedecor and Cochran 1967) was used to estimate the total number of organisms and number of specimens of various species impinged during the 12 months. The mean number impinged during the 12 months ($\overline{Y}_{st}$) was estimated by the formula:

$$\overline{Y}_{st} = \sum \left(\left[N_a/N \right] \cdot \overline{Y}_a \right)$$

N_a = number of sampling units in stratum a.

N = number of sampling units in all strata sampled.

$\overline{Y}_a$ = sample mean in stratum a.

The strata were the two time periods sampled during the night. The sampling unit size was 1 h, and each sample mean was expressed as the number of specimens impinged per hour. This sample mean was derived by dividing the number of individuals taken from all samples collected during a time period by the total duration of these samples. This weighted mean of the number impinged per hour was used as a single sample because the duration of individual samples in a time period was unequal.

The total number of individuals impinged at night during the 12 months (Y) was computed by the formula:

$$Y = \overline{Y}_{st} \cdot D \cdot T$$

D = the number of days the OCGS screens operated during the 12 months of the year.

T = 12.0 (average hours of darkness for the 12 months sampled).

Results

A total of 561 collections was taken from 4 September 1977 through 2 September 1978 with 282 collections taken in period 3 and 279 collections in period 4. Physicochemical parameters associated with each collection were summarized weekly (Table 11). An estimated 5,395,989 ± 736,288 fish and macroinvertebrates (124 taxa) that weighed 35,750 ± 6,809 kg were estimated by the stratified sampling method to have been impinged at night (Table 12). A total of 484,908 ± 93,939 fish (9% of all organisms, 91 taxa) that weighed 12,493 ± 4,004 kg (35% of the biomass) was impinged. Some 4,911,070 ± 704,791 invertebrates (91% of all organisms, 33 taxa) that weighed 23,257 ± 5,397 kg (65% of the biomass) were impinged (Table 12).

The most numerous fishes were the bay anchovy (25% of the fish), Atlantic silverside (13%), spot (11%), northern puffer (10%), Atlantic menhaden (9%), and blueback herring (8%). The most important fishes by weight were the winter flounder (35% of the fish biomass), Atlantic menhaden (25%), spot (13%), and weakfish (3%).

The most numerous invertebrates were the sand shrimp (73% of the invertebrates), blue crab (20%), and grass shrimp (7%). The blue crab (75% of the invertebrate biomass) and sand shrimp (16%) were the most important invertebrates by weight.

Estimates of impingement for each species were determined weekly but these were not used to estimate the total impingement for the year. Most of the specimens were impinged in fall and winter. From 9 October through 14 January, an estimated 65% of the fish were impinged (Tables 13 through 15). These were mostly blueback herring, Atlantic menhaden, bay anchovy, Atlantic silverside, and spot. Two-thirds of the invertebrates were impinged from 30 October through 18 February and were mostly grass shrimp, sand shrimp, and blue crab.

The total weekly night impingement estimates expressed as the number of specimens impinged per hour and per 10 million liters of cooling-water flow also indicated maximum impingement in the fall (Table 16). The most specimens collected per hour (6,408) were taken from 4 through 10 December and the least (67) from 18 through 24 June. The average number of specimens impinged per hour during the year was 1,390. The most specimens impinged per 10 million liters of cooling-water flow (627) were also taken from 4 through 10 December and the least (6) from 18 through 24 June. The average number of specimens per 10 million liters of cooling-water flow was 66.

Some 18,648 specimens were examined for condition (Tables 17 through 19). Most (64%) were live, 24% were damaged, and 12% were dead. For fish, 30% were live, 45% were damaged, and 25% were dead. The blueback herring (24% dead), Atlantic menhaden (21%), bay anchovy (60%), and Atlantic silverside (24%) comprised 83% of the dead fish. Most (84%) of the invertebrates were live, 12% damaged, and only 4% were dead. Highest invertebrate mortalities were observed for the sand shrimp (6%) and grass shrimp (5%). Blue crab mortality was only 3%. Some 65% of invertebrate mortality was comprised of sand shrimp.

From 4 September 1977 through 2 September 1978, 10 species accounted for 98% of the estimated 5,395,989 specimens (35,750 kg) impinged (Table 12). The abundance, mortality, impingement loss, and impingement in relation to water temperature (Table 20) for these 10 species and for other species which are considered important by the NRC and EPA are discussed below in order of their numerical abundance.

1. Sand shrimp

An estimated 3.6 million sand shrimp (3,734 kg) were impinged during the year with most (77%) impinged from 27 November through 4 February (Table 21). Few were collected from July through September. The sand shrimp was the most numerous species (66% of all specimens) but comprised only 10% of the biomass. Most (84%) of the sand shrimp were impinged at a water temperature of 1 to 10 C. The mean annual mortality of the sand shrimp was 6% and an estimated 267,264 (7% of those impinged) were lost to impingement.

2. Blue crab

Of the 972,741 blue crab (17,462 kg) estimated impinged for the year (Table 22), most (75%) were taken from 2 July through 2 September. Few individuals were impinged from December through March. The blue crab comprised 49% of the biomass of all organisms taken. About 69% of the blue crab were collected at a water temperature of 21 to 28 C. The blue crab had a mean annual mortality of 3% and 23% were damaged. The latter usually had lost one or more appendages. An estimated 27,101 blue crab (3% of those impinged) were lost.

3. Grass shrimp

Approximately 333,000 grass shrimp (229 kg) were estimated impinged from 4 September 1977 through 2 September 1978 (Table 23). Most (53%) were impinged from 6 November through 7 January and 24% were taken from 2 April through 10 June. Fewest were collected from July through September. Although grass shrimp comprised 6% of the specimens impinged, they made up less than 1% of the biomass. About 72% of the grass shrimp were impinged at a water temperature of 4 to 16 C. The grass shrimp suffered a 5% mean annual mortality; 12,854 (4% of those impinged) specimens were lost.

4. Bay anchovy

The bay anchovy was the most abundant fish impinged (25% of all fish) although it comprised only 2% of all organisms collected. An estimated 122,723 bay anchovy were impinged during the year (Table 24) with 40% taken from 4 September through 6 November and 44% taken from 23 April through 20 May. Fewest were impinged from 8 January through 22 April.

Some 82% of the bay anchovy were collected at a water temperature of 11 to 21 C. The bay anchovy had a 60% mean annual mortality and 62,576 (51% of those impinged) were lost.

5. Atlantic silverside

Of the 63,275 Atlantic silverside (287 kg) taken during the year (Table 25), 87% were impinged from 13 November through 14 January. Few individuals were collected from September through mid-October or from May through August. Most (89%) of the Atlantic silverside were impinged at a water temperature of 2 to 10 C. The mean annual mortality for Atlantic silverside was 24%. Some 19,071 (30% of those impinged) were lost.

6. Spot

An estimated 55,563 spot (1,638 kg) were impinged from 4 September 1977 through 2 September 1978 (Table 26), and most (97%) were impinged from 16 October through 10 December. No spot were collected from mid-January through August. Ninety-two percent of the spot were impinged at a water temperature of 7 to 12 C. The spot had a mean annual mortality of 8% and an estimated 5,371 (10% of those impinged) were lost.

7. Northern puffer

An estimated 50,414 northern puffer (227 kg) were impinged during the year (Table 27). Most (98%) were impinged from 9 July through 5 August at a water temperature of 23 to 28 C. Few were impinged during other months and none were taken from December through mid-May. A 9% mean annual mortality rate was observed for the northern puffer and an estimated 3,854 (8% of those impinged) specimens were lost.

8. Atlantic menhaden

Of the 43,919 Atlantic menhaden (3,100 kg) collected during the year (Table 28), 96% were impinged from 16 October through 31 December. Few were impinged at other times. A total of 89% was impinged at a water temperature of 7 to 16 C. The Atlantic menhaden had a mean annual mortality of 21% and an estimated 9,038 (21% of those impinged) were lost.

9. Blueback herring

Some 36,447 blueback herring (108 kg) were impinged during the year (Table 29); 97% of these were taken from 6 November through 14 January. Few were impinged in other months. About 80% were collected at a water temperature of 2 to 9 C. The mean annual mortality for blueback herring was 24%. A total of 9,791 (27% of those impinged) was lost.

10. Winter flounder

An estimated 23,000 winter flounder (4,386 kg) were impinged during the year (Table 30). It comprised only 5% of the fish impinged but 38% of the fish biomass. The winter flounder was impinged throughout the year but most (79%) were taken from 13 November through 21 January. Eighty-nine percent were taken at a water temperature of 0 to 9 C. The mean annual mortality rate for the winter flounder was only 1% and only 91 (0.4% of those impinged) of the 23,000 estimated impinged were lost.

Other fishes

Although the threespine stickleback, striped bass, and northern kingfish were designated by the EPA as important fishes, few individuals were impinged, and these species are not discussed. Other fishes that were designated as important by the EPA or the NRC but which did not rank among the 10 most numerous fishes and macroinvertebrates are discussed below.

An estimated 18,387 northern pipefish (42 kg) were impinged during the year (Table 31) with 63% collected from 9 October through 17 December and 20% from 2 April through 6 May. About 86% were collected at a water temperature of 4 to 15 C. The mean annual mortality was 1% and the total estimated number lost was 206 specimens (1% of those impinged).

An estimated 2,753 bluefish (127 kg) were impinged during the year (Table 32). Some 41% occurred from 9 October through 19 November and 44% from 2 July through 5 August. No bluefish were impinged from 20 November through 10 June. About 47% of the bluefish were collected at a water temperature of 11 to 16 C and 38% were collected at 20 to 25 C. The mean annual mortality was 47% and a total of 1,203 specimens (44% of those impinged) were lost.

An estimated 16,409 weakfish (403 kg) were impinged during the year (Table 33). From 4 September through 19 November, most (94%) of the weakfish were impinged. Few were impinged from 10 December through 22 July. Eighty percent of the weakfish were collected at a water temperature of 11 to 18 C. The mean annual mortality was 20% and a total of 2,985 weakfish (18% of those impinged) was lost.

An estimated 1,493 summer flounder (381 kg) were impinged during the year (Table 34). A total of 64% was impinged from 2 October through 5 November and 13% from 23 April through 20 May. Eighty-nine percent of the summer flounder were impinged at a water temperature of 11 to 16 C. The mean annual mortality was 5% and only 73 summer flounder (5% of those impinged) were lost.

Discussion

Previous impingement data (Miller 1977, 1978), as well as the present data, indicated that water temperature was one of the most important factors that affected impingement. Most organisms were impinged when the water temperature increased or decreased seasonally and when they migrated into, out of, or within the Bay. The maximum impingement of a species did not necessarily correspond to the time of its maximum abundance in the Bay. For example, the Atlantic menhaden, bay anchovy, Atlantic silverside, bluefish, weakfish, spot, and summer flounder were impinged mostly in the spring and fall when they migrated, but were present in the Bay throughout the summer. In the fall, decreased water temperature may also have reduced the swimming performance of some species and consequently their ability to avoid impingement. Although individuals were present in the Bay throughout much of the year at an ambient intake temperature range of 0.0 to 27.8 C, most impingement of a species occurred over a relatively small temperature range.

Prior to September 1977, impingement samples at OCGS were taken during both the day and night. Beginning 4 September 1977, all samples were taken at night, and therefore, the estimates given here are conservative and represent only a portion of the organisms impinged during the year. However, in past years most (83%) impingement at OCGS occurred at night (Miller 1977, 1978). Some species (e.g., sand shrimp, grass shrimp, and winter flounder) have been taken almost exclusively (> 90%) at night. Thus, the estimates given here are indicative of the magnitude of impingement during the year and may be similar to those from previous years.

Annual impingement estimates for the sand shrimp, blueback herring, Atlantic silverside, threespine stickleback, winter flounder, and northern puffer were larger during 1977-78 than during the previous 2 years (1975-76 and 1976-77). Present estimates were lower for the bay anchovy, bluefish, striped searobin, smallmouth flounder, and summer flounder. Impingement of other species such as the Atlantic menhaden, northern pipefish, weakfish, grass shrimp, and blue crab fluctuated yearly. Much of this yearly variation in impingement may be related to the fact that populations of fishes undergo natural fluctuations in abundance, and drastic changes in their populations can occur in a few years. For example, large variations in yearly abundance of various fishes such as spot, winter flounder, and northern puffer in Barnegat Bay were reported by Marcellus (1972) and by Danila (1977, 1978a).

The determination of impingement impact reported herein was species-specific because the mortality rates of impinged species varied greatly. Organisms with a hard exoskeleton (e.g., blue crab), bony plates (e.g., northern pipefish, and sticklebacks), or a tough integument (e.g., northern puffer) had a high survival rate while those fishes which were relatively sensitive, that is, difficult to collect and handle without inducing injury (e.g., Atlantic menhaden, bay anchovy, and young weakfish), had poor survival. High survival was found for the flatfishes (mostly summer flounder and winter flounder), although many were damaged with abrasions and hemorrhaging. Many blue crab were also damaged, but this was usually characterized by a lost appendage which probably did not appreciably affect their survival.

Mortalities were generally lower during 1977-78 than during the previous 2 years. However, this was probably due to the time of sampling. Miller (1977, 1978) reported lower mortalities for organisms impinged at night at OCGS and Landry and Strawn (1974) noted that injured or dead fish impinged at the P. H. Robinson Power Plant in Texas were less common at night. The installation of a continuously rotating screen with a fish recovery and return system (Ristroph screen) in May 1978 probably also reduced mortalities for the year. Results of sampling on the prototype Ristroph screen are discussed in the next section.

IMPINGEMENT OF FISHES AND MACROINVERTEBRATES ON THE PROTOTYPE RISTROPH SCREEN

Gerald J. Miller

Introduction

Since September 1975, Ichthyological Associates, Inc. has determined the species composition, abundance, and mortality of organisms impinged on the vertical traveling screens that precede the intake to the circulating water system. In an attempt to mitigate these mortalities, JCP&L has considered the installation of a continuously rotating traveling screen modified with a low pressure spray wash and fish recovery and return system (i.e., Ristroph screen).

A study to determine the efficiency of the Ristroph screen in reducing fish and macroinvertebrate impingement mortality was begun in May 1978 with the installation of a prototype screen at OCGS. The main objective of this program was to compare the condition (live, damaged, dead) of organisms impinged on the Ristroph screen to that of organisms impinged on the conventional traveling screens at OCGS. In addition, collections were taken to determine the effectiveness of the low pressure spray in removing organisms from the Ristroph screen. This report covers data collected from 15 May through 15 September 1978.

Materials and Methods

Samples were taken in the upper (live) and lower (debris) troughs which ran from the rear of the Ristroph screen to the sluiceway in front of the screen (Fig. 3). As many sets of samples as practical were taken once a week from sunset to 6 h after sunset. During the week of 16 July, an additional set of samples was taken because slightly more fish were impinged at that time.

With the Ristroph screen washing continuously, a 100 x 60 x 20-cm metal frame with a 1-m long section of nylon netting (1-cm stretch mesh) was placed into the live trough, and a similar sampler was placed simultaneously in the debris trough. After 1 min or less, depending on the abundance of organisms, the samplers were removed, and organisms were processed on a 0.8-m^2 sorting table. Most organisms from each trough were placed in water in separate insulated coolers, but crabs were placed in separate 10-liter plastic buckets. The samplers were then replaced, and the procedure repeated until a maximum of 10 samples was taken. Less than 10 samples were taken only if the number of organisms collected reached the holding capacity of the coolers.

About 5 min after a set of samples had been collected, the condition of the specimens was determined. Live denoted a specimen which had no apparent damage and which was swimming normally. Damaged specimens were alive (opercular movement in fishes) but showed external damage or abnormal behavior. Dead fish showed no opercular movement, and dead invertebrates showed no movement of either appendages or mouthparts.

The efficiency of the low pressure spray in removing organisms from the screen was expressed as the percentage of the total number of specimens taken (number in live trough plus number in debris trough) that was collected in the live trough. Data from the collections made to determine condition of organisms were used to examine the efficiency of the low pressure spray, but additional samples were also taken by placing the samplers simultaneously in the two troughs for a period of 5 to 30 min.

A chi-square test (Snedecor and Cochran 1967) was used to test for differences ($P \leq 0.05$) in the condition of individual species, all fishes combined, and all invertebrates. A proportion test (Sokal and Rohlf 1969) was used to detect differences ($P \leq 0.05$) in mortality among individual species, all fishes, and all invertebrates.

Results and Discussion

A total of 108 samples (sampling time of 1,249 min) was taken from 15 May through 15 September 1978, and of the 4,120 organisms impinged, 86% (n = 3,528) were invertebrates and 14% (592) were fish. The blue crab (56% of all organisms impinged), sand shrimp (21%), grass shrimp (8%), bay anchovy (6%), and northern puffer (5%) comprised 96% of the specimens collected (Table 35). Overall, an approximately equal number of fish was washed into the live (46%) and debris (54%) troughs while more invertebrates were washed into the live trough (59%) than the debris trough (41%). Some 43% of the bay anchovy collected and 42% of the northern puffer were washed into the live trough. Although 69% of the blue crab were washed into the live trough, only 43% of the sand shrimp and 37% of the grass shrimp were removed by the low pressure spray into the live trough.

On 18 August, a valve in the screen wash water system was replaced to reduce the high pressure of the spray on organisms washed into the debris trough and to increase the pressure of the low pressure spray to facilitate the removal of organisms into the live trough. Before the valve was installed, 43% of the fish and 58% of the invertebrates were washed into the live trough (Table 36). Although a limited number of organisms was examined after the installation, the valve apparently improved the system since 70% of the fish and 73% of the invertebrates were washed into the live trough (Table 37).

Over the entire study period, condition (live, damaged, dead) was determined for 3,357 invertebrates and 576 fish (Table 38). For both troughs combined, the mortality was higher for the fish (24%) than for the invertebrates (3%). Overall, bay anchovy experienced 42% immediate mortality, northern puffer 4%, grass shrimp 7%, sand shrimp 10%, and blue crab 1% (Table 38).

Mortality of organisms collected in the debris trough was greater than that of organisms collected in the live trough, and this difference was significant (Table 39) for the bay anchovy (65% dead in debris trough, 12% dead in live trough), all fishes combined (34%, 11%), grass shrimp (10%, 1%), sand shrimp (17%, 1%), and all invertebrates (8%, 1%). The overall condition (live, damaged, dead) was significantly different for the bay anchovy, all fish, grass shrimp, sand shrimp, and all invertebrates (Table 39), and these significant differences in condition reflected, in part, significant differences in mortality and the greater survival (% live) of organisms in the live trough. No significant difference in mortality was found for the northern puffer (4% dead in debris trough, 4% dead in the live trough) or blue crab (1%, 0%). Similarly, the condition of the northern puffer and blue crab from the live trough was not significantly different from the condition of the northern puffer and blue crab from the debris trough (Table 39).

The mortality of all fish (35% dead) and all invertebrates (8%) collected from the debris trough before the valve was installed (Table 40) was significantly greater than the mortality of all fish (8%) and all invertebrates (2%) collected after the valve was installed (Table 41). The condition for all invertebrates (80% live, 12% damaged, 8% dead) taken from the debris trough before the valve was installed (Table 40) was also significantly different than that of all invertebrates (77%, 21%, 2%) collected after the valve was installed (Table 41). An insufficient number of fish was taken in either trough to statistically test for differences in condition for individual species.

The mortality of all fish (11%) and all invertebrates (1%) collected from the live trough before the valve was installed (Table 40) was not significantly different from the mortality of all fish (18%) and invertebrates (1%) after the valve was installed (Table 41). However, the condition of all invertebrates (86% live, 13% damaged, 1% dead) taken from the live trough before the valve was installed (Table 40) was significantly different than the condition of all invertebrates (78%, 21%, 1%) after the valve was installed (Table 41). The slight decrease in survival after the pressure of the spray in the live trough had been increased was attributed to the species of invertebrates collected rather than a real decrease in survival. More sand shrimp and grass shrimp were taken before the valve was installed, and their high survival (>98%) contributed to the higher survival rate prior to the installation of the valve.

The overall mortality and overall condition (live, damaged, dead) of the abundant species impinged on the Ristroph screen (live and debris troughs combined) was statistically compared with the mortality of those impinged on the conventional vertical traveling screen from 8 September 1975 through 2 September 1977 (Tatham et al. 1978a). Significantly fewer bay anchovy (78% dead on conventional traveling screens, 42% dead on Ristroph screen), all fishes combined (48%, 24%), sand shrimp (14%, 10%), blue crab (7%, 1%), and all invertebrates (10%, 3%) were dead on the Ristroph screen, but no significant difference in mortality was found for the northern puffer (7%, 4%) or the grass shrimp (8%, 7%). The overall condition differed significantly for the bay anchovy, all fishes combined, sand shrimp, blue crab, and all invertebrates (Table 42). These differences were attributed to the significantly greater mortality of organisms on the conventional screens. The condition of the northern puffer and grass shrimp from both troughs was not significantly different from the condition of the northern puffer and grass shrimp from the conventional screens.

The condition of the bay anchovy and blue crab impinged on the Ristroph screen at the OCGS was compared with that reported for screens of similar design from other power plants. Specimens of the bay anchovy impinged at the Virginia Electric and Power Company Surry Power Station (White and Brehmer 1977) had a greater immediate survival (82%) than those from the Ristroph screen at OCGS (58%). The survival (38%) of the bay anchovy at the Public Service Electric and Gas Co. Salem Nuclear Generating Station (PSE&G 1978) was not as great as that at OCGS. Survival of the blue crab (93%) at the Salem station was slightly lower than the survival (99%) at OCGS. However, comparisons between generating stations are somewhat tentative since data have not been collected at OCGS for the same time period or in the same manner as at the Salem or Surry stations.

The remaining five conventional traveling screens at OCGS will be replaced by Ristroph screens in 1979. These preliminary studies indicate that the continuously-operating Ristroph screen will improve the immediate survival (live and damaged specimens) of impinged fishes and macroinvertebrates and appreciably reduce impingement impact at OCGS.

EFFECT OF SUDDEN TEMPERATURE CHANGES ON FISHES AND MACROINVERTEBRATES

Robert J. Hillman

Introduction

The heated water discharged by the OCGS has some potential effects on local fin- and shellfish. Organisms impinged on the traveling screens or passed through the dilution pumps are introduced into ambient temperature water in the discharge of the dilution pumps (Fig. 2). This water and the heated water discharged from the OCGS remain fairly discrete in the upper 60 m of the discharge canal. Thus, organisms introduced into the dilution pump discharge are generally not exposed to the maximum discharge temperature. When organisms leave this area, they may be exposed to elevated temperatures since they pass through the partially mixed flow of ambient and heated discharge water. With two dilution pumps in operation, the temperature of this partially mixed water averages 4.5 C (range of 2.0 to 7.5 C) above ambient temperature (M. B. Roche, personal communication). Since the OCGS began operation in 1969, two incidences of heat-shock mortality have been reported, but these occurred under both unusual operating and natural conditions.

Fishes attracted to and residing in the heated discharge from October through March may be subject to cooler, ambient temperature water if the OCGS shuts down. From January 1972 to February 1975, the winter shutdowns of the OCGS and the subsequent cooling of the water in Oyster Creek have resulted in mortality of fishes, primarily the Atlantic menhaden. However, recent operational changes during winter shutdowns (i.e., cessation of dilution pump operation immediately after shutdown) have apparently decreased mortality of fishes from cold shock.

The objective of this study was to determine the effect of a sudden increase or decrease in temperature (delta T) on fishes and macroinvertebrates acclimated to rising or relatively constant water temperature (March-August) and to falling or relatively constant water temperature (September-February). Tests were conducted primarily on organisms designated by the EPA as representative important species for the OCGS 316(a) demonstration. Heat-shock temperatures lethal to 50% of the organisms (LT_{50}, American Public Health Assoc. et al. 1971) were determined for some species at acclimation temperatures of 5.0, 10.0, 15.0, 20.0, and 25.0 C, and cold shock LT_{50} values were determined for some species at acclimation temperatures of 10.0, 15.0, 20.0, and 25.0 C.

This report summarizes data collected at the Oyster Creek closed-cycle experimental laboratory from Febraary 1977 through August 1978. Data collected during the period of falling ambient water temperature in 1977 and during the period of rising ambient water temperature in 1978 is reported. This supplements data collected in 1977 and reported in Hillman and Powers (1978).

Prior to September 1976, heat-shock bioassays were conducted in a flow-through system with fluctuating temperature water supplied from the OCGS heated discharge (Powers 1977).

Materials and Methods

The 15.2 x 3.0-m mobile experimental laboratory located at the OCGS was designed to test the heat shock and cold shock of organisms acclimated to a water temperature from 5.0 to 30.0 C. The laboratory was divided into a holding facility and three (heat-shock, cold-shock, and control) test facilities (Fig. 4). Water for the experimental systems was initially obtained from the discharge of the dilution pumps at the OCGS. Water used to replenish the systems came either from this area or it was fresh water that had cured for at least 48 h prior to addition to the systems. Compressed air bubbled into each aquarium of each test facility and the holding facility kept the oxygen level near 100% saturation.

Each test facility had an independent water system which included a mechanical-biological stack filter. Each filter consisted of a 79 x 66 x 94-cm filter box and a 37 x 66 x 94-cm temperature control box. The filter box contained an upper layer of 5 to 20-mm pebbles, a middle layer of 1 to 2-mm dolomite particles, and a lower layer of fine silica sand. Water entered the filter box, percolated through the various layers, and drained into the temperature control box where the temperature was controlled by either a YSI model 73 RC ($\pm$ 0.6 C) or model 71 A ($\pm$ 0.5 C) temperature controller. The controller operated 2, 1,000-watt Vycor immersion heaters and either a 0.5 or 1.0-hp Frigid Unit or a 0.75-hp Forma Scientific refrigeration unit.

Water was pumped from the temperature control box of the filter to either the holding facility or the three test facilities. The holding facility contained 2, 900-liter circular and 6, 200-liter oval fiberglass tanks. Each test facility consisted of 3, 76.2 x 66.0 x 76.2-cm test chambers. Each chamber contained 2, 56-liter aquaria which were covered with either a plastic grate or plastic mesh screen. Water from the chambers overflowed through standpipes and was returned by gravity feed to the appropriate filter.

The temperature in the control chamber of a test facility was the temperature to which the organisms were acclimated. Each temperature-shock facility had water at three different temperatures. The water in the temperature control box of each test facility was set to the greatest cold-shock or the smallest heat-shock temperature to be tested, and the other two test temperatures were produced by two step-up baths between the temperature control box and the test chambers (Fig. 4). Each 61.0 x 30.5 x 55.9-cm step-up bath was divided in half, and each half had two series of vertical baffles. One-third of the water from the temperature control box bypassed the bath and went to one of the three test chambers. The other two-thirds were diverted into the two halves of the step-up bath, and in each half of the bath, the other two test temperatures were obtained by heating the water with a series of 4, 1,000-watt Vycor immersion heaters. The last heater in each side of the bath was regulated by a YSI model 73 RC temperature controller and a 1,000-watt rheostat which was used either alone or in conjunction with the other heaters to maintain the desired temperature. Water from each half of the bath went to the other two chambers of the test facility. The temperature in the test chamber was continuously monitored for the duration of the test by a Leeds and Northrup Speedomax W Recorder.

Specimens were collected with a 4.9-m semiballoon trawl with the codend modified to reduce collection stress, a 12.2 x 1.5-m beach seine, a 1.1 x 1.1 x 1.2-m impingement sampler with 10.7-mm wire mesh, a 1.5-m cast net, and a 1-m diameter lift net. All specimens were brought to the laboratory in either a 56-liter insulated cooler or a 1,000-liter transport box. The relatively large volume of water in the transportation vessels minimized temperature changes during transport, and air was supplied when transport time exceeded 5 min.

In the holding facility, organisms were slowly acclimated (temperature changes $\leq$ 3 C/h) from the temperature at which they were collected to the acclimation temperature. Temperature in the holding facility was approximately the same temperature at which organisms were collected. Organisms were maintained in the holding facility at least 36 h prior to testing.

Lighting in the test facility was provided by cool-white fluorescent lights and an automatic timer which coincided with the natural photoperiod. Specimens in the holding facility were maintained at ambient light levels under the natural photoperiod.

Organisms were fed preferentially on a variety of foods: chopped fish, brine shrimp, and commercially-prepared flake (Tetramin) or pellet (Purina #4 floater) food. Organisms were not fed during or 24 h prior to a test.

For all species, handling during collection and testing was minimized. A scoop made from a 4-liter plastic bottle was used to transport organisms from the collection gear to coolers and from the holding tank to the test aquarium. Individuals showing stress were not tested.

Organisms from the holding facility were placed directly into either the control or the experimental aquaria. Although the number of specimens per aquarium varied with the size and availability of organisms, an attempt was made to place an equal number of specimens in each aquarium. One chamber (two aquaria) in the control facility served as a control for the heat-shock test and a second chamber as a control for the cold-shock test. LT_{50} was calculated by the following formulae:

$$M = \frac{Y_1 - Y_2}{X_1 - X_2}$$

$$LT_{50} = \frac{50 - Y_1 + MX_1}{M}$$

Y_1 = smallest mortality (%) greater than 50%.

Y_2 = greatest mortality (%) less than 50%

X_1 = mean temperature at which Y_1 occurred.

X_2 = mean temperature at which Y_2 occurred.

Heat-shock tests were conducted for 48 h and cold-shock tests for 96 h. Observations were made continuously for the first hour; hourly to 4 h; at 6, 8, and 24 h; and three times daily to the end of the test. Mortality, loss of equilibrium, and any other significant event were noted at each observation. Mortality was defined as either lack of opercular movement for 5 min or no reaction by the organisms after it was probed vigorously with a glass rod. The inability of an organism to maintain its normal orientation was considered as a loss of equilibrium. A test was invalid if more than 20% of the organisms in the control died for reasons other than mechanical failure of the system, and invalid data were not presented. Temperature (at the first hourly observation and at every observation thereafter), dissolved oxygen level, salinity, pH, and hydrogen sulfide level were determined daily throughout the test to insure that the water quality was similar between the test facilities. Hydrogen sulfide limits were not allowed to exceed 0.05 ppm.

Length of most specimens was measured to the nearest 0.1 mm with dial calipers. Fishes larger than 185 mm were measured to the nearest 1 mm on a blocked measuring board. The length of all fishes was measured from the snout to the proximal portion of the central rays of the caudal fin. The carapace width (distance between the ends of the anterolateral spines) of the blue crab and total length (distance from the anterior end of the spine on the antennal scale to the posterior tip of the telson) of the sand shrimp were determined to the nearest 0.1 mm. Individuals were weighed to the nearest 0.1 g with an Ohaus Autogram or Dial-O-Gram balance except for sand shrimp which were weighed to the nearest 0.01 g on an Ohaus Cent-O-Gram balance. The common and scientific names of fishes and macroinvertebrates used in this section are given in Tables 1 through 3.

Results

September through December 1977

A summary of heat-shock and cold-shock studies which were conducted during this period of falling or relatively constant ambient water temperatures and which produced a LT_{50} are presented in Tables 43 and 44.

Data from all valid tests, including those in which mortality did not exceed 50% of the test organisms, are presented in Tables 45 through 56. The length range given for the individuals tested is the range of the mean length of the individuals in the several temperatures tested at each acclimation temperature.

Heat Shock

The sand shrimp was tested at acclimation temperatures of 10.1 C and 15.0 C. At 10.1 C, the LT_{50} of individuals 29.6 to 35.5 mm was 24.8 C, and at 15.0 C the LT_{50} of individuals 41.8 to 42.1 mm was 28.0 C (Table 45).

When the blue crab was tested at an acclimation temperature of about 15.0 C, immature (36.0 to 37.0 mm) and mature crabs (124.5 to 129.0 mm) had less than 50% mortality at a shock temperature up to 31.9 C (Table 46). At acclimation temperatures of 20.4 C (individuals ranged from 100.2 to 104.9 mm) and 25.0 C (85.6 to 90.9 mm), relatively consistent LT_{50} values of 36.4 and 36.8 C, respectively, were determined.

Atlantic menhaden (147.8 to 210.0 mm) acclimated to 20.6 C and those (132.2 to 163.4 mm) acclimated to 25.7 C had LT_{50} values of 30.4 and 30.2 C, respectively (Table 47).

The bay anchovy was tested at acclimation temperatures of 15.2 and 25.6 C (Table 48). At 15.2 C, mortality of individuals 34.0 to 35.0 mm in length exceeded 50% at all shock temperatures (18.2, 21.2, 24.2 C). Young fish (26.0 to 27.6 mm) acclimated to 25.6 C had a LT_{50} of 31.3 C.

The Atlantic silverside was tested at acclimation temperatures of about 10, 15, 20, and 25 C (Table 49). No LT_{50} was determined for the six tests (individuals ranged from 74.9 to 76.7 mm) conducted at an acclimation temperature near 10 C although shock temperatures were up to 28.7 C. Similarly, fish acclimated to 15.1 C had less than 50% mortality at a shock temperature up to 30.7 C. At acclimation temperatures of 20.3 (individuals ranged from 60.6 to 65.6) and 25.0 C (52.2 to 55.8 mm) the LT_{50} values were similar (32.1 and 32.5 C, respectively).

Only one test each was conducted with the northern pipefish and with the weakfish. Northern pipefish (169.7 to 179.3 mm) acclimated to 14.9 C had a LT_{50} of 30.4 C (Table 50). No mortalities were noted for young weakfish acclimated to 19.6 C and tested at temperatures of 25.4 and 28.0 C (Table 51).

The LT_{50} value for bluefish acclimated to 19.7 and 17.9 C was 30.3 and 30.5 C, respectively (Table 52). Bluefish acclimated at 24.2 to 24.6 C had a similar LT_{50} (30.4 C). All organisms were young or age 1+ fish (159.0 to 179.6 mm).

Young of the winter flounder (60.7 to 67.8 mm) acclimated to 10.4 C had a slightly lower LT_{50} than adults (166.6 to 174.2 mm) acclimated to about 15 C (Table 53). The LT_{50} was 24.6 C for young and 25.8 C for adults.

Cold Shock

Young of the blue crab (36.0 to 37.0 mm) acclimated to 14.9 C were tested at a temperature as low as 7.1 C with no mortality or loss of equilibrium (Table 54).

Atlantic silverside (71.9 to 74.7 mm) acclimated to 10.2 C had a LT_{50} of 3.2 (Table 55). Mortality was 100% for individuals subjected to a shock temperature of 0.6 C over a 24-h period. Little (<10%) mortality occurred when Atlantic silverside (63.4 to 64.0 mm), acclimated to 14.8 C, were subjected to a shock temperature of 9.7 C.

Northern pipefish (151.5 to 164.2 mm) acclimated to 10.3 C and subjected to a shock temperature of 1.4 C experienced 10% mortality (Table 56). At an acclimation temperature of 15.6 C, 20% mortality (fish of 163.9 to 181.0 mm) occurred at a shock temperature of 6.4 C.

May through August 1978

A summary of LT50 values determined for heat-shock and cold-shock studies conducted during this period of rising or relatively constant ambient water temperatures is presented in Tables 57 and 58. Data from all valid tests, including those in which mortality did not exceed 50% of the test organisms, are presented in Table 20 through 29.

Heat Shock

Two macroinvertebrates were tested during this period. For sand shrimp (34.4 to 40.9 mm), acclimated to 19.7 C the LT_{50} was 29.6 C (Table 59). However, for organisms (25.6 to 27.4 mm) at an acclimation temperature of 25.2 C, mortality exceeded 50% at 28.0 C, the lowest shock temperature. In contrast to the LT_{50} values for the sand shrimp, immature blue crab (44.6 to 45.9 mm) acclimated to 10.0 C and those (54.8 to 66.0 mm) acclimated to 15.3 C experienced little ($<$20%) mortality at a delta t up to 21 C (Table 60).

Nine tests conducted with bay anchovy at acclimation temperatures from 20.0 to 20.3 C yielded a LT_{50} value of 30.5 C (Table 61). Most mortality occurred when the shock temperature exceeded 29.0 C. As the acclimation temperature increased to 25.2 C, the LT_{50} increased to 32.1 C. All organisms tested at both acclimation temperatures were adults (51.0 to 58.4 mm).

Young of the bluefish (75.1 to 76.8 mm) were tested at an acclimation temperature of about 15 C (Table 62). No mortality occurred at shock temperatures below 31.0 C. However at a shock temperature of 34.4 C, all bluefish died within 0.3 h, and the LT_{50} was 32.6 C.

Cold Shock

The two species of macroinvertebrates tested had no mortality at the temperatures tested. Sand shrimp (48.7 to 49.1 mm) acclimated to 15.1 C and tested at a shock temperature of 1.6 C showed no mortality (Table 63). Blue crab (70.5 to 96.7 mm) acclimated to 10.0 and 15.3 C (58.9 to 60.0 mm) had no mortality at the lowest temperatures tested (1.1 and 3.3 C, respectively; Table 64).

The LT_{50} value was determined for four fishes. Atlantic menhaden (208.2 to 231.6 mm) acclimated to 25.2 C had a LT_{50} of 10.9 C (Table 65); all individuals died within 0.8 h at 5.8 C. Bay anchovy (43.0 to 45.7 mm) acclimated to 19.8 C, had 100% mortality within 48 h at a shock temperature of 10.1 C. The LT_{50} was 12.6 C (Table 66). Atlantic silverside (80.5 to 82.7 mm) acclimated to 10.1 C had a LT_{50} of 2.4 C (Table 67). Those individuals (83.4 to 85.0 mm) tested at an acclimation temperature of 15.0 C had a LT_{50} of 4.6 C. Young of the bluefish (77.4 to 83.5 mm) had a LT_{50} of 8.3 at an acclimation temperature of 15.0 C (Table 68).

Overview-March 1977 through August 1978

All temperature-shock tests which produced a LT_{50} during rising, falling, or relatively constant ambient water temperatures are summarized for the representative important species in Tables 69 and 70, respectively. These data include tests reported for the closed-cycle experimental system in Tables 71 and 72 previously reported in Hillman and Powers (1978). Several representative important species (i.e., threespine stickleback, striped bass, northern kingfish, summer flounder, and northern puffer) could not be tested because they could not be collected in sufficient numbers or successfully held for the duration of the acclimation period.

Sand shrimp was tested at acclimation temperatures of 10.1 to 25.2 C. A maximum LT_{50} for heat-shock tests (29.6 C) was noted during rising ambient water temperature for shrimp acclimated to 19.7 C. As acclimation temperatures increased to 25.2 C, the LT_{50} decreased to less than 28.0 C. The test at the acclimation temperature of 25.2 C was somewhat artificial because relatively few sand shrimp occur in the Bay at temperatures above 25 C (Danila 1978a) and few juvenile sand shrimp are impinged and subsequently introduced into the discharge canal at temperatures above 23 C (Miller 1978). Sand shrimp acclimated to 5.0, 10.0, and 15.1 C were tested at the lowest temperatures available in the experimental apparatus. However, no mortality occurred, and only a few individuals showed loss of equilibrium, which was of short duration.

The LT_{50} values for blue crab (58.1 to 104.9 mm) subjected to heat shock during both rising and falling ambient water temperature were very consistent (LT_{50} of 36.4 to 36.8 C). Complete mortality occurred as the shock temperature approached or exceeded 38 C. Shock temperatures between 29 and 36 C produced molting in some individuals and these were often cannabalized by other blue crabs. More molting was observed among blue crabs held in heated water than among those held in ambient temperature water during the summer of 1978, and the optimum temperature for molting was apparently 30 to 31 C (Balog, unpublished data). No cold-shock mortalities of the blue crab occurred at acclimation temperatures from 10.0 to 15.3 C; however, some blue crab acclimated to 10.0 C displayed a loss of equilibrium throughout the test at a shock temperature of 1.1 C.

Although young Atlantic menhaden (77.7 to 86.2 mm) tested at an acclimation temperature of 24.0 C had a LT_{50} of 32.0 C; the LT_{50} of larger fish (143.0 to 145.7 mm) acclimated to 25.7 C was 30.2 C. All other heat shock tests conducted at acclimation temperatures of 15.0 to 25.0 C produced LT_{50} values which varied from only 29.6 to 30.4 C.

Cold-shock tests with Atlantic menhaden to temperatures at or above 13.0 C, produced neither cold shock mortality nor loss of equilibrium regardless of acclimation temperature. The lowest LT_{50} for Atlantic menhaden was 7.5 C for individuals acclimated to 14.0 C during rising ambient water temperature. At an acclimation temperature of 20.0 C, the LT_{50} for young Atlantic menhaden (62.8 to 64.3 mm) was

11.1 C while for larger individuals (208.2 to 221.2 mm) at an acclimation temperature of 25.2 C, the LT_{50} was 10.9 C. One test was conducted with fish (127.5 mm) acclimated to 10.0 C, and all individuals died within 32 h after exposure to a temperature of 3.9 C. Most Atlantic menhaden could not be acclimated below 10 C without suffering mortality. All cold-shock LT_{50} values were calculated during rising ambient water temperature because a malfunction of the refrigeration system prevented data collection during falling ambient water temperatures.

For bay anchovy at acclimation temperatures of 10.0 to 25.6 C, a direct correlation existed between the acclimation temperature and the heat-shock LT_{50}; the value increased as the acclimation temperature increased. Young bay anchovy acclimated to 25.6 C had a slightly lower LT_{50} (31.3 C) than adults acclimated to 25.2 C (LT_{50} of 32.0 C). For cold-shock tests, fish acclimated at 10.0 and 19.8 C had LT_{50} values from 6.4 to 12.6 C.

For all Atlantic silverside acclimated to 15 C or above, the LT_{50} for heat-shock tests ranged from 30.0 to 33.2 C. Fish acclimated to 10.0 C had a LT_{50} of 24.5 C. Mortality during cold-shock studies varied with acclimation temperature and fish size, and several inconsistencies were apparent between the LT_{50} values at a similar acclimation temperature during rising and falling ambient water temperature. The LT_{50} for experiments conducted during a rising ambient water temperature in 1978 (LT_{50} of 2.4 C at an acclimation temperature of 10.1 C) was lower than the LT_{50} during falling ambient water temperature in 1977 (LT_{50} of 3.2 C at 10.2 C). At an acclimation temperature of 15.0 C, the LT_{50} calculated during rising ambient water temperature was 4.6 C.

For the northern pipefish acclimated to 14.9 and 19.3 C, the LT_{50} values for heat-shock studies (30.4 and 30.5 C, respectively) were similar. Shock temperatures of 29.1 to 29.3 C, at the same acclimation temperatures, produced no mortality during either rising or falling ambient water temperature. No cold-shock LT_{50} was determined. Some mortality was observed at the coldest test temperatures (1.4 and 6.4 C) at acclimation temperatures of 10.0 and 15.0 C, respectively; however, mortality was always 20% or less.

Heat-shock tests for the bluefish were conducted at acclimation temperatures from about 15 to 25 C during both rising and falling ambient water temperatures. Small individuals ($<$100 mm) had the highest LT_{50} (32.6 C at an acclimation temperature of about 15 C) and the lowest LT_{50} (29.2 C at an acclimation temperature of 21.0 C) values. Both of these LT_{50} values were obtained during rising ambient water temperature; however, the tests were conducted in different years. The other LT_{50} values (30.3 to 31.3 C) varied by 1.0 C or less although they represented tests at acclimation temperatures from 17.9 to 25.0 C. Only one cold-shock test was accomplished; young fish (77.4 to 83.5 mm) acclimated to 15.0 C had a LT_{50} value of 8.3 C.

Winter flounder were tested for heat shock at acclimation temperatures from 5.0 to 20.0 C. A direct relationship was found between the acclimation temperature and the LT_{50}. Except for fish tested at about 15 C during falling ambient water temperature, lower acclimation temperatures coincided with lower LT_{50} values. Larger specimens (166.6 to 174.2 mm) acclimated at 15.0 to 15.4 C during falling ambient water temperatures had a somewhat lower LT_{50} value (25.8 C) than smaller winter flounder (129.2 to 134.5 mm) acclimated to 15.0 C during rising ambient water temperature (LT_{50} of 27.4 C). No cold-shock mortalities were noted for adults and young fish although those acclimated to 15.0 C were exposed to a shock temperature as low as 1.0 C.

Discussion

During normal operation (i.e., four circulating-water pumps in operation), the OCGS may produce a delta T of up to 12.8 C if the OCGS operates at maximum rated capacity (M. B. Roche, personal communication). Since 1975, however, the OCGS has operated at a monthly mean delta T of about 10 C (Tatham 1977, Kurtz and Swiecicki 1978). Since the rerouting of the screen wash sluiceway in 1977, fishes and macroinvertebrates impinged on the OCGS traveling screens have been returned to ambient temperature water in the dilution pump discharge rather than to the heated discharge. Only when the dilution pump near the sluiceway discharge is not in operation may these organisms be subjected to an elevated temperature immediately upon release from the sluiceway.

Organisms released into ambient temperature water and transported with the dilution water are generally not exposed to the maximum temperature increase associated with the heated discharge because the heated discharge partially mixes with the flow from two dilution pumps. This mixed flow averages 4.5 C above ambient (M. B. Roche, personal communication). The partial mixing of ambient temperature water and heated water occurs in the upper 60 m of the discharge canal; thereafter heated discharge and ambient temperature water are well mixed.

In evaluating the effect of the OCGS heated discharge on organisms three delta T's were used. They were the maximum which may occur under normal operating conditions (12.8 C), the historical average (10.0 C), and the mean where the dilution flow and the heated discharge mix (4.5 C). These delta T's, in conjunction with avoidance temperatures reported by other authors, were used to determine the effect and to analyze the heat-shock data (Table 73). The LT_{50} values, over a range of representative ambient temperatures (5, 10, 15, 20, and 25 C) were considered for organisms introduced into the discharge canal and fishes and macroinvertebrates present in the discharge canal which encountered the heated effluent.

A temperature increase of 4.5 C surpassed only the LT_{50} value for sand shrimp acclimated to 25.2 C. No other species tested had a LT_{50} value that surpassed a 4.5-C increase at an ambient temperature of 25 C or less. Based on the temperatures at which most organisms were impinged (Miller 1978), relatively few juvenile and adult fishes and sand shrimp should be introduced into the discharge canal when the ambient water temperature exceeds 25 C, and therefore few individuals should experience heat shock in the area of mixed flow.

Although many organisms introduced into the discharge canal have the ability to avoid lethal temperatures, some individuals washed from the traveling screens or passed through the dilution pumps are damaged to the extent that they may not be able to avoid stressful temperatures in the discharge canal. These fishes and macroinvertebrates may be passively carried into an area of elevated temperatures. Once in an area of elevated temperatures, the organisms may be subject to heat shock and may lose their ability to leave the heated water. The effect of the discharge on these individuals was evaluated by examination of LT_{50} data in respect to the undiluted discharge from the OCGS.

Below an ambient water temperature of 15 C, the LT_{50} of the species tested did not surpass or approach the discharge temperature after a thermal shock of 10 C. However, at an acclimation temperature of about 20 C, the 10-C heat shock exceeded the LT_{50} calculated for the sand shrimp, Atlantic menhaden, bluefish, and winter flounder. In addition, the LT_{50} for the bay anchovy, Atlantic silverside, and northern pipefish was within 1 C of the discharge temperature at a delta T of 10 C. At an acclimation temperature of 25 C, a temperature increase of 10 C exceeded the LT_{50} for the bay anchovy and Atlantic silverside. However, the number of individuals that may be exposed to lethal temperatures should be small because relatively few sand shrimp (17.1% of all impinged individuals), northern pipefish (14.4%), Atlantic menhaden (9.5%), and Atlantic silverside (3.1%) were impinged at temperatures exceeding 15 C (Miller 1978). Miller reported impingement of some young winter flounder at an ambient temperature of 19 to 31 C during 1977, but most individuals were impinged at a temperature below 15 C. In addition, few winter flounder washed from the screens or passed through the dilution pumps are damaged such that their ability to avoid stressful temperatures should be affected. Although more than 10% of all sand shrimp and northern pipefish were impinged at temperatures over 15 C, most individuals should be able to avoid stressful temperatures because few sand shrimp (9%) and northern pipefish (5%) were damaged (Miller 1978).

The impingement and subsequent release of the bay anchovy and bluefish into the discharge canal is greatest at times when the temperature in the undiluted discharge may be lethal to these species. Some 27.3% of the bay anchovy were impinged at temperatures of 20 C or above, but only 5%

of all impinged bay anchovy were live and 15% were damaged immediately after impingement (Miller 1978). Most damage to individuals was not obvious external physical damage, (G. J. Miller, personal communication). Some loss of equilibrium was noted during temperature-shock studies. Thus, some of the individuals which survive impingement at 20 C and above may be subject to stressful temperatures in the discharge canal. Most bluefish (64.3%) were impinged at a temperature above 20 C, but the number of young (age 0+) fish impinged was relatively small. Although 21% of the impinged bluefish were damaged, physical damage (e.g., scale loss, abrasions) was observed to be more common than either loss of equilibrium or impaired swimming, and no heat-shock mortality of bluefish was documented in the discharge canal.

At a delta T of 12.8 C, the LT_{50} value for almost all organisms acclimated to temperatures of about 20 and 25 C would be below the temperature of the OCGS discharge. The blue crab acclimated to 20 C would not be affected by this delta T. A delta T of 12.8 C would also exceed the LT_{50} of the sand shrimp, bay anchovy, and winter flounder acclimated to about 15 C. However, a delta T of 12.8 C has rarely been observed, and it would occur only in areas where the heated discharge was undiluted. As discussed for a delta T of 10 C, relatively few individuals of most representative important species tested were impinged at temperatures above 15 C, and many of these individuals (e.g., sand shrimp, northern pipefish, and winter flounder) should be able to avoid stressful temperatures. Only the blue crab was impinged in greatest numbers at the higher ambient temperatures, but most blue crab introduced into ambient or near ambient water should also be able to avoid the maximum delta T. Although 29% of the blue crab impinged (Miller 1978) and 25% of those passed through the dilution pumps (Moore 1978a) were damaged, this damage was primarily missing appendages which should not affect the ability of individuals to avoid stressful temperatures. Since the ambient temperature rarely exceeds 30 C (9 of 182 days from June 1975 through August 1977; M. B. Roche, personal communication), the temperature in the area of the mixed flow of ambient water and the heated discharge should not exceed the LT_{50} value (36.4 C) calculated for the blue crab.

With the exception of the bluefish, the LT_{50} generally was above the temperature at which the species tested should avoid the OCGS heated discharge (Table 73). Therefore, most fishes and blue crab either released in the discharge canal or attracted to the heated discharge should avoid lethal temperatures. Even though the avoidance temperature of the bluefish may be higher than the LT_{50}, it is doubtful that individuals would remain in an area of stressful temperature.

The absence of regular mortalities in the OCGS discharge canal during the summer months suggests that heat shock of organisms is not a chronic occurrence. Two incidents of heat-shock mortality have been documented since the OCGS began operation, and both were related to unusual natural and operating conditions. The unexpected shutdown of the only operating dilution pump in August 1973 resulted in the rapid increase of the temperature in the immediate vicinity of the OCGS discharge to 41.1 C and some blue crab mortalities of Atlantic menhaden and were noted (JCP&L 1978). In April 1976, rapidly increasing Bay temperature and a reduction in dilution flow caused the temperature of the OCGS discharge to increase from 2 to 29.4 C in 2 days, and mortality of some blue crab and bay anchovy was observed (Danila 1978a).

The possibility of cold-shock mortality of fishes (e.g., the Atlantic menhaden and bluefish) which may overwinter in the heated discharge is more likely than that of heat-shock mortality. To date, 11 incidents of such mortality have been observed. The warmer water of the heated discharge may be preferred by some fishes, and this attraction may delay or preclude normal emigration from the Bay. If the OCGS operates through the period of low ambient Bay temperatures, some fishes acclimatize to the discharge temperature and they usually remain in the warmest area of the heated discharge. However, if the OCGS shuts down and the discharge canal cools to ambient Bay temperature, mortalities may occur.

The Atlantic menhaden, in particular, has been affected by the OCGS shutdowns during the winter months when Bay temperatures were low. Cold-shock mortalities have occurred on several occasions at ambient Bay temperatures from 1.7 to 5.6 C (JCP&L 1978). These temperatures were lower than the calculated LT_{50} values which indicated that cold-shock mortality may occur if the OCGS shuts down at an ambient Bay temperature of about 11 C or below when the OCGS discharge temperature is about 20 C. All LT_{50} values calculated at an acclimation temperature of 20.0 C or below were within a 10.0-C decrease in temperature. Meldrim et al. (1977) found that mortality from instantaneous cold-shock of young Atlantic menhaden was greatest when the temperature decrease exceeded 7.0 C or when the shock temperature was below 10.0 C.

This apparent discrepancy between experimental data and the known mortalities may be attributable to the experimental procedure. This study instantaneously subjected organisms to the maximum temperature decrease while fishes in the discharge canal are exposed to a more gradual decrease in temperature. Data on the lower lethal temperature of the Atlantic menhaden suggest that this parameter may be more important in determining mortality of overwintering fish than the instantaneous temperature shock data presented here. Reintjes (1975) found that a water temperature of 3.0 C and below was lethal to young (age 0+) fish and a temperature of 5.0 to 7.0 C killed young acclimated to a temperature of 15.0 C or above. After gradual decreases in the shock temperature Lewis and Hettler (1968) reported that survival of young Atlantic menhaden was greater than 5 days at or above 6.0 C, about 2 days at 5.0 C, and 1 day or less at or below 4.0 C. Their studies were conducted at acclimation temperatures that varied from 7.5 to 20.0 C. These data are in better agreement with the temperatures at which cold-shock mortalities of Atlantic menhaden have occurred than the LT_{50} values reported here.

Operational changes at OCGS since November 1975 (i.e., the cessation of dilution water pumping during winter shutdowns) have apparently mitigated the effect of shutdown by causing a gradual reduction in the temperature of the heated water in the discharge canal. Abell and Burton (1977) reported that the likelihood of mortality (to 120 h) of Atlantic menhaden acclimated to 15.0 C was substantially reduced when a temperature decrease of 10.0 C occurred over a 6-h period. Substantial mortality of the Atlantic menhaden was not observed during two OCGS shutdowns in December 1975 at a Bay temperature of about 3 C (Tatham and Metzger 1976).

The calculated cold-shock LT_{50} for the bay anchovy, Atlantic silverside, and bluefish indicate that these fishes are susceptible to cold-shock mortality (temperature decrease of 10.0 C) when the discharge temperature is about 20 C or below. Most LT_{50} values would occur when the ambient water temperature was below 8.5 C. Three documented incidents of cold shock to bluefish (ambient temperature of 1.7 to 3.3 C) and two incidents of cold shock to bay anchovy (ambient temperature of 0.0 to 5.6 C) have been reported since 1971. No mortality of Atlantic silverside has been reported during the OCGS winter shutdowns.

The elevated temperatures in the heated discharge may lead to the formation of gas bubbles in fishes due to supersaturation of gases in the heated water. Powers (1977) reported these effects for northern pipefish in his experimental apparatus which utilized heated water pumped directly from the OCGS discharge. Younger (1974) reported gas bubble disease for Atlantic silverside collected in the discharge canal. However, fishes tested in the closed-cycle experimental system did not exhibit loss of equilibrium or mortality due to gas bubble disease.

DELAYED MORTALITY OF FISHES AND MACROINVERTEBRATES

Robert J. Hillman

Introduction

After impingement on the traveling screens at OCGS, organisms are passed into the ambient temperature discharge of the dilution pumps (Fig. 2). Only when the dilution pump that discharges nearest the screen wash flume (pump number 3) is not in operation are organisms subjected to an immediate thermal increase. Once introduced into the dilution flow, the route by which an organism can leave this area is through the mixed flow of heated condenser and ambient temperature dilution waters of Oyster Creek. This study was conducted to examine the latent effects of impingement and exposure to the undiluted discharge temperature on fishes and macroinvertebrates. It is a continuation and conclusion of studies reported by Rode and Boyle (1977) and by Hillman (1978).

Materials and Methods

Live and damaged fishes and macroinvertebrates collected during normal (intermittent) washes of the OCGS traveling screens were observed for 48 h beginning the morning following collection. Organisms were held in either a 900-liter circular fiberglass tank or one of two 60 x 80 x 120-cm wooden holding tanks. Organisms were maintained under flow-through conditions in either ambient temperature water or heated water pumped directly from the OCGS condenser discharge (Fig.2). Since during OCGS operation organisms are passed from the screen wash flume and released into ambient or near ambient temperature water by the dilution pump discharge, they are not subjected to the maximum test temperatures used in this study. Even when dilution pump number 3 is not in operation, organisms should not be exposed to the undiluted temperatures reported here. Thus, the mortality results reported herein are conservatively high.

The condition of impinged fishes and macroinvertebrates was recorded as live, dead, or damaged as outlined in the impingement section of this report. Organisms exhibiting loss of equilibrium were recorded as damaged. Condition and physicochemical parameters were determined immediately after collection and, thereafter, twice daily for 48 h beginning the following morning.

Results and Discussion

Individuals of 12 taxa were held for delayed mortality studies. For the year, the greatest overall mortalities (>50% in both ambient and heated water) occurred among the herrings (*Alosa* spp.), the Atlantic menhaden, and the bay anchovy (Table 74). Most (77.6%) of the individuals were damaged at the initiation of the test.

The delayed mortality among the herrings was greater in ambient temperature water (100%, 27 individuals) than in heated water (71.9%, 23 of 32). The Atlantic menhaden had greater delayed mortality in heated water (75.0%, 15 of 20) than in ambient water (57.9%, 11 of 19). Hillman (1978) reported that the Atlantic menhaden had greater delayed mortality when held under ambient temperature than in heated water. However, the number of specimens tested in both 1976-77 and 1977-78 was relatively small.

Bay anchovy mortality was slightly greater (100%) for the 71 fish held in heated water than for those held in ambient temperature water (96.3%, 77 of 80). Most bay anchovy mortality was noted during the first observation. Substantial delayed (92.6% in ambient water, 88.0% in heated water) and immediate (78% after impingement) bay anchovy mortality was reported by Hillman (1978) and Miller (1978), respectively.

The fishes with the greatest mortality (herrings, Atlantic menhaden, and bay anchovy) are generally considered delicate fish and the stress of impingement and handling may have contributed to the delayed mortality of these individuals. Temperature stress did not seem to be a factor in their delayed mortality. Relatively equal and, in some cases, lower delayed mortality was observed for fish held in heated water versus those held in ambient temperature water.

Temperature did have a direct effect on survival of young northern puffer and sand shrimp. All 18 northern puffer held in heated water died while only 1 of 15 (6.7%) fish held in ambient temperature water perished. Individuals were collected in May and June; most mortality occurred in July when heated temperatures ranged from 33.1 to 35.3 C and ambient temperature water was 25.1 to

27.6 C. Greater mortality of the sand shrimp was observed for individuals held in heated water (22.1%, 19 of 67) than for those held in ambient temperature water (4.3%, 4 of 92). Most mortality of the nothern puffer and sand shrimp occurred when temperatures approached 33 and 31 C, respectively.

The Atlantic silverside had little delayed mortality in ambient temperature (30.4%, 14 of 46) or in heated water (33.3%, 13 of 39) as did the northern pipefish (5.3% ambient, 5.9% heated). Relatively few tautog (13) and winter flounder (4) were tested and no delayed mortality was noted for either fish.

A total of 553 blue crab was tested. A large size range of blue crab of both sexes and various stages of maturity were utilized. Little delayed mortality was observed in either ambient temperature (6.9%, 16 of 266) or in heated water (5.7%, 14 of 244). The other blue crab (n=43) either escaped or were cannibalized. Miller (1978) reported low immediate mortality (7%) of blue crab taken from the OCGS traveling screens. About twice as many mortalities due to molting and cannibalization were observed for blue crab held in heated water; these data were not used in delayed mortality determinations. Balog (unpublished data) noted that more blue crab held in heated water molted than those held in ambient temperature water at OCGS in 1978.

The temperature of the heated discharge at OCGS was 19.4 to 35.5 C while the temperature of ambient water was 9.7 to 27.6 C.

Most delayed mortality of blue crab held in heated water (40%; 8 of 20) occurred in late June when test temperatures were 31.6 to 34.0 C.

Most fishes with high delayed mortality (combined heated and ambient temperature mortalities) such as the herrings (73.5%), Atlantic menhaden (66.7%), and bay anchovy (98.0%) also have high immediate mortality or damage. The immediate mortality or damage of individuals of the alewife (88%), blueback herring (83%), Atlantic menhaden (92%), and bay anchovy (93%) was substantial. Likewise, those fishes and macroinvertebrates with little delayed mortality had lower rates of immediate mortality and damage after impingement. These included the Atlantic silverside (66% immediate mortality and damage, 31.8% combined delayed mortality), northern pipefish (10%, 5.6%), sand shrimp (23%, 12.9%), and blue crab (36%, 5.8%).

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FISHES, THE SAND SHRIMP, AND THE BLUE CRAB TAKEN AT SELECTED STATIONS IN WESTERN BARNEGAT BAY

Donald J. Danila

Introduction

This report consists of data taken from September 1977 through August 1978 and is a continuation of studies conducted in western Barnegat Bay since September 1975. These data are used to determine the species composition and relative abundance of fishes, the sand shrimp, and the blue crab in western Barnegat Bay and the effect of the OCGS heated discharge on the distribution of these organisms at the mouth of Oyster Creek. Data from these studies may be compared with earlier studies (Marcellus 1972; McClain 1973; Danila 1977, 1978a) to access qualitative yearly differences in the fish community of western Barnegat Bay.

Materials and Methods

Stations at the mouth of Cedar Creek (Sta. 1), Forked River (4), Oyster Creek (17), and Double Creek (23) were sampled once a month from September 1977 through August 1978 (Fig. 1, Table 75). All stations were sampled during the day, and those at the mouth of Forked River and Oyster Creek were sampled again at night, beginning 1 h after sunset. Because of extensive ice in the Bay, no samples were taken by trawl at the mouth of Cedar Creek in December and January. In February, Oyster Creek was sampled with both the seines and trawl and Forked River was sampled by trawl; the other two stations were covered by ice. The record of the catch of one 12.2-m seine haul made at the mouth of Double Creek in September was lost in the lab before it was entered onto the computer data base.

Two consecutive 5-min hauls of a 4.9-m semiballoon otter trawl were made at each station. The trawl had a 4.9-m headrope, 5.8-m foot rope, and 61.0 x 30.5-cm doors. It had a 3.8-cm nylon stretch mesh body and a 3.2-cm stretch mesh codend fitted with a 1.3-cm stretch mesh inner liner. It was hauled at 1,600 rpm from a 6.4-m MonArk work boat, and an average haul covered 771.75 m^2. The boat returned to the starting point to take the second haul as soon as the first collection was processed.

Two hauls of a 45.7 x 2.4-m nylon seine (1.3-cm stretch mesh), with a 2.4-m bag in the center, were made at each station. One collection was made before and one after two consecutive hauls of a 12.2 x 1.5-m nylon seine (0.6-cm stretch mesh). The 45.7-m seine was set in a semicircle from a 4.3-m Starcraft with both ends at or near shore when the net was fully deployed, and it was then hauled onto the beach by hand. An average haul covered approximately 3,300 m^2. The 12.2-m seine was set by holding one brail stationary at the water's edge and sweeping the fully extended net through the water in a semicircle. The maximum area covered was 233 m^2. The 45.7-m seine captured primarily larger fishes and macroinvertebrates found in shallow water within about 50 m from shore while the 12.2-m seine took smaller organisms found from shore out to about 12 m.

At times, schools of young (age 0+) Atlantic silverside were observed in front of the 12.2-m or 45.7-m seines, but most specimens escaped through the mesh of the net because of their small size. In order to record the time and location of occurrence of these small specimens without biasing catch statistics, two relative estimates of abundance were used. The abundance of these small fish was recorded as occasional (few specimens) and numerous (many specimens) according to subjective estimates made by the biologists.

In trawl collections with large amounts of detritus and macroalgae, an estimate of abundant organisms was made by counting their number in a known volume of the sample. The number in this subsample was multiplied by the total volume of the sample to estimate the total number of these organisms. Fish tangled in the net were removed by hand, counted, and added to the estimated total. Prior to subsampling for abundant organisms, the entire collection was examined, and all other organisms were removed.

Most fish were identified, counted, and discarded in the field; uncommon species were brought back to the laboratory for identification and either preserved for the voucher collection or discarded.

Invertebrates other than the sand shrimp or blue crab were identified in the field to the lowest practical taxon. Their numbers were counted or estimated, and their relative abundance was categorized as rare (1 to 10 individuals or colonies), occasional (11 to 100), common (101 to 1,000), or abundant (>1,000).

Data were recorded on standardized data sheets, and a Hewlett-Packard 9830A programmable calculator was used for data compilation and preparation of some tables.

Results

Collections in western Barnegat Bay

From September 1977 through August 1978, a total of 17,878 fish (58 species), 16,789 sand shrimp, and 1,550 blue crab were collected by all gear (Table 76). Largest numbers of fish were taken in September (21.0% of total), October (22.9), July (13.9), and August (13.1), and fewest in January (0.9) and February (0.2). Most species were taken in September (n = 30), October (35), and November (31), and least in January (11) and February (9).

Nine fishes comprised 90.9% of the total catch of fish. Of these, the bay anchovy (50.1% of the total), Atlantic silverside (21.1), and winter flounder (5.0), made up 76.2% of the catch. Six other fishes, the tidewater silverside, fourspine stickleback, northern pipefish, bluefish, blue runner, and oyster toadfish formed the additional 14.7%.

The catch of fish with the 4.9-m trawl (Table 77) was dominated by the bay anchovy (n = 7,946, 85.8% of all fish). The sand shrimp was also abundant (9,764). Other common fishes were the fourspine stickleback (3.2%), Atlantic silverside (2.7), and winter flounder (1.7); 39 additional fishes were also taken (6.5). Fewest total fish and invertebrate specimens were taken by trawl from February through April and the most from September through December.

Fewest fish were taken by the 45.7-m seine of the three types of gear utilized, but the catch was not dominated by one or two species (Table 78). The Atlantic silverside (20.9%), winter flounder (18.3), blue runner (9.0), bluefish (8.8), bay anchovy (8.6), and oyster toadfish (5.4) were most common; 39 other fishes made up the remaining 29.0%. Fish were mostly taken in October and from May through August and only a few specimens were collected in January and February. Most blue crab (n = 873) were caught by this gear; they were most abundant in September and June through August. However, fewest sand shrimp were collected by the 45.7-m seine (1,873) because most of the smaller individuals of this species passed through the mesh of the net.

The Atlantic silverside was the most abundant fish (56.9% of total catch) taken in the shore zone by the 12.2-m seine (Table 79). Although not enumerated for the reasons given above, young of the Atlantic silverside were observed to be occasional to numerous from June through August. The bay anchovy (14.1%), tidewater silverside (12.0), and northern pipefish (4.0) were also common. Thirty-seven other fishes comprised the remaining 13.0%. Almost one-quarter of the catch occurred in July; few fish were taken in January and February. The sand shrimp was usually common except during the latter 2 months.

As in the previous 2 years (Danila 1977, 1978a), more fish, sand shrimp, and blue crab were taken at night than during the day at the mouth of Oyster Creek and Forked River (Table 80). Significantly more fish (55.8%), blue crab (54.6), and sand shrimp (92.1) were caught at night. The Atlantic silverside (53.9%), oyster toadfish (70.2), northern pipefish (77.4), winter flounder (77.7), bluefish (80.7), fourspine stickleback (89.4), and blue runner (99.4) were mostly taken at night. Most specimens of the latter species, however, were collected in one haul of the 45.7-m seine at the mouth of Oyster Creek in October. Two of the nine most numerous fishes, the bay anchovy (73.6%) and the tidewater silverside (56.9), were more abundant during the day. Danila (1977, 1978a) also reported that about 70% of the bay anchovy were taken during the day and 90% of the sand shrimp at night and this may be related to diurnal changes in behavior that affected their catch by the various sampling gear. Schools of bay anchovy move closer to the surface and inshore at night and are less available to the trawl. The sand shrimp is usually much less active during the day and burrows into the bottom sediment.

The abundance and species composition of specimens at the mouth of Cedar Creek and Double Creek were generally similar (Table 81). Most (78.5%) of the fish were bay anchovy, Atlantic silverside, and tidewater silverside. Some 78.2% and 74.6% of the bay anchovy were collected in September and October at Cedar Creek and Double Creek, respectively. Few fish were taken from November through May (Cedar Creek) or June (Double Creek). At both stations, most sand shrimp were taken in November and blue crab in August.

More fish and sand shrimp were taken at the mouth of Forked River than at Oyster Creek (Table 81). The most numerous fishes at Forked

River included the bay anchovy (37.2% of total catch), Atlantic silverside (20.2), winter flounder (15.5), and fourspine stickleback (5.2). Fish were uncommon from December through May and most numerous in September, July, and August. Most sand shrimp were found in November, December, and May and most blue crab in July and August. At Oyster Creek, the Atlantic silverside (27.5%), bay anchovy (27.2), blue runner (8.0), and bluefish (6.1) were most common. Fish were most abundant in October, March, and July. Most (63.1%) of the sand shrimp were taken in November. The blue crab was collected in all months, but was most abundant in August. Few specimens of any species were collected in February.

Mortality Observations

Several shutdowns of OCGS occurred during the year and collections and observations were made to determine the extent of potential mortalities to fish and invertebrates in Oyster Creek. On 21 October 1977, OCGS shut down at approximately 0030. Ambient water temperature at the intake was about 12.2 C and at the condenser discharge was 23.9 C. Although the dilution pumps were turned off immediately, the water temperature at the condenser discharge decreased to 13.3 C in less than an hour and a minor fishkill resulted. Seine and trawl collections and observations made during 21 and 22 October indicated that most mortalities consisted of crevelle jack and blue runner. These fishes are warm-water species of southern origins. A few dead Atlantic menhaden, bay anchovy, mummichog, Atlantic silverside, bigeye scad, lookdown, silver perch, spot, and blue crab were also noted. However, live bay anchovy, Atlantic needlefish, mummichog, Atlantic silverside, bluefish, spot, striped mullet, and blue crab were common throughout Oyster Creek. Water in the lagoons remained about 2 to 4 C warmer than in the main body of Oyster Creek and may have mitigated the effects of the shutdown. Some live jacks were taken in the lagoons whereas most of the individuals near OCGS were either dead or stressed.

The OCGS shut down briefly on both 14 June and 24 August 1978. Ambient intake temperature was about 20 C on 14 June and 25 C on 24 August and the delta T decreased from about 10 C to less than 1 C. No mortalities were observed in either instance. Large numbers of Atlantic menhaden, bay anchovy, mummichog, Atlantic silverside, and blue crab were noted in Oyster Creek on both dates and all individuals appeared to exhibit normal behavior.

Some other mortalities were observed from December through March. Several dead Atlantic menhaden, oyster toadfish, naked goby, rock crab, and blue crab were seen. However, the mortalities were apparently not related to OCGS operations but instead were individuals killed during the cold winter.

Discussion

In general, the species composition and relative abundance of the catch in 1977-78 was similar to that found during 1975-77 (Danila 1977, 1978a) and in earlier studies by Marcellus (1972) from 1966-70 and

McClain (1973) in 1971-72. Relatively few fishes dominated the catch and most individuals were immature or were small forage species. The sand shrimp was the singularly most abundant species and the bay anchovy the most numerous fish. Variations in the abundance of some species have occurred in Barnegat Bay since 1966, but this has been noted frequently for estuarine fish populations in other areas. Numbers of the spot, tidewater silverside, winter flounder, and blue crab have differed greatly during the past 3 years and probably reflected variations in production of their respective year-classes. The winter flounder has become more common each year since 1975. The northern puffer increased in number but is still less abundant than reported by Marcellus (1972). The variable catch over the past 3 years of some species such as the blueback herring and blue runner was due to a bias in the catch statistics caused by several large hauls of these fishes and is probably not related to changes in their true abundance.

A comparison of the catch between Oyster Creek and Forked River indicated species-specific seasonal attraction or avoidance to the heated discharge at the mouth of Oyster Creek. More species and specimens were generally taken at Oyster Creek from October through May. Conversely, collections were usually larger at Forked River in September and from June through August, when the water temperature was warmest. The bay anchovy, fourspine stickleback, winter flounder, northern puffer, and sand shrimp usually avoided Oyster Creek. However, in December and January the sand shrimp appeared to be attracted to Oyster Creek and in May the bay anchovy was more abundant there.

Adult winter flounder were attracted to Oyster Creek mostly from December through March but avoided the heated discharge thereafter as did young winter flounder in summer and fall. The Atlantic needlefish, jacks, and blue crab were evidently attracted to the warmer water of Oyster Creek and were much less common at other stations. The attraction and avoidance phenomena observed in 1977-78 were like that reported for the previous two years of study (Danila 1977, 1978a).

The shutdown of 21 October 1977 was similar to the one that occurred on 24 November 1975 (Tatham and Metzger 1976) in that most of the mortalities were limited to jacks, primarily crevalle jack and blue runner. These warm-water fishes are attracted to the OCGS heated discharge in the fall and suffer mortality when the discharge temperature decreases to about 10 C or less (Danila 1978a). The shutdown apparently had little effect on other species found in Oyster Creek. No other fishkills of any significance occurred during 1977-78.

LIFE HISTORY STUDIES

Ferdinand Metzger, Jr.

Introduction

Life history studies of 13 species designated as important by the NRC and EPA commenced in 1975 and continued through 1977 (Tatham et al. 1977a, 1978a). The Atlantic menhaden, bay anchovy, northern pipefish, winter flounder, and blue crab were designated important species by the NRC. The threespine stickleback, striped bass, bluefish, weakfish, northern kingfish, summer flounder, northern puffer, and sand shrimp were designated representative important species (RIS) by the EPA. Because of its abundance in Barnegat Bay, life history information on the Atlantic silverside was also taken beginning in 1976.

Beginning in November 1977, only lengths were recorded from a representative sample of important species at each of the four stations in the Bay (Fig. 1). The total number collected of each species and length data were examined and compared with the distribution, abundance, and length-frequencies reported during previous life history studies in Barnegat Bay (Tatham et al. 1977a, 1978a).

Materials and Methods

At each station, all individuals or a representative subsample of at least 50 specimens of the important species were measured during the day and again at night at the mouth of Oyster Creek and Forked River. Additional specimens of the summer flounder and northern puffer were measured after impingement on the OCGS screens. The length of all fishes (nearest 1 mm) was measured on a blocked measuring board from the snout to the distal portion of the central rays of the caudal fin. The distance between the end of the anterolateral spines of the carapace of the blue crab and the length from the anterior end of the spine on the antennal scale to the posterior tip of the telson of the sand shrimp was determined to the nearest 1 mm. Sand shrimp taken by 45.7-m seine were not measured as this gear took only the largest individuals. All data were compiled and analyzed with a Hewlett-Packard 9830A programmable calculator.

Results and Discussion

Atlantic menhaden

The Atlantic menhaden is a euryhaline species found in the inshore ocean and inland tidal waters along the eastern coast of the United States and Canada. It is most abundant near major estuaries while few are taken more than 60 km from shore (Reintjes 1969). Larval and older Atlantic menhaden enter estuaries in spring.

Larvae transform into juveniles (30 to 40 mm) in low salinity estuaries and remain there until fall when they migrate southward along with adults (June and Chamberlin 1959, Reintjes 1969, Kroger and Guthrie 1973).

The Atlantic menhaden has great economic importance in the United States. About 2.95 billion kg of Atlantic menhaden have been landed in the United States, more than the harvest of any other species (Gusey 1976). Atlantic menhaden supply about 75% of all fish meal, 80% of the marine oils, and nearly 80% of all fish solubles produced in the United States (Henry 1969).

Some 65 Atlantic menhaden were collected in Barnegat Bay from September 1977 through August 1978. Most (n = 45) Atlantic menhaden were taken at the mouth of Oyster Creek, 13 at Cedar Creek, 4 at Double Creek, and 3 at Forked River (Tables 82 and 95). Most specimens from the latter three areas were taken during spring and summer, but 16 of the 45 specimens were taken at Oyster Creek in December. The specimens taken in December in Oyster Creek and from the other three areas over the year were probably all young (age 0+) and ranged in length from 33 to 147 mm. Those taken in April and May in Oyster Creek were probably age 0+ through 4+.

The distribution of Atlantic menhaden, both seasonally and by area, was similar to that found by Kurtz (1978a) in Barnegat Bay. None were collected in the Bay between November and May and those taken were predominantly young. However, Atlantic menhaden were taken in Oyster Creek throughout the year. Young, attracted to the OCGS heated discharge, were taken in December in Oyster Creek after specimens from other areas had emigrated from the Bay.

Bay anchovy

The bay anchovy ranges along the coast of the United States from Maine to Texas (Bigelow and Schroeder 1953) and is one of the most numerous fishes (McHugh 1977). It is an important forage species for other fishes such as striped bass (Schaefer 1970), weakfish (Thomas 1971), summer flounder (Smith 1969), and bluefish (Metzger 1978a).

The bay anchovy enters Barnegat Bay during March and April and leaves the Bay in December. Most fish larger than 35 mm are probably mature (Kurtz 1978b) and spawn in the Bay from June through August. Individuals live only 2 or 3 years.

Some 1,084 of the 8,951 bay anchovy collected in Barnegat Bay from September through August were measured (Tables 83 and 96). Most (99%) of these were collected from May to August; a few were taken in November and December from Forked River (n = 2) and Oyster Creek (5). Lengths of bay anchovy from the four stations were not substantially different. Bay anchovy taken from Cedar Creek ranged in length from 25 to 90 mm with a mean length of 63 mm, those at Forked River from 22 to 90 mm (mean length of 62 mm), specimens at Oyster Creek from 27 to 99 mm (67 mm), and those at Double Creek from 25 to 84 mm (60 mm). Based on length-frequencies, young (28 to 65 mm) were collected only during November, December and August. The age composition of specimens measured during May through August was similar to that reported by Kurtz (1977, 1978b). In spring and summer, age 0+ and 1+ bay anchovy were predominant; some age 2+ fish were also found. This age structure was also similar to that reported by Perlmutter (1939) for bay anchovy from Long Island. Stevenson (1958) suggested that specimens over 80 mm (age 2+) were uncommon since older fish tended to remain at sea.

Atlantic silverside

The Atlantic silverside ranges from Nova Scotia to northern Florida (Hildebrand and Schroeder 1928). It is the most common of the silversides found in Barnegat Bay, which also include the tidewater silverside and the rough silverside. The Atlantic silverside, like the bay anchovy, is an important forage species for predacious fishes It is also utilized commercially in the retail bait market.

The Atlantic silverside is short-lived and usually dies soon after spawning at age 1+ (Bayliff 1950). Hoch (1978a) found ripe females common in the Bay during April and May; most were spent during May and June. Although the reproductive condition of female Atlantic silverside was not recorded during 1977-78, young were found from June through August.

The Atlantic silverside ranked second in abundance in seine collections in Barnegat Bay from September 1976 through August 1977 (Hoch 1978a). Although most Atlantic silverside were collected during March and April in 1976 and 1977, most specimens were taken in the fall and late spring and summer of 1977-78. Few specimens were taken during January and February of 1976 through 1978.

Some 1,532 Atlantic silverside were measured from a total of 3,765 taken from September through August (Tables 84 and 97).

Substantially more Atlantic silverside were taken at Oyster Creek than at the other three stations. The total of 687 fish measured at Oyster Creek ranged in length from 29 to 148 mm, with a mean length of 81 mm. Fish measured from the other three stations included 387 from Forked River that ranged from 23 to 113 mm (mean length of 65 mm), 270 from Double Creek (26 to 130 mm, mean of 59 mm), and 188 from Cedar Creek (19 to 134 mm, mean of 73 mm).

The number of Atlantic silverside collected by area was similar to that found by Hoch (1978a) during 1976-77. Substantially more specimens were taken at the mouth of Oyster Creek than at the other three stations, and the distribution of fish among the other three stations was relatively similar. The Atlantic silverside was taken in all months only at Oyster Creek. This was probably a result of an attraction to the heated discharge of OCGS.

Threespine stickleback

The threespine stickleback is found throughout the northern hemisphere in both freshwater and in estuaries. Along the eastern coast of North America it is found from Newfoundland to lower Chesapeake Bay (Bigelow and Schroeder 1953). The threespine stickleback is of no commercial or sport value in the United States.

Adult threespine stickleback enter the shore zone in spring to spawn in areas of dense vegetation Both the adult and young threespine stickleback leave the shallow portions of estuaries in summer and overwinter in deeper water, usually within the same estuary (Bigelow and Schroeder 1953).

The threespine stickleback has apparently been less common in Barnegat Bay recently than in past years. Marcellus (1972) collected 219 specimens in 1966-68 but only 25 specimens were collected during 1969-70. McClain (1973) reported only 8 threespine stickleback taken by seine and trawl in upper Barnegat Bay from December 1971 to November 1972. Only 1 young specimen was taken in the Bay and 57 were taken at the OCGS traveling screens in 1976-77, mostly during February and March (Boyle 1978a).

Six threespine stickleback were collected in Barnegat Bay; five were taken at the mouth of Forked River and one was taken at Double Creek between January and July (Table 85). They ranged in length from 29 to 100 mm. Boyle (1978a) reported a range of 22 to 68 mm (mean length of 59 mm) for specimens taken in 1976-77. Boyle (1978a) also determined that the specimen 22 mm in length was young; all others were older juveniles and adults. Most taken during 1978 were adults; one specimen (29 mm) taken was probably a young.

Northern pipefish

The northern pipefish ranges from Nova Scotia to South Carolina (Bigelow and Schroeder 1953). It is a year-round resident of Barnegat Bay and inhabits areas of eelgrass or other vegetation. It has no sport or commercial value but is food for some fishes such as striped bass (Hoff 1974), summer flounder (Poole 1964), and bluefish (Metzger 1978a).

Specimens taken in Barnegat Bay from November through August (n = 417) ranged in length from 35 to 258 mm and had a mean length of 135 mm (Tables 86 and 98). Some 136 (33%) northern pipefish were taken at the mouth of Oyster Creek and ranged in length from 92 to 258 mm (mean length of 155 mm), 118 (28%) at Forked River (35 to 210 mm, mean of 129 mm), 114 (27%) at Double Creek (52 to 200 mm, mean of 129 mm), and 49 (12%) at Cedar Creek (61 to 208 mm, mean of 131 mm). Most were taken from April through August and relatively few from November through February.

Growth of young northern pipefish is rapid and most usually live less than 2 years. Most specimens taken in Barnegat Bay during 1976-77 were young (Moore 1978b). Lengths of northern pipefish collected during 1977-78 were similar to that reported by Moore (1978b) for 1976-77 and most taken during the present study were probably also young.

Striped bass

The striped bass is found along the Atlantic coast from Canada to southern Florida and supports a valuable sport and commercial fishery in the mid-Atlantic. The major sport fishery for striped bass occurs within this region as well as over 80% of the commercial landings (Gusey 1976). In 1976, some 62,392 kg valued at $102,053 were landed commercially in New Jersey (U. S. Dept. of Commerce 1977). The area of Barnegat Bay in and around Barnegat Inlet has supported a limited sport fishery (Porch 1977), and Halgren (1973) estimated that 2,688 fish were caught in the upper Bay by sport fishermen in 1972.

The only striped bass was taken in the mouth of Oyster Creek in December. The specimen was 618 mm long and was probably age 6+. Boyle (1978b) examined 7 striped bass collected in Barnegat Bay from September 1976 through August 1977. They ranged in length from 305 to 810 mm and in age from 2+ to 9+.

On rare occasions a few striped bass have been observed in the condenser discharge of OCGS in spring and fall. From 21 to 28 April 1978, striped bass were observed there and 59 specimens were collected by hook and line. Scale samples were removed for ageing and the striped bass ranged in length from 240 to 592 mm and in age from 2+ to 6+.

Bluefish

In the mid-Atlantic Bight, adult bluefish are found from Cape Cod to Florida within coastal estuaries to the edge of the continental shelf (Gusey 1976). The bluefish spawns offshore in spring and summer and larval bluefish are most common in the ocean while juveniles are found in areas near the coast (Saila and Pratt 1973).

The bluefish is a much sought-after sport fish and more are taken by sportsmen than by commercial fishermen (Saila and Pratt 1973). From September 1975 through August 1977, young of the bluefish were the most abundant finfish caught by sportfishermen in western Barnegat Bay (Hillman 1977d). From September 1976 through August 1977, 175,142 kg of bluefish valued at $70,909 were landed commercially in

Ocean County (U. S. Dept. of Commerce 1977). In 1974, 84% of the commercial landings on the east coast were from the mid-Atlantic Bight (Gusey 1976).

Some 387 bluefish were taken in Barnegat Bay from September through August and 122 specimens were measured at the four stations (Table 87 and 99). The bluefish ranged in length from 26 to 181 mm; all were probably young. Specimens taken from the same areas during 1976-77 were also young (Metzger 1978a).

Collections at Oyster Creek accounted for most (n = 270, 70%) of the bluefish taken in the Bay. Samples at the mouth of Forked River (n = 72, 19%), Double Creek (25, 7%), and Cedar Creek (20, 5%), accounted for the remainder of the bluefish captured. All but one specimen taken in Barnegat Bay during 1976-77 were young; one age 1+ specimen was taken at the mouth of Oyster Creek. Older bluefish (ages 1+ through 3+) have been found only in the immediate vicinity of the OCGS condenser discharge.

Bluefish have been attracted to the OCGS heated discharge, especially during the spring and fall (Metzger 1977a, 1978a). Metzger (1978a) also reported that a few age 1+ to 3+ bluefish overwintered in the immediate vicinity of the OCGS discharge.

Weakfish

The weakfish is an important sport fish that ranges from Florida to Massachusetts Bay. It is a seasonal resident of Barnegat Bay and is usually present from April through December (Hillman 1977a). The weakfish is commercially important from New Jersey to North Carolina. From September 1976 through August 1977, it was the third most important commercial fish landed in Ocean County, New Jersey (83,640 kg; U. S. Dept. of Commerce 1977). It was one of the most abundant fish taken by anglers in New Jersey in 1976 (Figley 1977). McHugh (1977) reported that the sport catch in the mid-Atlantic during recent years may be twice that of commerical landings.

Weakfish spawn offshore primarily during June, and Tatham et al. (1974) collected larvae in the ocean off Great Bay, New Jersey mostly during this month. Young weakfish enter Barnegat Bay and utilize it as a nursery area.

A total of 114 weakfish were taken in Barnegat Bay from May to August. Most were taken in Forked River, where 73 (64%) specimens were collected. Thirty (26%) specimens were taken in Oyster Creek, 9 (8%) in Cedar Creek, and 2 (2%) in Double Creek. Only weakfish taken in Oyster Creek and Forked River were measured (Tables 88 and 100). Fish from Oyster Creek ranged in length from 24 to 395 mm and probably represented ages 0+, 1+, and 3+. Weakfish taken from Forked River were all young and ranged in length from 22 to 143 mm. Hoch (1978b) reported that most weakfish taken in Barnegat Bay from September 1976 through August 1977 were young; older fish were only collected in the OCGS heated discharge.

Weakfish were first taken in Oyster Creek during May. Hillman (1977a) first reported weakfish in April at the OCGS screens and they were collected as late as December in Oyster Creek. Larger, older weakfish collected by Hillman (1977a) were taken during mid-November and December near the condenser discharge. Weakfish probably are attracted to the OCGS heated discharge especially during the early spring and late fall. Despite an attraction to Oyster Creek, more weakfish were collected at the mouth of Forked River. However, these fish were mostly young that may have avoided the heated discharge in summer.

Northern kingfish

The northern kingfish ranges along the Atlantic coast of the United States from Florida northward to Cape Cod, and is most numerous from Chesapeake Bay to New York (Bigelow and Schroeder 1953). Off the coast of New Jersey, the northern kingfish is primarily a summer resident. It first arrives in May and leaves in October. Northern kingfish are found primarily in the nearshore ocean, in bays, and at river mouths (Bigelow and Schroeder 1953). In the mid-Atlantic the northern kingfish sport catch is greater than the commercial catch (McHugh 1977). In upper Barnegat Bay from December 1971 through November 1972, the northern kingfish ranked seventh in numerical abundance of the finfish taken by anglers (Halgren 1973).

The northern kingfish is primarily an ocean spawner and in New Jersey spawning begins in June and extends into August (Welsh and Breder 1923). No eggs or larvae have been found in Barnegat Bay (Tatham et al. 1977b, 1978b). It is short-lived and has a rapid growth rate. Welsh and Breder (1923) reported that northern kingfish reached a modal length of 120 mm by the first winter, 250 mm by the second, and 350 mm by the third.

From September through August, only 16 northern kingfish were collected in the Bay. All were young taken in August; 15 were found in Forked River (Table 89) that had a mean length of 34 mm. Boyle (1978c) reported that all but 1 of the 35 northern kingfish taken in Barnegat Bay from September 1976 through August 1977 were young.

The northern kingfish has been uncommon in Barnegat Bay in recent years (McClain 1973, Metzger 1977b, Boyle 1978c). Fluctuations in abundance and age-class structure of northern kingfish populations are common (Bean 1901, Phillips 1914). Schaeffer (1965) concluded that because the northern kingfish is short-lived, the abundance and size-distribution of populations from year-to-year were dependent upon the success of individual year-classes.

Since few northern kingfish have been taken during the past few years, its response to the heated discharge is unclear. However, since most (15 of 16) fish were collected at the mouth of Forked River, the northern kingfish may not exhibit an attraction to the heated discharge as was apparent for some of the other species.

Summer flounder

The summer flounder ranges from Maine to Florida (Freeman and Turner 1976) and is a seasonal resident of Barnegat Bay. In the mid-Atlantic region, adults are found at the edge of the continental shelf during winter, and inshore in the bays during summer (Gusey 1976).

They are usually common in Barnegat Bay from April to November (Metzger 1978b).

The summer flounder is commercially valuable in the mid-Atlantic, but has greater recreational value. From 1951 to 1974, commercial fishermen in the mid-Atlantic annually landed between 0.9 and 4.1 million kg (Gusey 1976), and annual recreational catches have reached 17.7 million kg (NMFS 1974).

Spawning occurs in the ocean during the fall migration (Murawski 1963, Smith 1969), and Festa (1975) suggested that larvae and young of the summer flounder entered New Jersey estuaries from October through March. The summer flounder generally matures at age 4, although a few mature at age 3 (Murawski 1963).

A total of 44 summer flounder was measured from Barnegat Bay and the OCGS traveling screens from September through August (Tables 90 and 101). Most summer flounder (n = 39) measured were collected at the OCGS screens; 3 were taken at the mouth of Forked River and 2 at Oyster Creek. No specimens were collected at Cedar Creek or Double Creek.

The summer flounder ranged in length from 80 to 490 mm. Those taken at the mouth of Forked River and Oyster Creek ranged in length from 80 to 245 mm and were probably age 0+ and 1+. All larger summer flounder were collected at the OCGS traveling screens and most were probably ages 2+ through 4+.

Fewer summer flounder were taken during the past year than the 2 previous years (Metzger 1978b, Hillman 1977b). Due to the primarily muddy bottom of western Barnegat Bay, this area is probably not a preferred habitat for the species. Ginsberg (1952) and Bigelow and Schroeder (1953) reported that it preferred a hard sandy bottom. Thus, the number of fish taken from the western Bay probably does not reflect the abundance of summer flounder in Barnegat Bay. Nevertheless, the small number of summer flounder taken at the OCGS screens during the past year is probably indicative of a decline in abundance.

Winter flounder

Although the winter flounder is of relatively minor commercial value in the New York Bight, it is a highly regarded sport fish (McHugh 1977). During its early life stages it is estuarine-dependent and resides year-round in Barnegat Bay. Adults move offshore in the spring and return in late fall to spawn during winter (Danila 1978b).

A total of 900 winter flounder were collected in Barnegat Bay from September through August. Most (727, 81%) were young taken from June through August at Forked River. Eighty (9%) winter flounder were taken at Oyster Creek, 38 (4%) at Double Creek, and 55 (6%) at Cedar Creek. Winter flounder taken at Forked River ranged in length from 31 to 379 mm with a mean length of 69 mm (Tables 91 and 102). Fish taken at Oyster Creek ranged in length from 46 to 367 mm (mean length of 140 mm) at Double Creek from 48 to 160 mm (75 mm), and at Cedar Creek from 45 to 268 mm (70 mm).

The mean length of winter flounder taken at all stations suggested that the majority of those collected were young. Most adults were taken between November and April at the mouth of Oyster Creek. Danila (1978b) found a similar distribution and attributed it to an attraction to the heated discharge. He also collected young in the Bay during June and July but very few (n = 5) during August; most young avoided Oyster Creek in summer.

A large increase in number of winter flounder collected at Forked River occurred from 1976-77 to 1977-78. This resulted from a large number of young taken from June through August of 1978. During these 3 months, 764 of the 900 winter flounder were taken and 89% of these (n = 677) were young collected at the mouth of Forked River. The large number of young collected was probably indicative of a successful local spawn.

Northern puffer

The northern puffer occurs along the Atlantic coast of the United States from Florida to the Bay of Fundy (Bigelow and Schroeder 1953). It is a seasonal resident of Barnegat Bay from May through August and moves offshore in winter. Although it is not commercially important, it is a desirable sport fish (Moore 1978c).

A total of 193 northern puffer taken in Barnegat Bay and 179 specimens collected at the OCGS traveling screens were measured. All specimens were taken from June through August. Most northern puffer were taken at the mouth of Forked River (n = 137); 45 fish were taken at Double Creek, 12 at Oyster Creek, and 1 at Cedar Creek (Tables 92 and 103).

Moore (1978c) determined the age of northern puffer from Barnegat Bay by counting annuli on vertebrae. A comparison of his age-length data to the mean lengths of the northern puffer taken in 1978 indicated that most specimens were probably young with the exception of a few larger specimens which were age 1+. Northern puffer taken in the Bay ranged in length from 6 to 211 mm, and fish taken from the OCGS traveling screens ranged from 33 to 214 mm.

Substantially more northern puffer were taken during 1977-78 than during the previous 2 years. This may be attributed to an increase in their population in the Bay since most fish taken were young. Moore (1978c) noted that a severe population decline occurred during the past 10 years, although numbers increased during 1976-77.

The northern puffer apparently avoided the OCGS heated discharge during summer. Compared to Forked River, where 137 specimens were taken, only 12 northern puffer were collected in Oyster Creek.

Sand shrimp

The sand shrimp ranges from Baffin Bay in Canada to Florida and is found from inshore to 450 m (Whitely 1948). It has been one of the most common organisms taken in Barnegat Bay and is a year-round resident, (Moore 1978d). The sand shrimp has no commercial importance but is a major forage species for many fishes in the Bay.

A total of 16,789 sand shrimp were taken in Barnegat Bay from September through August. Some 2,409 specimens measured from November through August ranged in length from 11 to 80 mm. For the year, mean length of specimens at all stations was similar and ranged from 36 mm in Oyster Creek to 42 mm in Cedar Creek (Tables 92 and 104). Examination of length-frequencies showed identical age-class structure as that reported by Moore (1978d); juveniles and two older age-groups were present.

Seasonal distributions indicated that sand shrimp were attracted to the OCGS heated discharge in the late fall and winter, and apparently avoided Oyster Creek during the summer when few were taken in comparison to Forked River. Similar distributions were reported by Moore (1978d).

Blue crab

The blue crab ranges from Nova Scotia to northern Argentina and is common from shallow water to depths of 35 m (Oesterling 1976). It is a year-round resident of Barnegat Bay. However, during the colder months (usually late December through February), it is inactive and remains completely or partially burrowed in the sediment.

The female blue crab matures and mates during the spring and summer of its second year (Norse 1977). Two to nine months after mating, the female moves to high salinity areas to spawn. Young blue crab pass through two larval stages after hatching, the zoeal and megalopal stages. Zoeae require a salinity of at least 20 ppt to develop (Fishler and Walburg 1962). Megalopae require less saline waters and transform into the first, small (3.2 mm) crab (Sandifer 1975). Megalopae have been found in the Bay near Barnegat Inlet (Tighe and Sandine 197

The blue crab has local sport and commercial importance. Some 59,581 kg of blue crab valued at $40,283 were landed commercially in Barnegat Bay in 1976 (U. S. Dept. of Commerce 1977). From September 1976 through August 1977, the blue crab comprised 65.9% of the sport catch in western Barnegat Bay near OCGS (Hillman 1977d).

A total of 1,550 blue crab were taken from Barnegat Bay from September through August. Generally, blue crab were active in the Bay from March through early December. However, blue crab were taken in all months in Oyster Creek where large numbers were attracted to the OCGS heated discharge. During January, a few were also taken in Forked River (n = 5) and Double Creek (3).

Blue crab taken in Barnegat Bay were divided into three size categories for comparison of age-class structure for the populations sampled each year (Metzger 1978c). The categories were recruitment (≤ 59 mm), growth (60-119 mm), and mature (≥120 mm) blue crab. Comparisons revealed a marked shift in age-structure for the population examined during 1975-76 and 1976-77. Less recruitment-size blue crab occurred in 1976-77 and this was attributed to the severe winter of 1976 (Metzger 1978c). However, a substantial increase in the number of recruitment-size blue crab was found in 1977-78 (Table 94 and 105). Recruitment-size blue crab comprised 57% of the catch and were indicative of the recovery of the blue crab population following the severe winter of 1976-77. Since recruitement- and growth-size blue crab were predominant from 1975 through 1978, Barnegat Bay can be classified as a significant nursery area (Miller et al. 1975).

COMMERCIAL FISHERIES

Michael F. Boyle

Introduction

Data were compiled to determine the magnitude of various commercial fisheries in Ocean County, New Jersey. Although commercial landings have value only as a relative index of the size of the population of a species, they may give some perspective to the biomass of fishes lost through impingement. These data are not estimates of absolute abundance because catches may not be accurately reported, fish caught in one area may be landed in another, and fishing effort is selective and dependent on the current economic value of the species. Species discussed were either taken mostly in Barnegat Bay or were considered as important species by the EPA or NRC.

Materials and Methods

Commercial fisheries data for Ocean County were obtained from the preliminary New Jersey monthly landings (U.S. Dept. of Commerce 1977, 1978) and unpublished data from the National Marine Fisheries Service (NMFS) in Woods Hole, Mass. Prior to 1977-78, commercial landings made specifically within Barnegat Bay were available from the NMFS at Toms River, New Jersey. However, due to internal changes in tabulation of landings by the NMFS, these data are no longer available and Barnegat Bay landings are included as a component in total Ocean County landings (E. LoVerde, personal communication).

Results and Discussion

A total of 1,225,514 kg of 8 important species of fin- and shellfish valued at $1,847,168 was landed in Ocean County from September 1977 to August 1978 (Table 106). This was a 3.0% decrease in weight but a 7.1% increase in value from the previous 12 months (Swider 1978). Landings of white perch, bluefish, weakfish, and winter flounder increased while those of all other species declined.

Largest landings occurred in June when 183,926 kg valued at $288,860 were taken (Table 106). Summer flounder comprised most (66.1%) of the June harvest. Smallest landings occurred in November when 40,538 kg of fin- and shellfish valued at $48,675 were harvested.

The predominant species landed by commercial fishermen in Barnegat Bay have been the American eel, alewife, white perch, winter flounder, blue crab, and northern quahog (Table 107). Since 1970, 100% of the total Ocean County landings for alewife, white perch, and blue crab were taken from Barnegat Bay. In addition, substantial portions of the landings of American eel (46.9 - 100%), winter flounder (21.0 - 98.8%), and northern quahog (21.8 - 41.5%) were taken from the Bay (I.A. 1978). Most of the other important species landed in Ocean County such as bluefish, weakfish, and summer flounder were not taken in Barnegat Bay (Hillman 1977c).

In Ocean County, the American eel was taken in September and October and from April through August. It was the most valuable finfish taken by commercial fishermen in Barnegat Bay from September through August ($0.90/kg). All American eel were taken by pot.

Although of minor commercial importance during the past few years, no landings of the alewife were reported for Barnegat Bay or Ocean County from September 1977 through August 1978. Landings of 1,333 and 1,000 kg were reported in 1975-76 and 1976-77, respectively.

White perch were harvested by fyke net in Barnegat Bay in October and November and January through March. The New Jersey Department of Environmental Protection permits fyke netting in bays from 1 October to mid-April. No reported landings of white perch were made in December, probably because of extensive ice cover in the Bay which limited the operations of fishermen. In Barnegat Bay, commercial fishermen harvested 4,914 kg of white perch valued at $3,311. Although this was 522 kg greater than that taken during the previous 12 months, the catch did not approach the 18,611 kg reported by Hillman (1977c) for 1975-76.

Winter flounder were taken mostly by fyke net in bays from October through March and by otter trawl in the ocean from May through June. Largest landings of winter flounder occurred in June (7,305 kg). All winter flounder landed from Barnegat Bay were taken by fyke net. From September 1977 through August 1978, the winter flounder brought $0.44/kg in Ocean County.

The blue crab was taken in September and October and in July and August. In Barnegat Bay, fishermen used baited pots in warmer months and dredged in winter for the species. An unusually long duration of ice cover during the winter of 1977-78 prevented any dredging in the Bay. The blue crab harvest from September through August was approximately one-half of that during the same period the previous year (14,152 kg vs 28,437 kg). The average price of blue crab landed in Barnegat Bay was $0.85/kg, an increase of $0.10/kg over the previous year. The blue crab is relatively short-lived and therefore catches are strongly affected by variations in year-class strength, market demand, and weather (Gusey 1976). Historically, commercial catches of blue crab in Barnegat Bay have been sporadic. Low catches in some years have followed very cold winters.

Northern quahog were taken throughout the year in Ocean County by tongs, rake, and by hand. From September through August, the northern quahog accounted for the largest weight (228,396 kg) and most of the dollar value ($714,813) of all species harvested exclusively within the bays of Ocean County (Table 106). From 1970 through 1977, landings from Barnegat Bay made up about one-third of the total Ocean County harvest. The northern quahog was the second most abundant by weight and total value of the 8 species reported. It comprised 8.4% of the value of the total Ocean County landings (all species) and was commercially the most important species in Barnegat Bay.

The bluefish and weakfish were caught primarily by gill net. Bluefish were taken from September through January and May through August. Maximum landings occurred in July when 57,391 kg valued at $27,546 were taken. Weakfish were harvested September though December and May through August. The largest catch was in October when 40,877 kg valued at $17,381 were taken.

The summer flounder was the most valuable finfish landed in Ocean County, and landings were reported throughout the year. Largest landings were in June when 121,570 kg valued at $182,785 were reported. The summer flounder had the highest dollar per kilogram value of fishes landed in Ocean County ($1.55/kg, Table 106) and comprised 49.7% of the weight and 51.2% of the total value of the 8 species reported from September through August.

Unlike most species taken in the bays (e.g., alewife, blue crab, and northern quahog), those taken in the ocean (e.g., weakfish, bluefish, and summer flounder) and landed in Ocean County did not exhibit a major decline from the previous year. Weakfish and bluefish landings increased 20.3% and 33.2%, respectively; summer flounder landings were 2.8% smaller.

From September 1975 through August 1977, Hillman (1977c) and Swider (1978) reported that Barnegat Bay contributed 16.0% and 12.3% of the weight and 19.6% (in both years) of the dollar value to the total Ocean County landings. With the exception of white perch, commercial landings in Barnegat Bay declined from 1975-76 through 1977-78. The severe winters of 1976-77 and 1977-78 have been the main factor in this decline. Swider (1978) reported that the winter of 1976-77 contributed to substantial mortality of the blue crab and its harvest was one-third of that in 1975-76. In addition, long duration of ice cover during the past two years eliminated most fishing in Barnegat Bay during the winter.

ENTRAINMENT OF ORGANISMS THROUGH THE COOLING-WATER SYSTEM

Felicia C. Miller and Kenneth A. Tighe

Introduction

Planktonic organisms, because of their relatively small size, pass through the mesh of the traveling-water screens in front of the intake to the OCGS circulating-water pumps and travel through the cooling-water system. During this entrainment, organisms are subjected to mechanical, thermal, hydraulic, and chemical stresses.

The entrainment studies reported here are a continuation of studies conducted from September 1975 through August 1977 (Sandine et al. 1977, 1978) which included the species composition and abundance of macrozooplankton (planktonic invertebrates >500 microns in length), and ichthyoplankton.

Materials and Methods

Samples were taken once a week starting 2 h after sunset (Period 3A) because greater densities of plankton are generally collected at night (Bridger 1956; Johnson 1957; Tatham et al. 1977b, 1978b). Collections were also taken once a month during four periods over a 24-h interval. Period 1 was from 2 h after sunrise to 6 h before sunset, period 2 was from 6 h before sunset to sunset, period 3A was from 2 to 6 h after sunset, and period 4 was from 6 h before sunrise to sunrise.

Samples were taken with a 36-cm bongo sampler (505-micron mesh) to determine the species composition and abundance of macrozoo- and ichthyoplankton entrained at OCGS. From October 1977 through August 1978, collections were taken simultaneously at both the intake (Sta. 7) and discharge (Sta. 11) of the circulating-water system (Fig. 2). In September, tows at these stations were taken consecutively. The simultaneous tow at the discharge was made 1 to 5 min after the tow at the intake to sample the same water mass after it circulated through the OCGS cooling-water system. Sampling the same water mass was an attempt to reduce the large sampling variability associated with the patchy distributions typical of plankton populations.

The sampling gear was attached to a wire approximately 30 to 38 cm above a 27-kg weight, and it was deployed and retrieved with a hand winch mounted on a stationary boom. Two consecutive oblique tows were taken at each station and each tow sampled the entire water column at least once. Tow duration was usually from 1 to 5 min, depending upon detrital levels and abundance of organisms. Because of the substantially greater current flow at the discharge, the tow duration at the discharge was approximately half that of the intake in order to sample a comparable volume of water. The volume of water sampled was determined with a digital flowmeter (General Oceanics Model 2030) centered in the mouth of one side of the sampler at the discharge and in the mouth of each side of the sampler used at the intake. Current flow variation (i.e., eddies) at the intake resulted in differences in the volume filtered by the two sides of the sampler at this station. To determine whether these current flow irregularities produced differences in calculated densities of macrozooplankton between the two sides of the bongo sampler, the right and left (side) samples from 20 collections taken from 26 April through 5 June were analyzed separately. The non-parametric Wilcoxon signed rank test (Tate and Clelland 1957) was used to test for differences in density of total amphipods, mud crabs, mysids, cumaceans, and zoeae of the sand shrimp and grass shrimp. No significant ($P \leq 0.05$) differences in density were found for these forms between the right and left side of the bongo sampler. In addition, densities calculated from the side registering the greater volume of water filtered were compared with those from the other side for each collection; again no significant differences were detected. Although both sides of the bongo sampler were metered separately in subsequent collections at the intake, samples from the right and left sides were combined to make a single collection. Densities were then calculated using a average of the two volume-filtered estimates.

When the nets were removed from the water, they were gently rinsed with either low pressure water from a pump or with water poured from buckets. Samples were preserved in the field using a 5% formalin (2% formaldehyde) solution buffered with sodium borate. However, when ctenophores were abundant, they were counted and identified before preservation because ctenophores disintegrated in formalin. All other macrozooplankton and all ichthyoplankton were identified in the laboratory at a later date. Most ichthyoplankton were identified to species with the exception of larval gobies, blennies, and silver-sides; these larvae cannot be identified to species until the juvenile stage. All anchovy larvae were classified as bay anchovy since no striped anchovy eggs were found in plankton collections and adult striped anchovy were rarely taken in the Bay. For collections made at the intake, all amphipods, mysids, and mud crab zoeae were grouped into their respective familes. All forms were identified to species from collections taken at the discharge.

The number of a form entrained at OCGS was estimated using stratified sampling with optimal allocation (Snedecor and Cochran 1967). The mean number entrained per hour for the year ($\bar{Y}_{st}$) was estimated by the formula:

$$\bar{Y}_{st} = \Sigma \frac{(N_p \cdot \bar{Y}_p)}{N}$$

N_p = number of sampling units in stratum p.

$\bar{Y}_p$ = mean density of a form in stratum p.

N = number of sampling units in all strata.

The strata used were day and night. A sample was the mean density of all the individual tows collected in a stratum multiplied by the volume of water pumped through OCGS in 1 h on the sampling date. Each sampling unit was 1 h, and each sample was expressed as the number of a form entrained per hour because the duration of the individual tows was unequal. The total number entrained during the year (E) was estimated by the formula:

$$E = \overline{Y}_{st} \cdot D \cdot 24\text{ h}$$

D = number of days the OCGS circulating-water pumps operated during the year.

In calculating E for macrozooplankton (with the exception of ctenophores) and ichthyoplankton collected from September 1977 through August 1978, only the density of forms at the discharge was used. Samples from the intake were not used because of the variation in the volume filtered between the two sides of the bongo sampler. However, since ctenophores are easily fragmented during passage through the circulating-water system, the total number of ctenophores entrained during the year was estimated using intake collections.

Immediate mortality determinations were conducted only when selected ichthyoplankton (e.g., winter flounder and bay anchovy) or macrozooplankton were abundant enough to allow examination of a substantial number of individuals. Samples were taken with an expansion cone mortality sampler (Fig. 5). This sampler had a mouth opening of 20-cm expanded to a 36-cm base. It was fitted with a 333-micron mesh cylinder-cone nylon net, and a 500-ml plastic cup with a window of 250-micron netting was attached as a codend. The collection techniques employed for these samples were somewhat different than techniques employed during regular sampling. These differences were intended to reduce various stresses that may have affected mortality estimates. The sampler was deployed similarly to that reported for bongo collections, although the intake and discharge stations were not sampled simultaneously.

The net was thoroughly rinsed before each tow to prevent contamination of the sample from the previous tow. To further reduce collection stress and the amount of detritus in the sample, tow duration was reduced to 1 min or less and the codend was not rinsed. The sample was immediately taken to a nearby trailer where the condition of organisms was determined.

For juveniles of the bay anchovy, mortality determinations were made from the regular bongo samples since previous work (Sandine et al. 1978) showed that sampling mortality at the intake was relatively low for this form in bongo collections. Also, densities of juvenile bay anchovy were low and it would have been difficult to collect sufficient numbers with the mortality sampler.

For determination of the immediate condition of macrozooplankton and larval and juvenile fish, the sample was poured into a glass pan placed in a water bath that maintained the organisms near (± 1 C) the collection temperature. Live, dead, and damaged larvae were separately preserved; measurements and enumerations were made at a later date. Specimens were considered live if normal mobility was exhibited, dead if no movement was observed, and damaged if they exhibited abnormal behavioral patterns (e.g., swimming on their sides) but had other vital functions (e.g., respiration, muscular spasm). A minimum of 25 specimens per station was required in order to use the binomial proportion test (Snedecor and Cochran 1967) to determine significant differences in mortality between individuals collected at the intake and discharge. Collections were taken until at least 25 specimens were examined at each station or until a total of 10 tows was taken at each station.

Determination of the condition of fish eggs through visual observation was difficult, and therefore a biological stain (neutral red) was used which was incorporated into live embryos (Crippen and Perrier 1974). Samples that contained numerous eggs of the bay anchovy were set aside in a gallon jar for about 1 h before addition of the stain at a concentration of 1 ml of stock solution (1 g of powdered neutral red per 100 ml of distilled water) per liter of sample. This 1 h period allowed organisms that were near death upon collection to die before the stain was added. After staining, the sample was left for 4 to 6 h before examination. Condition determinations (live or dead) of eggs were more subjective than determinations for larvae and were based on two criteria: first, whether the egg had a recognizable, intact embryo, and second, whether that embryo had taken up the stain. If both of these criteria were present, the egg was considered live. If either criteria was absent, the egg was considered dead. Due to the somewhat subjective nature of the condition determinations, paired intake and discharge samples were examined by a single person.

Results and Discussion

Macrozooplankton

A total of 356 collections was taken at the intake (Sta. 7) and discharge (Sta. 11) from 1 September 1977 through 31 August 1978.

Because of the variations in flow in front of the intake, the relative abundance and species composition of most macrozooplankton were based primarily on 177 collections from the discharge. The abundance of ctenophores, however, was determined from collections at the intake because ctenophores were easily fragmented during condenser tube passage.

An estimated $4.94 \times 10^{10} \pm 6.10 \times 10^{9}$ organisms were entrained from September 1977 through August 1978 (Table 108). Mean monthly densities at the discharge ranged from $19.6/m^3$ in February to $132.2/m^3$ in May and averaged $53.8/m^3$ for the year (Table 109). Twenty-five taxa represented 95% by density of all macrozooplankton collected; amphipods (30.3%), mysids (29.8%), decapod larvae (18.5%) and hydromedusae (10.7%) were most numerous.

Neomysis americana was the most abundant macrozooplankter by number and frequency of collection (Table 110). It accounted for 27.7% of all organisms taken and occurred in almost every sample (98% of all collections). As in previous years, it was more prevalent at night than during the day due to its marked diurnal migration (Table 111).

An estimated 1.35×10^{10} specimens of N. americana (lifestage not determined) and 1.05×10^{8} gravid females were entrained (Table 108). They were collected throughout the year over a wide range of temperatures (1 to 29 C). The temporal distribution of N. americana was highly variable, however (Figs. 6 thorugh 9). In Hereford Inlet, New Jersey Allen (1978) found that major changes in the abundance and population structure of *N. americana* could occur over a period of a few days. He attributed this phenomenon to the migration of dense aggregations of mysids into and out of the inlet. At OCGS, highest monthly densities (Table 109) were found in January ($30.9/m^3$), May ($45.1/m^3$), and July ($30.4/m^3$) and lowest concentrations from February through April (1.6 to $8.7/m^3$). Most gravid females were collected from April through October at a temperature of 11 to 28 C. Based on the findings of Allen (1978) the large number of *N. americana* found from May through July was probably due to the active reproduction by the overwintering population, reproduction by the first spring generation, and immigration of mysids to the Bay from nearshore coastal areas. The low concentrations found from February through April were probably due to the movement of *N. americana* out of the Bay to deeper water and to natural mortality of the overwintering population.

Mysidopsis bigelowi comprised 7.8% of all mysids collected (mean annual density of $1.2/m^3$) and an estimated 1.06×10^9 specimens were entrained (Tables 108 and 109). It also migrates diurnally and was more common at night (Table 111). *M. bigelowi*, which has a more southerly distribution than *N. americana*, was collected primarily from July through December (Figs. 10 and 11). Highest concentrations were found in September ($2.5/m^3$) and October ($7.6/m^3$) at temperatures from 11 to 24 C (Table 109). A similar seasonal pattern of abundance was found by Swiecicki et al. (1977) near Little Egg Inlet and by Allen (1978) in Hereford Inlet, New Jersey.

As in 1976-1977, medusae of the hydrozoan *Sarsia* spp. ranked third in overall abundance (Table 109). They comprised 9.3% of all macrozooplankton and some 4.54×10^9 specimens were entrained (Table 108). They were collected from February through May (Figures 12 and 13) at a temperature of 2 to 15 C and were abundant (>100/m^3) from mid-March to mid-April at temperatures from 8 to 12 C. Based on temperature data for the past 3 years, the seasonal occurrence and abundance of *Sarsia* spp. hydromedusae appeared to be highly correlated with temperature. Every winter, *Sarsia* spp. were first collected when water temperatures declined to about 0 to 2 C. As Bay waters began to warm in late winter and early spring, densities increased sharply and peaked at a temperature range of 8 to 12 C. Thereafter, *Sarsia* declined in abundance and virtually disappeared when the water temperature reached 15 C.

An estimated 5.07×10^8 hydromedusae of *Rathkea octopunctata* were entrained (Table 108). *R. octopunctata* was less conspicuous in 1977-78 than in 1976-77 when it was the most abundant macroplankter. Small numbers were collected from October through May at a temperature of 2 to 16 C (Figs. 14 and 15).

Some 1.48×10^{10} amphipods representing 33 taxa were entrained (Table 108). The most numerous amphipods included the tubicolous forms *Jassa falcata*, *Ampelisca* spp., *Microdeutopus gryllotalpa* and Corophiidae (*Corophium* spp., *Cerapus tubularis* and *Erichthonius* spp.), and forms such as Caprellidea and Stenothoidae which are associated with colonial hydroids.

Jassa falcata is a temperate to warm temperate amphipod which is considered a dominant fouling organism (Bousfield 1973). It ranked second in overall abundance (mean annual density of $7.8/m^3$) and frequency of collection (98% of all samples) and comprised 14.5% of all macrozooplankton taken (Table 109). From September through August, and estimated 7.04×10^9 *J. falcata* were entrained (Table 108). It occurred throughout the year with lowest densities from January through April and highest concentrations in the late summer and fall (Figs. 16 and 17). Its density averaged more than $10/m^3$ in collections taken at a temperature of 10 to 19 C. Gravid females occurred in every month (3 to 13% of all specimens) but were most prevalent in April and June.

As in previous years, amphipods of the genus *Ampelisca* were numerous primarily from June through August ($4.1/m^3$ to $10.1/m^3$) at temperatures greater than 19 C (Table 109). They were rare or absent in other months (Figures 18 and 19). Approximately 1.97×10^9 specimens were entrained (Table 108), and most entrainment probably occurred at night because more *Ampelisca* spp. were collected at night (Table 111).

Some 3.04×10^9 amphipods of the genus *Corophium* were entrained. They averaged $3.4/m^3$ for the year at the discharge and accounted for 20.7% of all amphipods collected (Table 109). Four species were identified; *C. tuberculatum*, *C. acherusicum*, *C. bonelli*, and *C. insidiosum*. *C. tuberculatum* was most common (59.3% of all *Corophium*). It was collected in every month but August (Figs. 20 and 21), and concentrations greater than $1.0/m^3$ were found in February ($1.9/m^3$), March ($2.4/m^3$), and May ($17.5/m^3$).

Gravid females were noted in May, June, and September (2.1 to 8.8% of all specimens). Small numbers of *C. acherusicum* were found from September through June; *C. insidiosum* and *C. bonelli* were only collected sporadically.

Zoeae of three species of mud crab were collected in September and May through August (Figs. 22 through 25) and an estimated 4.04×10^9 specimens were entrained (Table 108). As in previous years, zoeae of *Neopanope texana* were predominant, although they were not as numerous (mean annual density of $3.1/m^3$) as in 1975-76 ($7.2/m^3$) or 1976-77 ($6.5/m^3$). Approximately 2.84×10^9 zoeae were entrained. They occurred at temperatures of 19 to 29 C and were common in June (mean monthly density of $32.3/m^3$). A few collections that yielded concentrations greater than $100/m^3$ were taken in June at a temperature of 20 to 22 C.

Although zoeae of *Panopeus herbstii* occurred over a similar temperature range as *N. texana*, most ($>10/m^3$) occurred from late June through early August at slightly higher temperatures (24 to 28C). This corresponds to the temperature range of maximum abundance (25 to 28 C) reported by Sandifer (1973) for *Panopeus herbstii* zoeae in Chesapeake Bay. At OCGS, zoeae averaged $1.2/m^3$ for the year and 1.15×10^9 specimens were entrained (Tables 108 and 109).

In comparision with other years, zoeae of *Rhithropanopeus harrisii* were relatively scarce and only 4.50×10^7 were entrained (Table 108).

Zoeae of the sand shrimp accounted for 8.9% of all macrozooplankton and an estimated 4.65×10^9 larvae were entrained (Tables 108 and 109).

They occurred from October through early August over a wide temperature range (2 to 26 C). Most of the larvae from the major spawn in spring occurred in May (average monthly density of $21.6/m^3$) and June ($30.0/m^3$) at a temperature between 13 and 24 C (Figs. 26 and 27).

Concentrations greater than $100/m^3$ were found on 15 May (14 C), 1 June (23 C), and 5 June (22 C). In laboratory studies, Regnault and Costlow (1970) noted that a temperature of 15 to 20 C was satisfactory and 20 C optimal for development of sand shrimp zoeae.

Zoeae of the blue crab were collected sporadically and in small numbers from June through August (22 to 26 C). As in previous years, megalopae were more prevalent than zoeae. Zoeae are usually scarce at OCGS because gravid females migrate to areas of higher salinity such as inlets and the nearshore coastal zone for their eggs to hatch. Zoeae usually remain in these areas or are dispersed further out to sea until they develop to the more motile and euryhaline megalopal stage. Megalopae then migrate into bays or estuaries and are recruited into the local blue crab population (Sandifer 1975).

At OCGS, some 6.58×10^7 megalopae of the blue crab were entrained (Table 108). They occurred from August through December (mean monthly densities of $0.01/m^3$ to $0.39/m^3$) at a temperature of 4 to 29 C (Table 109, Figs. 28 and 29). Most megalopae, however, were found in September and October at a temperature of 14 to 27 C.

Based on densities calculated for collections taken at the intake, an estimated 8.65×10^8 specimens of the ctenophore Mnemiopsis leidyi were entrained (Table 108). M. leidyi occurred in September and from June through August at a temperature of 20 to 29 C. However, highest concentrations (>10/m^3) were found for a brief period in early September and in late August (Table 109, Figs. 30 and 31).

Ichthyoplankton

Ichthyoplankton were sorted from the 352 bongo collections taken at the OCGS intake (Sta. 7) and discharge (Sta. 11). Data for individual collections from September 1977 through March 1978 were reported by Smith and Swiecicki (1979), and data from April through August 1978 by Danila et al. (1979). The following analysis is based exclusively on the 177 collections taken at the discharge (Sta. 11) due to the aforementioned difficulties in accurately measuring the volume filtered at the intake.

Mean yearly densities and percent composition of the ichthyoplankton entrained from September 1977 through August 1978 are given in Table 112. Eggs of the bay anchovy were the dominant fish egg collected during the year (90.1% of the eggs collected, yearly mean density of 2,875/1000m^3) and occurred in 41 of the 177 samples taken. Although winter flounder eggs are demersal, they were the second most abundant egg collected during the year (7.5%, 238/1000m^3) and occurred in 28 of the 177 samples. The above two forms accounted for most of the eggs collected. Other eggs collected in order of decreasing abundance were unidentified eggs, eggs of either the tautog or cunner, and those of the Atlantic silverside, sand lance, hogchoker, and white perch.

Larvae of the bay anchovy were the dominant fish larvae collected during the year (37.1% of the larvae collected, yearly mean density of

549/1000m^3) and occurred in 51 of the 177 samples. Larvae of the winter flounder were the second most abundant larvae (31.0%, 458/1000m^3) and occurred in 25 collections. Larvae of the sand lance were found in more collections (58) but were less abundant (11.6%, 172/1000m^3) than those of winter flounder. Goby larvae comprised 9.7% of the larvae and juveniles collected, and occurred in 47 collections (yearly mean density of 144/1000m^3). Juveniles of the bay anchovy were also abundant and made up 5.8% of the total larvae and juveniles. They had a yearly mean density of 85/1000m^3, and occurred in 57 of the 177 collections. The above forms comprised over 95% of the larvae and juveniles entrained during 1977-78. Other common larval and juvenile forms were northern pipefish juveniles, silverside larvae, blenny larvae, American eel elvers, Atlantic croaker larvae, and Atlantic menhaden juveniles.

The species composition and periods of abundance of ichthyoplankton from September 1977 through August 1978 were similar to that for 1975-1976 and 1976-1977 (Sandine et al. 1977, 1978). Two major periods of abundance occurred during winter and early spring (January through April) and summer (June through August).

From January through April, the eggs and larvae of the winter flounder and larvae of the sand lance were the dominant ichthyoplankton (Table 113). Larvae of the sand lance (Fig. 32) were first collected at low densities during December (monthly mean density of 177/1000m^3). They were abundant through April and were most numerous during February (688/1000m^3) and April (715/1000m^3). The estimated number of sand lance entrained for the year was 1.53×10^8 (Table 114).

Eggs of the winter flounder (Fig. 33) were first collected in January (817/1000m^3, Table 113) and were most abundant in February (1,022/1000m^3) and March (989/1000m^3). The eggs are demersal and those taken were probably dislodged from the substrate by storms or other natural phenomena, or by turbulence created by the circulating-water pumps at OCGS. Consequently, these eggs were probably only a small portion of the eggs in the Bay and thus no entrainment estimates were calculated.

Larvae of the winter flounder (Fig. 34) were the most common ichthyoplankton during the winter-spring period (Table 113). A single larva was collected in January; none were taken in February. Larvae were again collected in March (3,630/1000m^3) and April (1,865/1000m^3). By the end of April, larvae had metamorphosed and were demersal. The estimated number of larvae entrained during the year was 4.13 x 10^8 (Table 114).

The dominant ichthyoplankton during the summer were the eggs and larvae of the bay anchovy (Table 113). Bay anchovy eggs (Fig. 35) were first collected in low densities during May (monthly mean density of 133/1000m^3). Densities were largest in June (10,449/1000m^3) and remained high during July (8,403/1000m^3) and August (10,512/1000m^3). The estimated number of bay anchovy eggs entrained during the year was 2.75 x 10^9 (Table 114).

Larvae and juveniles of the bay anchovy from the 1977 year-class were collected from September through January (Table 113, Figs. 36 and 37). During this period, the monthly mean density decreased from 382/1000m^3 in September to 5/1000m^3 in January. No larvae or juveniles were collected at the discharge during December, although several juveniles were collected at the intake. Larvae of the bay anchovy from the 1978 year-class were first collected in June (monthly mean density of 1,196/1000m^3), remained abundant during July (1,262/1000m^3), and were most numerous in August (3,911/1000m^3). The estimated number of bay anchovy larvae and juveniles entrained from September through August was 5.95 x 10^8 (Table 114).

Goby (Gobiosoma spp.) larvae were the second most abundant species of ichthyoplankton during summer (Table 113, Fig. 38). Small numbers of larvae and juveniles from the 1977 year-class were taken from September (monthly mean density of 352/1000m^3) to November (7/1000m^3). Larvae from the 1978 year-class were first taken in May (16/1000m^3), were abundant during June (717/1000m^3) and July (576/1000m^3), and were uncommon in August (58/1000m^3). The estimated number of larvae entrained was 1.39 x 10^8 (Table 114).

Mean densities of the different ichthyoplankton forms were calculated for the day and night for each month (Table 115). While comparisons were somewhat confounded by the larger number of night collections, most forms exhibited greater densities at night. This was also true during 1975-1976 and 1976-1977 (Sandine et al. 1977, 1978). The greater densities at night probably resulted from a combination of factors such as decreased net avoidance, changes in vertical distribution, and increased spawning activity at night.

The mortality of larvae and juveniles entrained varied by species and size. Mortality estimates were made for juveniles of the bay anchovy in bongo collections from October and November (Table 116). For October, the mortality at the discharge (46%) was significantly greater than at the intake (3%). In November, the difference between the mortality at the discharge (15%) and the intake (26%) was not significant.

Mortality studies with the special mortality sampler were conducted in March, April, June and July (Table 116). Ichthyoplankton collected in sufficient numbers to test for differences in immediate mortality between the intake and discharge were larvae of sand lance, winter flounder, bay anchovy and goby, and eggs of the bay anchovy. In March, sand lance larvae had significantly greater mortality at the discharge (30%) than at the intake (3%). During March and April, winter flounder larvae had significantly greater mortality at the discharge (72% and 59%, respectively) than at the intake (25%, 3%). The lesser mortalities reported for April were due to older, larger larvae that were more hardy than the small larvae found in March. Larvae of the bay anchovy in July had a significantly greater mortality at the discharge (100%) than at the intake (36%). Goby larvae also had a significantly greater mortality at the discharge (80%) than at the intake (33%).

Mortality estimates of the eggs of the bay anchovy were more subjective than for larvae and were probably less reliable. Significant differences were found between intake and discharge mortality. In June, mortality at the intake was 40% while it was 62% at the discharge. In July, the intake and discharge mortalities were 5% and 38%, respectively. The difference between intake and discharge mortality of bay anchovy eggs was greater in July probably because higher discharge temperatures caused an increase in entrainment mortality. The total mortalities found in July were lower probably due to a lower proportion of naturally dead eggs in the population. Maiden et al. (1976) reported that the proportion of viable bay anchovy eggs in the Delaware River was relatively low in June, increased in July, and then decreased during August and September.

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Table 1. Alphabetical listing by common name of all vertebrates collected by fish and impingement programs from September 1977 through August 1978.

African pompano - Alectis crinitus
Alewife - Alosa pseudoharengus
American eel - Anguilla rostrata
American shad - Alosa sapidissima
Atlantic croaker - Micropogon undulatus
Atlantic herring - Clupea harengus
Atlantic menhaden - Brevoortia tyrannus
Atlantic moonfish - Vomer setapinnis
Atlantic needlefish - Strongylura marina
Atlantic silverside - Menidia menidia
Atlantic spadefish - Chaetodipterus faber
Banded killifish - Fundulus diaphanus
Banded rudderfish - Seriola zonata
Bay anchovy - Anchoa mitchilli
Bigeye scad - Selar crumenophthalmus
Black sea bass - Centropristis striata
Blueback herring - Alosa aestivalis
Bluefish - Pomatomus saltatrix
Blue runner - Caranx crysos
Bluespotted cornetfish - Fistularia tabacaria
Bluntnose stingray - Dasystis sayi
Butterfish - Peprilus triacanthus
Chain pickerel - Esox niger
Chain pipefish - Syngnathus louisianae
Conger eel - Conger oceanicus
Crevalle jack - Caranx hippos
Cunner - Tautogolabrus adspersus
Diamondback terrapin - Malaclemys terrapin
Feather blenny - Hysoblennius hentzi
Fourspine stickleback - Apeltes quadracus
Fowler's toad - Bufo fowleri
Gizzard shad - Dorosoma cepedianum
Golden shiner - Notemigonus crysoleucas
Gray snapper - Lutjanus griseus
Grubby - Myoxocephalus aenaeus
Halfbeak - Hyporhamphus unifasciatus
Hickory shad - Alosa mediocris
Hogchoker - Trinectes maculatus
Inshore lizardfish - Synodus foetens
Lined seahorse - Hippocampus erectus
Longhorn sculpin - Myoxocephalus octodecemspinosus
Lookdown - Selene vomer
Mummichog - Fundulus heteroclitus
Naked goby - Gobiosoma bosci
Northern kingfish - Menticirrhus saxatilis
Northern pipefish - Syngnathus fuscus
Northern puffer - Sphoeroides maculatus
Northern searobin - Prionotus carolinus
Northern sennet - Sphyraena borealis
Northern stargazer - Astroscopus guttatus
Orange filefish - Aluterus schoepfi
Oyster toadfish - Opsanus tau
Permit - Trachinotus falcatus
Pirate perch - Aphredoderus sayanus
Planehead filefish - Monacanthus hispidus
Pollock - Pollachius virens
Pumpkinseed - Lepomis gibbosus
Rainwater killifish - Lucania parva
Red goatfish - Mullus auratus
Red hake - Urophycis chuss
Rough silverside - Membras martinica
Sand lance - Ammodytes sp.
Scup - Stenotomus chrysops
Seaboard goby - Gobiosoma ginsburgi
Sheepshead minnow - Cyprinodon variegatus
Silver hake - Merluccius bilinearis
Silver perch - Bairdiella chrysura
Smallmouth flounder - Etropus microstomus
Smooth dogfish - Mustelus canis
Smooth trunkfish - Lactophrys triqueter
Snapping turtle - Chelydra serpentina
Spot - Leiostomus xanthurus
Spotfin butterflyfish - Chaetodon ocellatus
Spotted hake - Urophycis regius
Spotted scorpionfish - Scorpaena plumieri
Striped anchovy - Anchoa hepsetus
Striped bass - Morone saxatilis
Striped blenny - Chasmodes bosquianus
Striped burrfish - Chilomycterus schoepfi
Striped cusk-eel - Rissola marginata
Striped killifish - Fundus majalis
Striped mullet - Mugil cephalus
Striped searobin - Prionotus evolans
Summer flounder - Paralichthys dentatus
Tautog - Tautoga onitis
Threespine stickleback - Gasterosteus aculeatus
Tidewater silverside - Menidia beryllina
Weakfish - Cynoscion regalis
White mullet - Mugil curema
White perch - Morone americana
Windowpane - Scophthalmus aquosus
Winter flounder - Pseudopleuronectes americanus
Yellow bullhead - Ictalurus natalis

Table 2. Alphabetical listing by scientific name of all vertebrates collected by fish and impingement programs from September 1977 through August 1978.

Alectis crinitus - African pompano
Alosa aestivalis - Blueback herring
Alosa mediocris - Hickory shad
Alosa pseudoharengus - Alewife
Alosa sapidissima - American shad
Aluterus schoepfi - Orange filefish
Ammodytes sp. - Sand lance
Anchoa hepsetus - Striped anchovy
Anchoa mitchilli - Bay anchovy
Anguilla rostrata - American eel
Apeltes quadracus - Fourspine stickleback
Aphredoderus sayanus - pirate perch
Astroscopus guttatus - Northern stargazer
Bairdiella chrysura - Silver perch
Brevoortia tyrannus - Atlantic menhaden
Bufo fowleri - Fowler's toad
Caranx crysos - Blue runner
Caranx hippos - Crevalle jack
Centropristis striata - Black sea bass
Chaetodipterus faber - Atlantic spadefish
Chaetodon ocellatus - Spotfin butterflyfish
Chasmodes bosquianus - Striped blenny
Chelydra serpentina - Snapping turtle
Chilomycterus schoepfi - Striped burrfish
Clupea harengus - Atlantic herring
Conger oceanicus - Conger eel
Cynoscion regalis - Weakfish
Cyprinodon variegatus - Sheepshead minnow
Dasyatis sayi - Bluntnose stingray
Dorosoma cepedianum - Gizzard shad
Esox niger - Chain pickerel
Etropus microstomus - Smallmouth flounder
Fistularia tabacaria - Bluespotted cornetfish
Fundulus diaphanus - Banded killifish
Fundulus heteroclitus - Mummichog
Fundulus majalis - Striped killifish
Gasterosteus aculeatus - Threespine stickleback
Gobiosoma bosci - Naked goby
Gobiosoma ginsburgi - Seaboard goby
Hippocampus erectus - Lined seahorse
Hyporhamphus unifasciatus - Halfbeak
Hypsoblennius hentzi - Feather blenny
Ictalurus natalis - Yellow bullhead
Lactophys triqueter - Smooth trunkfish
Leiostomus xanthurus - Spot
Lepomis gibbosus - Pumpkinseed
Lucania parva - Rainwater killifish
Lutjanus griseus - Gray snapper
Malaclemys terrapin - Diamondback terrapin
Membras martinica - Rough silverside
Menidia beryllina - Tidewater silverside
Menidia menidia - Atlantic silverside
Menticirrhus saxatilis - Northern kingfish
Merluccius bilinearis - Silver hake
Micropogon undulatus - Atlantic croaker
Monacanthus hispidus - Planehead filefish
Morone americana - White perch
Morone saxatilis - Striped bass
Mugil cephalus - Striped mullet
Mugil curema - White mullet
Mullus auratus - Red goatfish
Mustelus canis - Smooth dogfish
Myoxocephalus aenaeus - Grubby
Myoxocephalus octodecemspinosus - Longhorn sculpin
Notemigonus crysoleucas - Golden shiner
Opsanus tau - Oyster toadfish
Paralichthys dentatus - Summer flounder
Peprilus triacanthus - Butterfish
Pollachius virens - Pollock
Pomatomus saltatrix - Bluefish
Prionotus carolinus - Northern searobin
Prionotus evolans - Striped searobin
Pseudopleuronectes americanus - Winter flounder
Rissola marginata - Striped cusk-eel
Scophthalmus aquosus - Windowpane
Scorpaena plumieri - Spotted scorpionfish
Selar crumenophthalmus - Bigeye scad
Selene vomer - Lookdown
Seriola zonata - Banded rudderfish
Sphoeroides maculatus - Northern puffer
Sphyraena borealis - Northern sennet
Stenotomus chrysops - Scup
Strongylura marina - Atlantic needlefish
Syngnathus fuscus - Northern pipefish
Syngnathus louisianae - Chain pipefish
Synodus foetens - Inshore lizardfish
Tautoga onitis - Tautog
Tautogolabrus adspersus - Cunner
Trachinotus falcatus - Permit
Trinectes maculatus - Hogchoker
Urophycis chuss - Red hake
Urophycis regius - Spotted hake
Vomer setapinnis - Atlantic moonfish

Table 3. Alphabetical listing by scientific name of all macroinvertebrate taxa collected by fish an impingement programs from September 1977 through August 1978.

Aequorea spp. - a hydromedusa	Ovalipes ocellatus - a lady crab
Callinectes sapidus - blue crab	Pagurus longicarpus - long-armed hermit crab
Callinectes similis - lesser blue crab	Palaemonetes pugio - grass shrimp
Cancer irroratus - rock crab	Palaemonetes vulgaris - grass shrimp
Carcinus maenus - green crab	Panopeus herbstii - a mud crab
Crangon septemspinosa - sand shrimp	Penaeus aztecus - brown shrimp
Cyanea capillata - lion's mane jellyfish	Penaeus setiferus - white shrimp
Echinodermata (phylum) - spiny-skinned animals	Polinices duplicata - Atlantic moon snail
Ensis directus - Atlantic jackknife clam	Polychaeta (class) - bristle worms
Libinia dubia - spider crab	Porifera (phylum) - sponges
Limulus polyphemus - horseshoe crab	Portunus gibbesi - a portunid crab
Lolliguncula brevis - brief squid	Portunus spinimanus - a portunid crab
Mytilus edulis - blue mussel	Procambarus acutus - a crayfish
Nemertea (phylum) - ribbon worms	Rhopilema verrilli - a jellyfish
Neopanope sayi - a mud crab	Scyphozoa (class) - true jellyfishes
Olencira praegustator - a parasitic isopod	Squilla empusa - mantis shrimp

Table 4. Mean surface (S) and bottom (B) water temperatures at thermally unaffected and affected stations in Western Barnegat Bay from September 1977 through August 1978.

Location (Station No.)		September	October	November	December	January	February	March	April	May	June	July	August
Thermally unaffected													
Mouth of Cedar Creek (1)	S	20.2	14.8	9.2	3.1	-0.5	-	6.1	10.9	13.2	22.2	24.6	26.9
	B	20.2	15.3	7.4	-	-	-	1.8	9.6	12.1	23.0	25.2	25.0
Mouth of Forked River (4)	S	21.5	16.3	9.7	1.9	-0.8	0.1	7.5	11.9	13.0	24.4	25.6	27.9
	B	23.7	16.5	7.1	1.0	-1.0	0.0	3.5	10.3	11.9	23.9	25.7	26.7
Mouth of Double Creek (23)	S	21.4	15.8	10.2	3.2	0.1	-	7.6	13.7	14.7	24.7	23.7	28.5
	B	21.5	15.5	8.1	0.0	-0.8	-	2.4	9.4	11.9	22.0	25.9	25.7
Mean	S	21.0	15.6	9.7	2.7	-0.4	0.1	7.1	12.2	13.6	23.8	24.6	27.8
	B	21.8	15.8	7.5	0.5	-0.9	0.0	2.6	9.8	12.0	23.0	25.6	25.8
Thermally affected													
Mouth of Oyster Creek (17)	S	24.3	18.5	11.7	7.0	2.8	7.7	11.3	15.0	16.9	28.0	28.8	29.5
	B	26.1	19.1	8.3	5.4	3.2	9.9	9.2	14.6	16.1	26.7	29.2	29.7

Table 5. Mean monthly water temperature (C) in the OCGS condenser intake and the condenser discharge and the difference between these temperatures (ΔT) during plant operation and shutdown from September 1977 through August 1978.

Month	Days		Mean Temp. of Condenser Intake		Mean Temp. of Condenser Discharge		ΔT	
	Operating	Shutdown	Operating	Shutdown	Operating	Shutdown	Operating	Shutdown
September	30	0	22.5	-	34.8	-	12.3	-
October	28	3	14.8	12.0	26.4	13.7	11.6	1.7
November	29	1	10.7	7.2	22.3	12.2	11.6	5.0
December	30	1	3.9	6.7	16.0	9.5	12.1	2.8
January	31	0	1.6	-	13.1	-	11.5	-
February	28	0	1.3	-	12.1	-	10.8	-
March	31	0	5.4	-	16.2	-	10.8	-
April	30	0	11.8	-	22.2	-	10.4	-
May	31	0	15.7	-	25.8	-	10.1	-
June	28	2	23.1	20.0	33.0	20.6	9.9	0.6
July	31	0	25.0	-	34.4	-	9.4	-
August	30	1	26.1	25.0	34.7	25.6	8.6	0.6

Mean ΔT = 10.8

Table 6. Mean surface (S) and bottom (B) salinities at thermally unaffected and affected stations in Western Barnegat Bay from September 1977 through August 1978.

Location (Station No.)		September	October	November	December	January	February	March	April	May	June	July	August
Thermally unaffected													
Mouth of Cedar Creek (1)	S	24.3	19.0	14.2	20.3	13.8	-	2.1	16.0	14.8	13.8	11.3	11.3
	B	20.8	-	16.0	-	-	-	16.3	17.3	15.5	15.0	13.5	16.0
Mouth of Forked River (4)	S	25.7	22.8	17.5	18.8	18.3	18.5	17.7	18.2	20.1	18.5	17.8	18.8
	B	26.5	22.5	17.5	18.8	21.0	19.0	19.4	17.1	17.6	18.5	18.5	19.5
Mouth of Double Creek (23)	S	24.4	24.2	19.6	22.5	21.1	-	18.3	20.5	21.2	20.7	20.3	20.2
	B	26.3	22.0	20.5	22.0	24.5	-	20.5	17.3	22.0	21.0	19.5	20.3
Mean	S	24.8	22.0	17.1	20.5	17.7	18.5	12.7	18.2	18.7	17.7	16.5	16.8
	B	24.5	22.3	18.0	20.4	22.8	19.0	18.7	17.2	18.4	18.2	17.2	18.6
Thermally affected													
Mouth of Oyster Creek (17)	S	24.7	22.1	16.8	16.8	18.4	17.3	17.6	18.6	18.3	17.3	16.7	17.8
	B	26.0	17.1	16.5	14.8	19.9	15.3	18.4	17.0	17.3	18.3	16.3	17.8

Table 7. Mean monthly surface (S) and bottom (B) temperatures, salinities, dissolved oxygen concentrations, and pH measurements at the cooling water intake from September 1977 through August 1978.

		September	October	November	December	January	February	March	April	May	June	July	August
Temperature (C)	S	21.6	13.9	11.3	4.9	2.0	1.9	5.8	11.4	15.0	22.5	23.8	25.4
	B	22.0	14.5	11.7	4.3	2.7	1.9	5.8	11.7	14.6	22.8	23.9	25.7
Salinity (ppt)	S	24.1	22.8	19.8	18.4	19.7	20.1	19.7	18.5	18.1	17.6	16.8	17.8
	B	24.1	22.8	20.3	18.0	19.3	20.1	19.8	18.9	17.9	17.8	16.7	17.4
Oxygen (ppm)	S	5.6	6.9	8.8	10.2	14.6	15.6	13.4	10.5	8.5	7.0	7.0	6.7
	B	5.5	7.1	8.7	10.2	14.3	15.1	13.4	10.9	8.9	7.0	7.0	6.7
pH	S	7.9	7.8	7.7	7.7	7.8	7.9	8.0	7.8	7.7	7.7	7.8	7.8
	B	7.9	7.8	7.7	7.7	7.8	7.9	8.0	7.9	7.8	7.7	7.8	7.9

Table 8. Mean surface (S) and bottom (B) pH at thermally unaffected and affected stations in Western Barnegat Bay from September 1977 through August 1978.

Location (Station No.)		September	October	November	December	January	February	March	April	May	June	July	August
Thermally unaffected													
Mouth of Cedar Creek (1)	S	7.7	7.4	7.9	7.5	7.8	–	7.9	8.0	7.9	8.1	8.1	7.7
	B	7.9	–	7.8	–	–	–	–	8.0	7.8	8.0	7.9	8.0
Mouth of Forked River (4)	S	7.8	7.9	8.0	7.6	7.7	8.1	7.9	8.0	7.9	8.0	7.9	7.9
	B	8.0	8.0	8.0	7.8	8.0	8.1	7.9	8.0	8.0	7.9	8.0	8.1
Mouth of Double Creek (23)	S	7.8	8.0	8.2	7.9	7.9	–	8.2	7.9	8.0	8.2	7.9	7.9
	B	8.1	7.8	8.1	8.1	8.1	–	8.2	8.0	8.0	8.3	8.1	8.1
Mean	S	7.8	7.8	8.0	7.7	7.8	8.1	8.0	8.0	7.9	8.1	8.0	7.8
	B	8.0	7.9	8.0	8.0	8.1	8.1	8.1	8.0	7.9	8.1	8.0	8.1
Thermally affected													
Mouth of Oyster Creek (17)	S	7.9	7.9	7.9	7.6	7.8	8.0	8.0	8.0	7.8	8.0	7.9	7.9
	B	8.1	7.8	7.8	7.6	7.9	8.1	8.0	8.0	8.0	8.0	8.1	8.1

Table 9. Mean surface (S) and bottom (B) dissolved oxygen at thermally unaffected and affected stations in Western Barnegat Bay from September 1977 through August 1978.

Location (Station No.)		September	October	November	December	January	February	March	April	May	June	July	August
Thermally unaffected													
Mouth of Cedar Creek (1)	S	7.0	7.4	9.8	11.3	13.6	-	10.8	6.1	8.8	8.7	9.1	6.9
	B	7.0	7.9	10.2	-	-	-	15.5	6.5	8.9	8.4	10.4	7.2
Mouth of Forked River (4)	S	7.2	8.1	9.4	11.4	12.4	13.8	11.3	6.5	8.9	8.3	8.0	8.0
	B	7.1	8.2	9.4	12.5	12.3	13.8	13.9	6.5	9.0	9.2	8.0	8.1
Mouth of Double Creek (23)	S	7.1	9.1	10.3	11.9	12.5	-	10.2	6.8	10.0	9.0	7.8	9.1
	B	8.2	7.5	9.9	-	11.9	-	11.5	6.8	9.4	8.3	7.2	7.4
Mean	S	7.1	8.2	9.8	11.5	12.8	13.8	10.8	6.5	9.2	8.7	8.3	8.0
	B	7.4	7.9	9.8	12.5	12.1	13.8	13.6	6.6	9.1	8.6	8.5	7.6
Thermally affected													
Mouth of Oyster Creek (17)	S	6.9	7.7	8.9	11.0	11.1	12.9	10.9	6.6	8.6	8.0	7.5	7.4
	B	6.6	8.0	9.6	9.6	10.7	13.0	14.1	6.5	8.5	8.4	6.8	7.5

Table 10. Mean Secchi disc readings at thermally unaffected and affected stations in Western Barnegat Bay from September 1977 through August 1978.

Location (Station No.)	September	October	November	December	January	February	March	April	May	June	July	August
Thermally unaffected												
Mouth of Cedar Creek (1)	120	80	80	–	–	–	200	140	140	120	65	80
Mouth of Forked River (4)	135	120	100	110	70	–	220	140	120	200	75	75
Mouth of Double Creek (23)	135	140	100	110	110	–	160	130	140	160	110	85
Mean	130	113	93	110	90	–	193	137	133	160	83	80
Thermally affected												
Mouth of Oyster Creek (17)	100	90	75	110	50	–	200	140	140	190	70	80

Table 11. Weekly minimum, maximum, and mean air and water temperature (C), salinity (ppt), dissolved oxygen (ppm), and pH measurements taken at the traveling screens during impingement sampling at the Oyster Creek Generating Station from 2 April through 2 September 1978.

Week		2-8 APRIL			9-15 APRIL			16-22 APRIL			23-29 APRIL		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temperature	air	2.2	7.5	4.8	6.5	20.0	9.5	2.0	12.0	7.0	3.0	13.0	6.8
	surface	8.5	12.0	9.8	10.9	14.4	12.7	10.6	14.0	11.9	9.5	13.0	11.2
	bottom	8.2	11.8	10.5	11.2	15.0	13.1	10.8	13.5	11.8	9.3	12.8	11.4
Salinity	surface	19.0	20.5	19.7	16.0	20.0	18.2	18.0	21.0	19.2	15.0	18.0	16.6
	bottom	19.0	20.5	19.8	17.0	21.0	18.8	18.0	21.0	19.5	16.5	18.3	17.5
Oxygen	surface	10.3	15.8	13.3	8.2	11.8	9.5	8.3	10.6	9.5	9.6	10.2	9.9
	bottom	10.3	16.1	14.1	8.4	11.0	9.6	8.6	10.2	9.6	9.5	11.2	10.1
pH	surface	7.5	8.1	7.9	7.7	7.9	7.8	7.8	7.9	7.8	7.5	8.1	7.8
	bottom	7.5	8.1	7.9	7.7	7.9	7.8	7.8	8.0	7.9	7.7	8.0	7.8

Week		30 APRIL-6 MAY			7-13 MAY			14-20 MAY			21-27 MAY		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temperature	air	2.0	7.0	5.2	9.5	12.0	10.7	8.4	13.3	10.4	15.1	18.0	16.6
	surface	10.5	12.1	11.4	12.0	16.5	14.2	13.1	15.0	14.3	16.5	19.7	17.8
	bottom	10.8	12.6	11.7	12.0	15.4	13.6	13.9	14.9	14.3	15.3	17.2	16.3
Salinity	surface	18.0	21.5	19.4	17.0	22.0	18.9	16.0	20.0	18.1	16.0	20.5	17.9
	bottom	16.0	21.0	18.5	17.0	21.0	18.6	16.0	22.0	18.6	15.5	20.0	17.7
Oxygen	surface	9.0	10.7	9.8	7.8	11.8	9.1	6.5	8.6	7.6	7.1	7.5	7.3
	bottom	9.2	12.0	10.4	7.8	13.0	10.2	6.0	8.3	7.4	7.4	7.9	7.7
pH	surface	7.2	8.0	7.8	7.5	7.8	7.7	7.4	8.0	7.7	7.3	7.8	7.6
	bottom	7.6	7.9	7.8	7.7	7.9	7.8	7.7	8.0	7.8	7.4	7.8	7.6

Week		28 MAY-3 JUNE			4-10 JUNE			11-17 JUNE			18-24 JUNE		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temperature	air	16.8	21.0	18.4	14.0	22.9	18.8	11.7	19.5	16.5	16.0	21.6	18.8
	surface	19.3	23.6	21.4	20.0	23.8	21.7	19.4	25.0	22.2	21.0	24.2	22.7
	bottom	19.0	22.8	21.2	20.5	22.1	21.6	20.8	25.0	23.1	21.0	23.5	22.6
Salinity	surface	13.5	17.0	15.3	16.0	18.0	16.7	15.5	17.0	16.5	17.0	20.0	18.2
	bottom	13.5	17.0	15.5	16.5	17.5	16.9	16.0	17.5	16.8	17.0	19.5	18.3
Oxygen	surface	7.0	11.7	8.3	7.0	7.7	7.4	6.3	7.7	7.0	6.6	8.0	7.0
	bottom	7.4	11.6	8.8	7.0	7.7	7.4	6.2	7.5	7.0	6.5	8.0	6.9
pH	surface	7.6	8.1	7.8	7.4	7.8	7.5	7.4	7.7	7.6	7.2	7.8	7.6
	bottom	7.6	8.0	7.8	7.4	7.5	7.5	7.4	7.7	7.6	7.6	7.8	7.7

Week		25 JUNE-1 JULY			2-8 JULY			9-15 JULY			16-22 JULY		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temperature	air	18.1	22.0	19.7	14.3	19.0	16.5	17.7	22.0	19.8	17.8	23.3	20.4
	surface	23.0	24.5	23.7	19.7	23.1	21.4	23.3	25.8	24.5	18.0	27.8	24.2
	bottom	23.2	24.5	23.8	19.9	22.5	21.4	24.2	25.9	24.9	18.0	27.8	24.1
Salinity	surface	19.0	20.5	19.9	14.5	17.0	15.9	16.0	18.0	16.5	8.8	18.0	17.1
	bottom	19.0	21.0	19.8	14.5	16.5	15.9	15.5	17.0	16.4	8.8	18.0	16.6
Oxygen	surface	5.8	6.8	6.4	7.2	7.9	7.5	6.2	7.2	6.7	5.7	8.8	7.1
	bottom	5.4	6.9	6.3	7.1	7.8	7.5	6.0	7.2	6.7	5.7	8.7	7.2
pH	surface	7.8	8.1	7.9	7.6	[illegible]	7.7	7.0	7.9	7.5	7.9	8.1	8.[illegible]
	bottom	7.9	8.1	8.0	7.7	[illegible]	7.7	6.9	7.9	7.5	7.9	8.1	8.[illegible]

Table 11. (cont.)

Week		23-29 JULY			30 JULY-5 AUGUST			6-12 AUGUST			13-19 AUGUST		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Temperature	air	21.0	23.4	22.4	22.0	23.0	22.5	20.0	24.5	22.3	19.5	23.0	21.7
	surface	25.5	26.6	26.0	23.5	24.8	24.3	25.0	26.3	25.7	25.0	26.9	26.1
	bottom	26.2	26.7	26.5	23.7	24.6	24.2	25.0	26.5	26.0	25.4	27.0	26.3
Salinity	surface	18.0	19.0	18.1	17.5	19.0	18.3	17.0	19.0	17.9	15.0	18.0	16.7
	bottom	18.0	18.0	18.0	18.0	19.0	18.5	17.0	19.0	17.8	16.0	18.0	16.8
Oxygen	surface	6.0	7.2	6.6	5.2	6.0	5.7	5.8	7.3	6.6	5.1	8.6	6.6
	bottom	5.8	7.2	6.5	5.2	5.8	5.5	6.0	7.4	6.6	5.2	8.4	6.6
pH	surface	8.2	8.4	8.3	7.4	7.8	7.7	7.4	7.8	7.6	7.7	8.1	7.9
	bottom	8.2	8.3	8.3	7.8	7.8	7.8	7.6	7.9	7.7	7.8	8.0	7.9

Week		20-26 AUGUST			27 AUGUST-2 SEPTEMBER		
		Min	Max	Mean	Min	Max	Mean
Temperature	air	16.8	27.0	22.1	20.0	25.0	22.9
	surface	23.0	26.2	24.8	23.8	26.8	24.9
	bottom	-	-	-	23.8	25.8	24.8
Salinity	surface	17.0	24.0	19.2	15.5	18.0	17.2
	bottom	-	-	-	15.5	19.0	17.4
Oxygen	surface	5.3	8.1	7.0	5.2	11.1	6.7
	bottom	-	-	-	5.3	10.9	7.2
pH	surface	7.7	8.1	7.9	7.8	8.1	8.0
	bottom	-	-	-	7.9	8.1	8.0

Table 12. Total estimated number and weight (kg), with 80% confidence interval, of selected fishes and macroinvertebrates impinged at night on the traveling screens at the Oyster Creek Generating Station from 4 September 1977 through 31 August 1978.

Species	Estimated Number	Estimated Weight
Alosa aestivalis	36,447 ± 18,383	108 ± 65
Alosa pseudoharengus	4,280 ± 930	154 ± 24
Brevoortia tyrannus	43,919 ± 23,658	3,100 ± 2,480
Anchoa mitchilli	122,723 ± 36,937	389 ± 126
Menidia menidia	63,275 ± 16,374	287 ± 76
Gasterosteus aculeatus	1,848 ± 512	5 ± 1
Syngnathus fuscus	18,387 ± 2,784	42 ± 6
Pomatomus saltatrix	2,753 ± 851	127 ± 58
Cynoscion regalis	16,409 ± 7,795	403 ± 282
Leiostomus xanthurus	55,653 ± 29,088	1,638 ± 875
Menticirrhus saxatilis	23 ± 14	.5 ± .4
Prionotus evolans	10,633 ± 4,467	73 ± 18
Etropus microstomus	5,813 ± 1,798	15 ± 5
Paralichthys dentatus	1,493 ± 427	381 ± 123
Pseudopleuronectes americanus	23,000 ± 6,388	4,386 ± 448
Sphoeroides maculatus	50,414 ± 39,204	227 ± 120
Total of all Vertebrates	484,908 ± 93,939	12,493 ± 4,004
Palaemonetes vulgaris	333,053 ± 49,095	229 ± 42
Crangon septemspinosa	3,578,637 ± 658,174	3,734 ± 672
Callinectes sapidus	972,741 ± 286,298	17,462 ± 5,467
Total of all Invertebrates	4,911,070 ± 704,791	23,257 ± 5,397
Grand total of all species[a]	5,395,989 ± 736,288	35,750 ± 6,809

[a] Grand total of all species does not equal the total of all vertebrates and invertebrates because each total was a separate estimate.

Table 13. Weekly estimated number of fishes and macroinvertebrates with more than 100 specimens impinged at night on the traveling screens at the Oyster Creek Generating Station from 4 September 1977 through 2 September 1978.

	SEPTEMBER			OCTOBER					NOVEMBER	
	4-10	11-17	18-24	25-1	2-8	9-15	16-22	23-29	30-5	6-12
Vertebrates										
Anguilla rostrata	22	11	11	21	-	-	-	-	-	21
Alosa aestivalis	157	4	4	-	-	4	53	4	32	2632
Alosa pseudoharengus	4	11	-	193	18	28	130	39	340	214
Brevoortia tyrannus	149	60	39	38	21	470	18183	215	1551	8551
Anchoa mitchilli	4940	2188	3209	1255	3036	15576	7014	242	4393	1152
Synodus foetens	-	-	22	46	95	95	4	-	140	49
Opsanus tau	46	18	39	25	42	56	42	46	60	56
Urophycis chuss	-	-	-	-	-	-	-	-	14	123
Cyprinodon variegatus	-	-	-	4	-	-	14	4	-	14
Fundulus heteroclitus	-	-	-	-	-	-	21	26	-	11
Membras martinica	32	95	96	110	4	22	4	-	-	-
Menidia menidia	11	4	18	11	7	11	459	547	942	1635
Apeltes quadracus	-	-	-	-	-	-	-	8	4	4
Syngnathus fuscus	54	4	4	14	70	1001	1103	505	1271	497
Morone americana	-	-	4	-	14	14	18	9	42	28
Pomatomus saltatrix	53	46	50	40	35	598	343	13	28	70
Caranx hippos	7	11	36	26	25	141	-	12	-	-
Selene vomer	244	221	240	235	140	264	14	39	56	39
Bairdiella chrysura	14	7	4	42	4	182	980	125	322	494
Cynoscion regalis	659	385	178	852	219	4000	5516	216	718	1001
Leiostomus xanthurus	84	70	74	107	95	749	13689	610	1260	1327
Micropogon undulatus	-	-	-	-	4	-	4	-	25	137
Tautoga onitis	-	-	-	-	-	7	46	40	35	343
Mugil curema	-	14	115	80	4	21	81	-	4	4
Hypsoblennius hentzi	-	-	-	-	-	25	56	15	84	39
Prionotus evolans	12	11	4	137	278	2819	1838	123	3511	634
Etropus microstomus	-	-	-	-	-	4	-	-	249	585
Paralichthys dentatus	26	21	14	57	193	394	147	8	168	28
Scophthalmus aquosus	-	4	4	-	4	11	98	4	56	7
Pseudopleuronectes americanus	-	-	4	-	14	67	119	118	417	480
Trinectes maculatus	11	14	14	22	54	81	77	36	49	42
Sphoeroides maculatus	44	4	7	85	88	28	7	-	-	112
Total of all Vertebrate Species	6607	3269	4252	3531	4604	26930	50460	3089	15932	20521
Invertebrates										
Aequorea spp	-	7	103	183	7	93	102	4	-	-
Cyanea capillata	-	-	-	-	4	18	18	-	42	4
Class Polychaeta	-	-	-	-	-	14	21	-	42	67
Penaeus aztecus	4	7	32	45	46	383	109	159	791	2443
Palaemonetes vulgaris	-	4	4	-	11	25	1785	117	4893	23618
Crangon septemspinosa	7	14	14	-	46	816	3248	120	41696	35830
Ovalipes ocellatus	19	11	32	95	35	95	165	142	2051	1180
Portunus gibbesi	-	7	-	-	-	81	14	32	581	165
Callinectes sapidus	4378	11606	12159	34529	8874	6043	5905	2612	14378	92771
Callinectes similis	298	140	333	251	60	87	56	5	133	105
Phylum Nemertea	-	-	-	-	-	60	4	4	42	60
Total of all Invertebrate Species	4720	11795	12705	35102	9086	7719	11438	3217	64715	156321
Grand Totals of all Species	11327	15064	16957	38633	13690	34649	61898	6306	80647	176841

Table 13. (cont.)

	NOVEMBER 13-19	20-26	DECEMBER 27-3	4-10	11-17	18-24	25-31	JANUARY 1-7	8-14	15-21
Vertebrates										
Anguilla rostrata	4	4	14	7	-	7	4	-	-	-
Alosa aestivalis	2079	347	1760	7712	274	771	23805	1034	1184	36
Alosa pseudoharengus	1122	248	33	155	4	39	178	53	137	-
Alosa sapidissima	-	-	-	-	-	28	608	270	123	-
Brevoortia tyrannus	4853	1071	1406	2069	178	353	1542	50	262	-
Anchoa mitchilli	391	338	820	297	61	7	54	140	-	12
Synodus foetens	15	4	4	-	-	-	-	-	-	-
Opsanus tau	84	21	14	4	4	-	4	-	-	-
Merluccius bilinearis	42	-	90	290	28	14	43	46	12	-
Urophycis chuss	120	53	85	695	86	77	131	64	140	8
Cyprinodon variegatus	4	22	120	310	51	67	21	63	10	18
Fundulus heteroclitus	25	18	18	15	14	25	4	4	4	-
Menidia menidia	4744	3573	3641	10101	5491	3519	13036	3299	13226	614
Apeltes quadracus	158	18	36	21	65	74	108	188	154	764
Gasterosteus aculeatus	-	9	-	21	-	14	322	155	118	51
Syngnathus fuscus	1697	779	2571	1154	909	166	245	205	109	54
Morone americana	78	78	26	53	21	70	34	77	30	8
Pomatomus saltatrix	106	-	-	-	-	-	-	-	-	-
Selene vomer	-	9	-	-	-	-	-	-	-	-
Bairdiella chrysura	456	313	288	177	-	-	-	-	-	-
Cynoscion regalis	325	11	105	43	-	-	-	-	-	-
Leiostomus xanthurus	31872	3284	358	979	88	269	11	4	13	-
Micropogon undulatus	65	18	4	33	52	21	18	56	7	4
Tautoga onitis	95	301	63	91	77	35	22	-	7	-
Mugil curema	23	7	-	-	-	-	-	-	5	-
Hypsoblennius hentzi	116	73	4	-	-	-	-	-	-	7
Ammodytes sp.	-	-	-	7	-	-	4	4	10	15
Prionotus evolans	505	120	77	32	23	7	-	-	-	-
Myoxocephalus aenaeus	-	-	-	42	33	60	236	431	427	407
Etropus microstomus	378	323	1271	2088	979	336	103	14	67	-
Paralichthys dentatus	39	11	7	4	-	58	-	-	-	-
Scophthalmus aquosus	15	7	18	32	7	7	4	7	7	4
Pseudopleuronectes americanus	882	838	404	1980	506	2311	2103	1741	7654	1251
Trinectes maculatus	32	25	21	4	-	-	-	-	-	-
Sphoeroides maculatus	136	73	-	-	-	-	-	-	-	-
Total of all Vertebrate Species	50826	12055	13325	28482	8965	8381	42691	7910	23707	3353
Invertebrates										
Aequorea spp	7	-	-	4	-	-	-	-	-	-
Class Polychaeta	56	37	665	1668	424	1466	18	18	70	74
Penaeus aztecus	1337	16	4	11	-	-	-	-	-	-
Palaemonetes vulgaris	9212	13458	55724	30970	4283	13071	7446	21210	6200	6293
Crangon septemspinosa	27052	64171	402129	591617	510590	149758	438769	296652	107016	227075
Cancer irroratus	-	-	33	4	4	4	14	18	6	5
Ovalipes ocellatus	1487	655	582	99	4	-	-	-	-	-
Portunus gibbesi	133	-	-	-	-	-	-	-	-	-
Callinectes sapidus	1180	148	64	7	-	7	4	4	-	14
Callinectes similis	14	-	-	-	-	-	-	-	-	-

Table 13. (cont.)

	NOVEMBER 13-19	20-26	DECEMBER 27-3	4-10	11-17	18-24	25-31	JANUARY 1-7	8-14	15-21
Phylum Nemertea	25	44	431	96	11	28	4	7	7	-
Total of all Invertebrate Species	40545	78534	459644	624473	515324	164338	446254	317909	113298	233468
Grand Totals of all Species	91372	90589	472969	652955	524289	172719	488946	325819	137006	236821

Table 13. (cont.)

	JANUARY 22-28	FEBRUARY 29-4	5-11	12-18	19-25	MARCH 26-4	5-11	12-18	19-25	APRIL 26-1
Vertebrates										
Anguilla rostrata	-	5	4	-	7	4	7	4	4	-
Alosa aestivalis	-	-	4	4	-	11	32	135	321	85
Alosa pseudoharengus	-	-	-	-	-	-	-	28	360	173
Brevoortia tyrannus	-	-	-	-	-	-	-	24	-	-
Opsanus tau	-	4	-	-	-	4	4	-	-	4
Urophycis chuss	-	-	-	-	-	-	7	7	4	-
Cyprinodon variegatus	-	-	-	12	-	4	4	-	21	-
Fundulus heteroclitus	-	-	4	7	11	-	11	7	85	21
Menidia menidia	119	134	49	205	392	317	588	1074	440	206
Apeltes quadracus	861	435	89	179	98	7	53	137	443	276
Gasterosteus aculeatus	21	8	28	23	21	57	326	363	259	33
Syngnathus fuscus	21	9	4	21	7	11	4	14	70	284
Morone americana	-	4	-	-	4	-	7	18	4	7
Leiostomus xanthurus	-	-	-	-	-	4	-	8	7	4
Micropogon undulatus	-	-	7	-	4	4	-	17	-	-
Tautoga onitis	7	-	-	-	-	-	7	-	-	4
Mugil curema	-	-	-	-	-	-	14	17	-	-
Ammodytes sp.	7	-	-	-	4	-	4	7	-	-
Myoxocephalus aenaeus	252	69	47	63	28	-	18	7	4	-
Scophthalmus aquosus	-	-	-	-	-	-	-	-	18	4
Pseudopleuronectes americanus	462	348	315	473	182	123	151	520	114	128
Total of all Vertebrate Species	1757	1014	550	1009	760	550	1239	2393	2151	1249
Invertebrates										
Class Polychaeta	28	50	-	23	7	8	-	239	166	258
Palaemonetes vulgaris	3073	7719	5411	11886	1985	1739	3000	3103	5491	5513
Crangon septemspinosa	70175	71116	30713	37612	16751	7865	18984	37063	8827	20196
Cancer irroratus	14	-	-	15	-	-	-	-	21	7
Ovalipes ocellatus	-	-	-	-	-	-	-	-	4	7
Callinectes sapidus	-	8	-	-	-	4	7	-	42	260
Phylum Nemertea	-	-	-	-	-	-	-	-	43	49
Total of all Invertebrate Species	73290	78893	36124	49539	18746	9619	21991	40409	14605	26289
Grand Totals of all Species	75047	79907	36673	50548	19506	10169	23230	42802	16757	27539

Table 13 (cont.)

	APRIL 2-8	9-15	16-22	23-29	MAY 30-6	7-13	14-20	21-27	JUNE 28-3	4-10
Vertebrates										
Anguilla rostrata	-	7	4	31	4	4	-	-	7	4
Alosa aestivalis	46	7	7	193	156	32	-	4	-	-
Alosa pseudoharengus	35	42	39	88	39	61	11	49	11	14
Brevoortia tyrannus	-	4	7	9	52	21	25	25	11	11
Anchoa mitchilli	-	4	42	6404	29434	6581	5376	1159	977	207
Opsanus tau	-	4	-	-	15	62	21	39	35	105
Urophycis chuss	-	-	-	-	16	-	-	-	-	-
Cyprinodon variegatus	-	7	7	4	-	4	-	-	-	-
Fundulus heteroclitus	7	11	49	4	8	4	7	4	74	-
Membras martinica	-	-	-	-	-	-	-	-	4	-
Menidia menidia	105	74	298	547	81	49	32	28	35	7
Apeltes quadracus	77	35	35	28	-	4	7	4	-	-
Gasterosteus aculeatus	32	-	7	12	-	-	7	-	4	-
Syngnathus fuscus	942	872	889	374	335	230	140	81	123	119
Morone americana	4	4	11	15	11	14	39	25	35	14
Cynoscion regalis	-	-	-	-	-	-	-	4	-	-
Micropogon undulatus	-	-	-	-	-	-	-	-	4	-
Tautoga onitis	-	4	-	-	-	-	-	-	-	-
Hypsoblennius hentzi	-	-	-	-	-	-	-	-	4	4
Ammodytes sp.	18	-	32	105	237	11	-	-	-	-
Prionotus evolans	-	-	-	15	8	4	4	4	-	-
Myoxocephalus aenaeus	-	-	4	7	11	-	-	-	-	-
Etropus microstomus	-	-	4	7	14	-	-	-	-	4
Paralichthys dentatus	7	-	14	40	100	25	18	4	4	4
Scophthalmus aquosus	4	18	7	21	49	22	32	-	4	-
Pseudopleuronectes americanus	39	4	25	374	178	9	-	-	11	25
Trinectes maculatus	4	7	7	28	70	37	21	11	14	18
Sphoeroides maculatus	-	-	-	-	-	-	42	39	7	4
Total of all Vertebrate Species	1320	1103	1484	8348	30833	7186	5796	1488	1372	539
Invertebrates										
Cyanea capillata	-	-	-	-	372	77	795	333	396	-
Class Polychaeta	7	-	4	34	39	-	-	-	35	-
Limulus polyphemus	7	7	4	5	4	-	25	56	42	56
Palaemonetes vulgaris	14466	8715	5621	15191	3389	1857	1141	942	14725	13972
Crangon septemspinosa	21333	7161	8726	150440	63760	32514	5425	1915	63662	27580
Cancer irroratus	4	4	32	61	21	19	25	18	7	21
Ovalipes ocellatus	7	7	-	9	21	14	11	-	11	11
Callinectes sapidus	3220	17829	11176	5329	3705	3778	2765	1110	3535	6430
Phylum Nemertea	7	4	4	21	135	-	-	-	-	-
Total of all Invertebrate Species	39050	33730	25571	171088	71455	38263	10203	4372	82432	48094
Grand Totals of all Species	40369	34832	27055	179437	102287	45449	15999	5859	83804	48633

Table 13 (cont.)

	JUNE 11-17	18-24	JULY 25-1	2-8	9-15	16-22	23-29	AUGUST 30-5	13-19	20-26	SEPTEMBER 27-2
Vertebrates											
Anguilla rostrata	-	-	7	18	11	18	7	19	76	-	28
Alosa aestivalis	-	-	-	4	4	28	7	19	6	30	17
Alosa pseudoharengus	21	18	21	19	14	18	21	31	37	58	18
Brevoortia tyrannus	4	-	-	18	35	84	42	131	47	16	26
Anchoa mitchilli	333	98	156	620	1320	1744	1302	5604	425	468	537
Opsanus tau	91	32	9	8	63	39	56	275	318	228	236
Fundulus heteroclitus	4	11	-	-	-	-	-	-	-	-	-
Menidia menidia	-	-	4	11	4	-	-	24	-	-	4
Syngnathus fuscus	210	42	21	86	141	74	84	523	21	40	9
Morone americana	4	4	-	-	-	-	-	-	-	-	-
Pomatomus saltatrix	25	35	86	185	102	63	175	702	38	-	-
Caranx hippos	-	-	-	4	4	4	-	24	86	-	-
Selene vomer	-	-	-	-	-	4	7	35	21	5	4
Cynoscion regalis	-	-	-	-	4	25	70	80	238	149	182
Hypsoblennius hentzi	-	-	-	-	-	-	-	29	-	-	4
Prionotus evolans	-	-	-	-	-	28	7	111	94	7	40
Myoxocephalus aenaeus	4	-	-	-	-	-	-	-	-	-	-
Etropus microstomus	4	-	-	-	-	-	-	-	-	-	-
Paralichthys dentatus	-	-	-	7	7	-	-	10	9	-	-
Scophthalmus aquosus	7	-	-	20	21	-	-	29	-	-	-
Pseudopleuronectes americanus	102	-	4	36	99	11	42	360	9	-	-
Trinectes maculatus	14	4	25	55	51	35	70	97	35	-	7
Sphoeroides maculatus	4	-	-	4	28723	1193	2436	18265	203	32	131
Total of all Vertebrate Species	840	245	334	1120	30616	3386	4333	26429	1672	1033	1266
Invertebrates											
Rhopilema verilli	-	-	-	171	57	42	7	-	-	-	-
Cyanea capillata	-	-	183	7	-	-	-	-	-	-	-
Class Polychaeta	4	-	4	4	-	-	-	-	-	-	4
Limulus polyphemus	49	70	30	11	4	7	21	-	-	7	4
Penaeus aztecus	-	-	-	-	-	-	-	-	-	16	17
Palaemonetes vulgaris	6923	518	724	350	231	91	14	193	86	-	-
Crangon septemspinosa	125048	46	79	342	6725	88	14	25	50	-	7
Cancer irroratus	14	-	7	4	-	7	-	-	-	-	-
Ovalipes ocellatus	14	14	43	53	22	11	21	35	36	26	96
Callinectes sapidus	6174	3276	6920	42005	184926	55216	154175	294819	41065	11329	16145
Callinectes similis	-	-	-	-	-	-	-	-	-	-	33
Phylum Nemertea	-	-	-	-	-	4	-	-	-	-	-
Total of all Invertebrate Species	138254	3945	7998	42950	191984	55493	154259	295096	41237	11378	16308
Grand Totals of all Species	139094	4190	8332	44070	222600	58879	158592	321525	42910	12410	17574

Table 14 . Weekly estimated weight (g) of fishes and macroinvertebrates with more than 100 specimens impinged on the traveling screens at the Oyster Creek Generating Station from 4 September 1977 through 2 September 1978.

	SEPTEMBER 4-10	11-17	18-24	OCTOBER 25-1	2-8	9-15	16-22	23-29	NOVEMBER 30-5	6-12
Vertebrates										
Anguilla rostrata	1673	1379	1410	2811	-	-	-	-	-	2002
Alosa aestivalis	1988	46	49	-	-	60	959	81	973	9163
Alosa pseudoharengus	123	46	-	1008	81	308	2786	446	9856	5677
Brevoortia tyrannus	5369	2629	1495	2300	2293	41786	1822429	7941	62108	168473
Anchoa mitchilli	13020	6234	4872	3803	8347	46597	20619	656	13468	3483
Synodus foetens	-	-	972	2083	6022	4591	154	-	4788	2702
Opsanus tau	5352	2436	8222	4121	10934	2909	16664	9246	9041	4263
Urophycis chuss	-	-	-	-	-	-	-	-	91	777
Cyprinodon variegatus	-	-	-	7	-	-	53	7	-	49
Fundulus heteroclitus	-	-	-	-	-	-	95	96	-	63
Membras martinica	133	427	234	462	11	112	11	-	-	-
Menidia menidia	54	18	78	56	21	60	1575	2042	3759	7812
Apeltes quadracus	-	-	-	-	-	-	-	15	4	7
Syngnathus fuscus	102	7	7	35	200	2551	2664	1154	2867	1246
Morone americana	-	-	1061	-	242	2443	2730	1144	4704	4022
Pomatomus saltatrix	1666	2695	1299	3224	2178	51304	26289	812	2114	9041
Caranx hippos	18	11	308	165	735	4789	-	361	-	-
Selene vomer	2651	2167	3707	3846	2547	5801	536	942	767	802
Bairdiella chrysura	63	63	28	557	53	2478	9552	994	1810	2450
Cynoscion regalis	2250	2244	1123	12821	4633	76812	204169	5603	8953	10675
Leiostomus xanthurus	1298	721	2348	2298	3035	23804	513149	14638	27178	26240
Micropogon undulatus	-	-	-	-	399	-	7	-	98	378
Tautoga onitis	-	-	-	-	-	2076	9538	8034	8743	87794
Mugil curema	-	382	2959	1682	126	966	2548	-	347	63
Hypsoblennius hentzi	-	-	-	-	-	280	434	88	595	480
Prionotus evolans	501	186	81	6975	9701	15241	2380	570	7728	5128
Etropus microstomus	-	-	-	-	-	123	-	-	844	1379
Paralichthys dentatus	3132	6034	1818	17180	34007	96732	66280	1609	26866	3346
Scophthalmus aquosus	-	1082	459	-	214	987	7970	133	4529	725
Pseudopleuronectes americanus	-	-	229	-	3063	13573	28742	25437	92680	104031
Trinectes maculatus	329	448	616	1190	2860	6066	3920	2056	1873	2968
Sphoeroides maculatus	2692	88	2115	5010	15505	3419	802	-	-	536
Total of all Vertebrate Species	47730	34342	38586	82220	115975	415110	2769981	87603	304812	473830
Invertebrates										
Aequorea spp	-	312	5719	6944	333	2580	2548	63	-	-
Cyanea capillata	-	-	-	-	623	1413	7893	-	3178	991
Class Polychaeta	-	-	-	-	-	18	35	-	119	214
Penaeus aztecus	14	67	217	429	489	4331	1439	1323	4722	16947
Palaemonetes vulgaris	-	4	4	-	11	25	1089	87	3416	18515
Crangon septemspinosa	7	14	11	-	61	805	3133	151	38749	44447
Ovalipes ocellatus	331	144	556	1781	1400	1654	1281	1527	9569	7095
Portunus gibbesi	-	11	-	-	-	413	67	140	2412	819
Callinectes sapidus	235362	205051	259985	341916	216467	463514	414540	97977	285205	466750
Callinectes similis	4091	1600	3836	3726	634	1142	557	66	1463	2821
Phylum Nemertea	-	-	-	-	-	224	11	25	473	287
Total of all Invertebrate Species	241136	207200	270430	354798	220141	476228	433188	103070	350858	560630
Grand Totals of all Species	288866	241542	309016	437017	336116	891338	3203169	190673	655669	1034460

Table 14 (cont.)

	NOVEMBER 13-19	20-26	DECEMBER 27-3	4-10	11-17	18-24	25-31	JANUARY 1-7	8-14	15-21
Vertebrates										
Anguilla rostrata	1162	3133	98	788	-	1348	245	-	-	-
Alosa aestivalis	8513	1416	7066	44875	1128	5037	75235	5352	4049	105
Alosa pseudoharengus	24271	4140	731	1775	105	682	2484	1334	1596	-
Alosa sapidissima	-	-	-	-	-	137	4732	2212	1101	-
Brevoortia tyrannus	211289	77493	107959	114767	8249	10286	41433	956	6956	-
Anchoa mitchilli	1342	1245	2787	904	219	28	169	343	-	12
Synodus foetens	369	25	11	-	-	-	-	-	-	-
Opsanus tau	9531	291	46	14	7	-	4	-	-	-
Merluccius bilinearis	368	-	848	5268	482	835	517	427	84	-
Urophycis chuss	677	1017	641	5080	548	550	1306	544	1644	53
Cyprinodon variegatus	4	51	276	554	116	158	43	98	32	28
Fundulus heteroclitus	165	66	53	48	49	70	14	14	13	-
Menidia menidia	20096	15024	16279	45820	24647	15071	58910	13968	63757	2383
Apeltes quadracus	186	42	101	35	92	89	154	223	269	735
Gasterosteus aculeatus	-	27	-	60	-	39	719	219	272	128
Syngnathus fuscus	3041	1571	4971	2556	1299	279	433	387	198	81
Morone americana	6231	2858	847	2485	1256	5653	2065	9793	3107	162
Pomatomus saltatrix	13786	-	-	-	-	-	-	-	-	-
Selene vomer	-	18	-	-	-	-	-	-	-	-
Bairdiella chrysura	2726	1182	1772	1000	-	-	-	-	-	-
Cynoscion regalis	20549	161	2202	606	-	-	-	-	-	-
Leiostomus xanthurus	777854	132975	15183	31369	2290	8798	245	84	302	-
Micropogon undulatus	148	35	7	76	84	25	18	56	7	4
Tautoga onitis	23258	83246	20034	16863	19299	6540	3937	-	1089	-
Mugil curema	572	228	-	-	-	-	-	-	574	-
Hypsoblennius hentzi	1196	494	39	-	-	-	-	-	-	63
Ammodytes sp.	-	-	-	102	-	-	11	11	49	39
Prionotus evolans	2438	738	371	119	102	81	-	-	-	-
Myoxocephalus aenaeus	-	-	-	452	289	375	2116	3624	2556	2553
Etropus microstomus	917	1480	4161	4408	1585	543	141	1061	81	-
Paralichthys dentatus	3952	1012	487	147	-	69	-	-	-	-
Scophthalmus aquosus	1074	714	2664	3052	980	781	1121	98	538	8
Pseudopleuronectes americanus	203054	167737	103605	367527	59548	536940	250251	245977	1695141	166010
Trinectes maculatus	3458	2664	1505	161	-	-	-	-	-	-
Sphoeroides maculatus	593	308	-	-	-	-	-	-	-	-
Total of all Vertebrate Species	1369896	503795	299418	654132	124322	594903	447951	287098	1783469	172489
Invertebrates										
Aequorea spp	77	-	-	70	-	-	-	-	-	-
Class Polychaeta	224	170	2619	12909	1696	5805	151	110	306	192
Penaeus aztecus	7920	115	14	35	-	-	-	-	-	-
Palaemonetes vulgaris	6717	9079	45702	19629	3287	7722	4491	13701	3820	3666
Crangon septemspinosa	25556	68369	427396	603971	621672	162500	432603	337458	117470	228129
Cancer irroratus	-	-	904	67	88	102	833	763	254	517
Ovalipes ocellatus	10151	7227	4659	1577	4	-	-	-	-	-
Portunus gibbesi	375	-	-	-	-	-	-	-	-	-
Callinectes sapidus	44311	16514	1240	228	-	39	8	438	-	84
Callinectes similis	144	-	-	-	-	-	-	-	-	-

Table 14 (cont.)

	NOVEMBER 13-19	20-26	DECEMBER 27-3	4-10	11-17	18-24	25-31	JANUARY 1-7	8-14	15-21
Phylum Nemertea	203	399	3199	571	60	214	35	15	53	-
Total of all Invertebrate Species	97295	101915	485869	639056	627056	176495	438121	352485	121902	232636
Grand Totals of all Species	1467191	605710	785287	1293188	751378	771398	886071	639583	1905371	405125

Table 14 (cont.)

	JANUARY 22-28	FEBRUARY 29-4	5-11	12-18	19-25	MARCH 26-4	5-11	12-18	19-25	APRIL 26-1
Vertebrates										
Anguilla rostrata	-	5	242	-	364	253	858	595	1575	-
Alosa aestivalis	-	-	11	18	-	42	88	423	1334	440
Alosa pseudoharengus	-	-	-	-	-	-	-	4948	4457	1684
Brevoortia tyrannus	-	-	-	-	-	-	-	795	-	-
Opsanus tau	-	14	-	-	-	4	7	-	-	7
Urophycis chuss	-	-	-	-	-	-	46	42	49	-
Cyprinodon variegatus	-	-	-	55	-	4	7	-	39	-
Fundulus heteroclitus	-	-	18	21	28	-	42	21	292	144
Menidia menidia	560	453	175	959	1729	1425	2657	5427	2182	1052
Apeltes quadracus	861	406	85	197	151	7	46	171	543	311
Gasterosteus aculeatus	42	25	77	58	46	132	840	952	693	85
Syngnathus fuscus	49	17	7	31	14	14	4	22	183	698
Morone americana	-	753	-	-	196	-	77	547	46	1365
Leiostomus xanthurus	-	-	-	-	-	74	-	191	158	53
Micropogon undulatus	-	-	7	-	4	4	-	44	-	-
Tautoga onitis	763	-	-	-	-	-	823	-	-	14
Mugil curema	-	-	-	-	-	-	648	883	-	-
Ammodytes sp.	28	-	-	-	4	-	7	39	-	-
Myoxocephalus aenaeus	1442	938	154	463	95	-	67	39	31	-
Scophthalmus aquosus	-	-	-	-	-	-	-	-	2541	4
Pseudopleuronectes americanus	72086	35220	42343	69165	29208	21356	25197	124708	15763	28260
Total of all Vertebrate Species	75838	37831	43117	71223	31857	23331	31479	140479	29883	35446
Invertebrates										
Class Polychaeta	42	210	-	127	28	22	-	939	738	783
Palaemonetes vulgaris	1806	4691	3123	6982	1274	992	1617	1806	3652	3129
Crangon septemspinosa	81200	79718	35572	43241	19397	10043	19012	32699	8325	20971
Cancer irroratus	686	-	-	795	-	-	-	-	1177	473
Ovalipes ocellatus	-	-	-	-	-	-	-	-	77	28
Callinectes sapidus	-	42	-	-	-	7	4	-	123	1320
Phylum Nemertea	-	-	-	-	-	-	-	-	293	389
Total of all Invertebrate Species	83734	84661	38695	51149	20703	11069	20633	35486	14420	27092
Grand Totals of all Species	159572	122491	81813	122372	52560	34399	52112	175965	44303	62538

Table 14 (cont.)

	APRIL 2-8	9-15	16-22	23-29	MAY 30-6	7-13	14-20	21-27	JUNE 28-3	4-10
Vertebrates										
Anguilla rostrata	-	284	4	2194	130	287	-	-	1236	609
Alosa aestivalis	592	252	298	9711	6434	2435	-	14	-	-
Alosa pseudoharengus	1701	5366	3476	10796	3290	9422	1614	5992	1523	2839
Brevoortia tyrannus	-	1404	3059	3586	10741	5194	2996	2972	851	714
Anchoa mitchilli	-	18	158	26795	101693	23650	18970	3805	2930	676
Opsanus tau	-	354	-	-	2711	15779	3913	9888	2720	32603
Urophycis chuss	-	-	-	-	57	-	-	-	-	-
Cyprinodon variegatus	-	18	14	11	-	18	-	-	-	-
Fundulus heteroclitus	25	39	161	14	35	28	18	18	203	-
Membras martinica	-	-	-	-	-	-	-	-	21	-
Menidia menidia	539	445	1789	2867	448	305	189	151	224	39
Apeltes quadracus	91	63	60	33	-	4	7	7	-	-
Gasterosteus aculeatus	77	-	25	52	-	-	14	-	4	-
Syngnathus fuscus	2209	1925	2083	856	872	612	406	287	347	249
Morone americana	70	893	1831	1803	3007	3164	12355	7690	7697	3465
Cynoscion regalis	-	-	-	-	-	-	-	3182	-	-
Micropogon undulatus	-	-	-	-	-	-	-	-	11	-
Tautoga onitis	-	494	-	-	-	-	-	-	-	-
Hypsoblennius hentzi	-	-	-	-	-	-	-	-	25	98
Ammodytes sp.	56	-	287	840	1616	70	-	-	-	-
Prionotus evolans	-	-	-	7081	3654	2016	2496	1880	-	-
Myoxocephalus aenaeus	-	-	4	43	77	-	-	-	-	-
Etropus microstomus	-	-	7	7	14	-	-	-	-	11
Paralichthys dentatus	788	-	2020	7244	35058	7225	6125	2748	900	1208
Scophthalmus aquosus	571	931	28	194	2833	666	207	-	84	-
Pseudopleuronectes americanus	9779	109	4169	94941	44642	1345	-	-	11	2524
Trinectes maculatus	620	182	746	1827	7701	3139	1082	1299	676	588
Sphoeroides maculatus	-	-	-	-	-	-	8761	7767	1334	312
Total of all Vertebrate Species	17126	12782	20213	171479	225369	77314	60949	48475	21119	46076
Invertebrates										
Cyanea capillata	-	-	-	-	61994	10675	149450	80385	85838	319
Class Polychaeta	21	-	4	170	97	-	-	-	28	-
Limulus polyphemus	13125	7700	2223	5159	2853	-	24203	50243	37478	69104
Palaemonetes vulgaris	8358	5317	3609	6862	2246	1188	865	662	10763	14448
Crangon septemspinosa	24931	7543	9366	186642	71342	33052	5282	2072	44265	26324
Cancer irroratus	249	641	2597	4869	1526	1900	2587	1267	525	1624
Ovalipes ocellatus	49	182	-	47	89	84	193	-	91	252
Callinectes sapidus	9328	51622	47971	46134	28954	42604	12803	22554	19649	41906
Phylum Nemertea	63	18	21	145	899	-	-	-	-	-
Total of all Invertebrate Species	56123	73049	65891	250027	170103	135051	203763	387132	223157	161326
Grand Totals of all Species	73248	85831	86104	421506	395473	212365	264712	435607	244276	207403

Table 14 (cont.)

	JUNE 11-17	18-24	JULY 25-1	2-8	9-15	16-22	23-29	AUGUST 30-5	13-19	20-26	SEPTEMBER 27-2
Vertebrates											
Anguilla rostrata	-	-	186	635	3262	3455	378	1790	5464	-	3789
Alosa aestivalis	-	-	-	18	605	2507	952	2066	179	2914	2019
Alosa pseudoharengus	2027	2492	2575	2109	1376	1932	2212	1585	1440	5361	1244
Brevoortia tyrannus	319	-	-	28	2046	368	42	213	3045	1716	4848
Anchoa mitchilli	847	186	411	1622	3789	4396	3332	13940	1328	1467	1425
Opsanus tau	8176	6741	70	1089	8452	1860	5376	4503	3016	2531	799
Fundulus heteroclitus	11	28	-	-	-	-	-	-	-	-	-
Menidia menidia	-	-	35	24	4	-	-	24	-	-	11
Syngnathus fuscus	658	165	81	393	576	259	322	1301	147	68	9
Morone americana	497	763	-	-	-	-	-	-	-	-	-
Pomatomus saltatrix	28	49	122	531	546	214	1687	4800	307	-	-
Caranx hippos	-	-	-	4	4	4	-	24	107	-	-
Selene vomer	-	-	-	-	-	7	14	123	126	42	11
Cynoscion regalis	-	-	-	-	7	88	322	681	445	282	454
Hypsoblennius hentzi	-	-	-	-	-	-	-	114	-	-	32
Prionotus evolans	-	-	-	-	-	49	21	705	1083	7	144
Myoxocephalus aenaeus	32	-	-	-	-	-	-	-	-	-	-
Etropus microstomus	28	-	-	-	-	-	-	-	-	-	-
Paralichthys dentatus	-	-	-	5835	2461	-	-	8568	5956	-	-
Scophthalmus aquosus	224	-	-	1137	2937	-	-	1761	-	-	-
Pseudopleuronectes americanus	12460	-	18	114	1150	39	1197	2138	713	-	-
Trinectes maculatus	193	112	931	609	597	1266	1267	4806	1502	-	249
Sphoeroides maculatus	819	-	-	4	87133	2738	9842	77810	1427	410	1909
Total of all Vertebrate Species	28109	10189	4435	14851	114975	19282	26985	127274	26661	15135	17770
Invertebrates											
Rhopilema verilli	-	-	-	46307	17732	16454	1806	-	-	-	-
Cyanea capillata	-	-	17973	252	-	-	-	-	-	-	-
Class Polychaeta	4	-	4	4	-	-	-	-	-	-	4
Limulus polyphemus	36722	47891	24893	12250	3196	4935	22260	-	-	6293	3570
Penaeus aztecus	-	-	-	-	-	-	-	-	-	26	128
Palaemonetes vulgaris	5198	420	465	269	179	84	14	135	48	-	-
Crangon septemspinosa	77711	42	65	275	5401	77	14	25	50	-	7
Cancer irroratus	1169	-	294	42	-	599	-	-	-	-	-
Ovalipes ocellatus	81	140	655	471	330	119	210	837	43	26	95
Callinectes sapidus	45028	30772	46404	294071	1379333	895612	3230129	9258190	1894240	645890	958724
Callinectes similis	-	-	-	-	-	-	-	-	-	-	82
Phylum Nemertea	-	-	-	-	-	14	-	-	-	-	-
Total of all Invertebrate Species	168319	80717	91309	366074	1407800	921804	3255756	9261664	1894380	652236	962616
Grand Totals of all Species	196427	90906	95744	380925	1522775	941085	3282741	9388938	1921041	667371	980385

Table 15. Actual and estimated number and weight (g) of fishes and macroinvertebrates impinged at night on the traveling screens at the Oyster Creek Generating Station from 4 September 1977 through 2 September 1978.

Species	Actual		Estimated	
	Number	Weight	Number	Weight
Vertebrates				
Mustelus canis	1	408	4	1428
Dasyatis sayi	2	935	7	3273
Anguilla rostrata	110	12158	400	43638
Conger oceanicus	4	377	15	1320
Alosa aestivalis	12293	56552	43037	199441
Alosa mediocris	1	25	4	88
Alosa pseudoharengus	1182	39144	4163	138904
Alosa sapidissima	294	2337	1030	8181
Brevoortia tyrannus	11874	783147	41645	2741142
Clupea harengus	23	1189	81	4162
Dorosoma cepedianum	14	796	49	2786
Anchoa hepsetus	1	15	10	105
Anchoa mitchilli	29845	94555	107911	339579
Esox niger	4	79	14	277
Synodus foetens	135	6204	473	21716
Notemigonus crysoleucas	1	2	4	7
Ictalurus sp	1	12	4	42
Ictalurus natalis	1	4	4	12
Aphredoderus sayanus	1	3	4	11
Opsanus tau	583	53928	2205	193687
Merluccius bilinearis	161	2522	565	8828
Pollachius virens	2	9	8	30
Urophycis chuss	466	3749	1630	13122
Urophycis regius	27	177	95	621
Rissola marginata	15	1151	53	4028
Hyporhamphus unifasciatus	5	25	19	86
Strongylura marina	64	1217	255	4377
Cyprinodon variegatus	223	468	781	1638
Fundulus heteroclitus	145	539	507	1886
Fundulus majalis	3	37	11	130
Membras martinica	104	403	364	1409
Menidia beryllina	8	14	27	48
Menidia menidia	19897	89956	69710	315138
Apeltes quadracus	1125	1303	4368	4992
Gasterosteus aculeatus	537	1304	1890	4584
Fistularia tabacaria	19	509	68	1781
Hippocampus erectus	75	258	263	903
Syngnathus fuscus	5112	11335	18208	40507
Syngnathus louisianae	5	60	18	210
Morone americana	235	27719	821	97017
Morone saxatilis	1	214	4	749
Centropristis striata	30	1224	105	4283
Lepomis gibbosus	9	27	32	95
Pomatomus saltatrix	673	34128	2793	122691
Alectis crinitus	1	25	4	88
Caranx crysos	22	921	77	3224
Caranx hippos	104	1862	378	6529
Selar crumenophthalmus	1	52	4	182
Selene vomer	444	6868	1575	24105
Trachinotus falcatus	4	123	14	431

Table 15 (cont.)

Species	Actual		Estimated	
	Number	Weight	Number	Weight
Vomer setapinnis	13	58	46	203
Lutjanus griseus	7	19	25	67
Stenotomus chrysops	16	2886	57	10102
Bairdiella chrysura	973	7065	3406	24727
Cynoscion regalis	4258	102217	14976	358260
Leiostomus xanthurus	15704	452652	54963	1584282
Menticirrhus saxatilis	6	157	22	549
Micropogon undulatus	137	403	478	1409
Mullus auratus	1	35	4	123
Chaetodipterus faber	48	838	169	2932
Chaetodon ocellatus	34	228	119	800
Tautoga onitis	337	83474	1182	292541
Tautogolabrus adspersus	20	3780	70	13229
Mugil cephalus	4	389	14	1362
Mugil curema	111	3422	387	11975
Sphyraena borealis	1	66	4	231
Astroscopus guttatus	40	1644	139	5755
Chasmodes bosquianus	23	144	82	503
Hypsoblennius hentzi	126	1108	457	3935
Ammodytes sp.	131	898	461	3156
Gobiosoma bosci	41	64	148	228
Peprilus triacanthus	41	2681	145	9383
Scorpaena plumieri	1	7	4	25
Prionotus carolinus	76	10642	266	37246
Prionotus evolans	2969	20317	10449	71474
Myoxocephalus aenaeus	578	4179	2148	15348
Myoxocephalus octodecemspinosus	1	357	4	1250
Etropus microstomus	1836	4797	6427	16788
Paralichthys dentatus	405	98434	1422	348802
Scophthalmus aquosus	152	11532	545	41242
Pseudopleuronectes americanus	7027	1332709	25026	4702193
Trinectes maculatus	287	16133	1089	59503
Aluterus schoepfi	25	2230	88	7806
Monacanthus hispidus	15	375	53	1313
Lactophrys triqueter	1	5	4	18
Sphoeroides maculatus	11804	53573	51665	231331
Chilomycterus schoepfi	4	505	15	1767
Fish fragments	-	1660	-	5810
Bufo fowleri	8	141	26	492
Chelydra serpentina	1	-	4	-
Malaclemys terrapin	3	970	11	3395
Total Vertebrates	133155	3462761	482303	12234711
Invertebrates				
Phylum Porifera	3	168	12	589
Aequorea spp	145	5327	508	18646
Class Scyphozoa	2	566	7	1981

Table 15 (cont.)

Species	Actual		Estimated	
	Number	Weight	Number	Weight
Rhopilema verilli	78	23256	277	82298
Cyanea capillata	642	120280	2246	420981
Polinices duplicata	4	193	14	676
Mytilus edulis	1	1	4	4
Ensis directus	1	4	4	14
Lolliguncula brevis	1	21	4	74
Class Polychaeta	1582	7934	5549	27790
Limulus polyphemus	113	103704	406	374095
Squilla empusa	49	1044	172	3654
Penaeus setiferus	7	30	25	106
Penaeus aztecus	1548	10918	5416	38214
Palaemonetes vulgaris	95643	65767	336391	231162
Palaemonetes pugio	6	4	22	15
Crangon septemspinosa	1055928	1119012	3730856	3957160
Pagurus longicarpus	4	8	14	28
Libinia dubia	45	4414	172	17056
Cancer irroratus	108	7486	384	26543
Carcinus maenas	1	33	4	116
Ovalipes ocellatus	2027	15008	7122	53052
Portunus gibbesi	289	1210	1012	4235
Portunus spinimanus	6	26	21	91
Callinectes sapidus	241552	4516822	1069929	22053036
Callinectes similis	432	5760	1514	20161
Panopeus herbstii	4	98	15	341
Neopanope sayi	16	160	57	561
Phylum Echinodermata	3	6	11	23
Invertebrate fragments	-	93085	-	326092
Phylum Nemertea	310	2173	1085	7607
Procambarus acutus	4	11	14	39
Olencira praegustator	1	1	4	4
Total Invertebrates	1400555	6104533	5163267	27666442
Grand Totals	1533711	9567294	5645569	39901153

Table 16. Weekly night impingement estimate with number of specimens impinged per hour, total intake circulating water flow, and total number impinged per 10 million liters of circulating water flow at the Oyster Creek Generating Station from 4 September 1977 through 2 September 1978.

Date		Estimated Number	Hours of Darkness	Number/Hour	% of Darkness	Liters x 10^7 (24 hours)	Liters x 10^7 (night)	Number/Liter x 10^7
September	4-10	11,327	78.2	145	47	1,753.9	824	14
	11-17	15,064	80.4	187	48	1,753.9	842	18
	18-24	16,957	82.5	206	49	1,753.9	859	20
	25-Oct. 1	38,633	84.6	457	50	1,753.9	877	44
October	2-8	13,690	86.8	158	52	1,753.9	912	15
	9-15	34,649	88.9	390	53	1,753.9	930	17
	16-22	61,898	90.9	681	54	1,571.2	848	73
	23-29	6,306	93.0	68	55	1,655.8	911	7
	30-Nov. 5	80,647	95.0	849	57	1,753.9	1,000	81
November	6-12	176,841	96.7	1,829	58	1,753.9	1,017	174
	13-19	91,372	97.4	938	58	1,678.8	974	94
	20-26	90,589	99.8	908	59	1,753.9	1,035	88
	27-Dec. 3	472,969	101.1	4,678	60	1,735.4	1,041	454
December	4-10	652,955	101.9	6,408	61	1,708.6	1,042	627
	11-17	524,289	102.5	5,115	61	1,753.9	1,070	490
	18-24	172,719	102.7	1,682	61	1,753.9	1,070	161
	25-31	488,946	102.5	4,770	61	1,753.9	1,070	457
January	1-7	325,819	102.1	3,191	61	1,669.6	1,018	320
	8-14	137,006	101.3	1,352	60	1,556.6	934	147
	15-21	236,821	100.1	2,366	60	1,753.9	1,052	225
	22-28	75,047	98.7	760	59	1,753.9	1,035	73
	29-Feb. 4	79,907	96.9	825	58	1,753.9	1,017	79
February	5-11	36,673	95.2	385	57	1,753.9	1,000	37
	12-18	50,548	93.2	542	55	1,753.9	965	52
	19-25	19,506	91.3	214	54	1,753.9	947	21
	26-Mar. 4	10,169	89.0	114	53	1,753.9	930	11

Table 16. (cont.)

Date		Estimated Number	Hours of Darkness	Number/Hour	% of Darkness	Liters x 10^7 (24 hours)	Liters x 10^7 (night)	Number/Liter x 10^7
March	5-11	23,230	86.7	268	52	1,753.9	912	25
	12-18	42,802	84.6	506	50	1,753.9	877	49
	19-25	16,757	82.2	204	49	1,753.9	859	20
	26-Apr. 1	27,539	79.8	345	48	1,753.9	842	33
April	2-8	40,369	77.5	521	46	1,753.9	807	50
	9-15	34,832	76.1	458	45	1,753.9	789	44
	16-22	27,055	74.2	365	44	1,753.9	772	35
	23-29	179,437	72.1	2,489	43	1,753.9	754	238
	30-May 6	102,287	70.3	1,455	42	1,753.9	737	139
May	7-13	45,449	68.6	663	41	1,753.9	719	63
	14-20	15,999	67.0	239	40	1,753.9	702	23
	21-27	5,859	65.6	89	39	1,753.9	684	9
	28-Jun. 3	83,804	64.4	1,301	38	1,753.9	666	126
June	4-10	48,633	63.6	765	38	1,753.9	666	73
	11-17	139,094	63.1	2,204	38	1,654.6	629	221
	18-24	4,190	62.9	67	37	1,753.9	649	6
	25-Jul. 1	8,332	63.0	132	38	1,753.9	666	13
July	2-8	44,070	63.6	693	38	1,743.6	663	66
	9-15	222,600	64.4	3,457	38	1,753.9	666	334
	16-22	58,879	65.4	900	39	1,753.9	684	86
	23-29	158,592	66.7	2,378	40	1,753.9	702	226
	30-Aug. 5	321,525	68.3	4,708	41	1,753.9	719	447
August	6-12	321,525[a]	70.0	4,593	42	1,753.9	737	436
	13-19	42,910	71.8	598	43	1,753.9	754	57
	20-26	12,410	73.7	168	44	1,753.9	772	16
	27-Sep. 2	17,574	75.9	232	45	1,753.9	789	22
Totals		5,967,100	4,294.2			90,391.2		
Average		114,752	82.6	1,390	49	1,738.3	852	66

[a]Estimate taken from previous week.

Table 17. Total number of live, dead, and damaged fishes and macroinvertebrates impinged by month on the traveling screens at the Oyster Creek Generating Station from 4 September 1977 through 2 September 1978.

	6-30 SEPTEMBER				
Species	Number	Live	Dead	Damaged	% Dead
Anguilla rostrata	3	2	-	1	0.0
Alosa aestivalis	2	-	1	1	50.0
Alosa pseudoharengus	8	-	1	7	12.5
Brevoortia tyrannus	4	-	1	3	25.0
Anchoa mitchilli	251	10	185	56	73.7
Synodus foetens	1	-	-	1	0.0
Opsanus tau	3	1	-	2	0.0
Membras martinica	2	-	1	1	50.0
Menidia menidia	1	-	1	-	100.0
Syngnathus fuscus	1	-	-	1	0.0
Pomatomus saltatrix	5	1	2	2	40.0
Caranx hippos	2	1	-	1	0.0
Selene vomer	25	12	5	8	20.0
Bairdiella chrysura	1	-	1	-	100.0
Cynoscion regalis	29	5	8	16	27.6
Leiostomus xanthurus	7	-	3	4	42.9
Mugil curema	5	-	2	3	40.0
Prionotus carolinus	2	1	-	1	0.0
Prionotus evolans	5	-	2	3	40.0
Paralichthys dentatus	2	1	-	1	0.0
Trinectes maculatus	3	3	-	-	0.0
Chilomycterus schoepfi	1	-	-	1	0.0
Total Vertebrates	363	37	213	113	58.7
Aequorea spp	7	-	-	7	0.0
Penaeus aztecus	1	1	-	-	0.0
Crangon septemspinosa	2	2	-	-	0.0
Ovalipes ocellatus	7	6	-	1	0.0
Portunus gibbesi	2	1	-	1	0.0
Portunus spinimanus	2	1	-	1	0.0
Callinectes sapidus	820	625	35	160	4.3
Callinectes similis	50	35	-	15	0.0
Total Invertebrates	891	671	35	185	3.9
Grand Totals	1254	708	248	298	19.8