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Brunswick Steam Electric Plant

CP&L

1997 Environmental Monitoring Report

Environmental Services Section

BRUNSWICK STEAM ELECTRIC PLANT
1997 BIOLOGICAL MONITORING REPORT

Prepared by:

Environmental Services Section

CAROLINA POWER & LIGHT COMPANY
New Hill, North Carolina
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Preface

This copy of the report is not a controlled document as detailed in the *Environmental Services Section Biology Program Procedures Manual and Quality Assurance Manual.* Any changes made to the original of this report subsequent to the date of issuance can be obtained from:

Manager
Environmental Services Section
Carolina Power & Light Company
Harris Energy and Environmental Center
3932 New Hill-Holleman Road
Box 327
New Hill, North Carolina 27562-0327

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Metric-English Conversion and Units of Measure

Length

1 micron (μm) = 4.0×10^{-5} inch
1 millimeter (mm) = 1000 m = 0.04 inch
1 centimeter (cm) = 10 mm = 0.4 inch
1 meter (m) = 100 cm = 3.28 feet
1 kilometer (km) = 1000 m = 0.62 mile

Area

1 square meter (m^2) = 10.76 square feet
1 hectare (ha) = 10,000 m^2 = 2.47 acres

Temperature

Degrees Celsius (°C) = 5/9 (°F-32)

Volume

1 milliliter (ml) – 0.034 fluid ounce
1 liter = 1000 ml = 0.26 gallon
1 cubic meter = 35.3 cubic feet

Weight

1 microgram (μg) = 10^{-3} mg or
10^{-6} g = 3.5×10^{-8} ounce
1 milligram (mg) = 3.5×10^{-5} ounce
1 gram (g) = 1000 mg = 0.035 ounce
1 kilogram (kg) = 1000 g = 2.2 pounds
1 metric ton = 1000 kg = 1.1 tons
1 kg/hectare = 0.89 pound/acre

Common and Scientific Names of Species Used in This Report

Atlantic stingray	*Dasyatis sabina*
Shrimp eel	*Ophichthus gomesi*
Atlantic menhaden	*Brevoortia tyrannus*
Anchovies	*Anchoa* spp.
Bay anchovy	*A. mitchilli*
Silvbersudes	*Atherinidae*
Atlantic silversides	*Menidia menidia*
Spotted Hake	*Urophysis regius*
Pinfish	*Lagodon rhomboides*
Silver perch	*Bairdiella chrysura*
Weakfish	*Cynoscion regalis*
Spot	*Leiostomus xanthurus*
Star drum	*Stellifer lanceolatus*
Croaker	*Micropogonias undulatus*
Croaker	*Micropogonias undulatus*
Gobies	*Gobionellus spp.*
Gobies	*Gobiosoma spp..*
Atlantic cutlassfish	*Trichiurus lepturus*
Southern flounder	*Paralichthys lethostigma*
Tonguefish	*Symphurus spp.*
Blackcheek tonguefish	*S. Plagiusa*
Shrimp	*Penaeus* spp.
Brown shrimp	*P. aztecus*
Pink shrimp	*P. duorarum*
White shrimp	*P. Setiferus*
Hardback shrimp	Trachypenaeus spp.
Swimming crab larvae	Portunid megalops
Swimming crabs	Portunidae ($\leq$ 10 m)
Blue crabs	*Callinectes* spp.
Blue crabs	*Callinectes* spp.
Blue crab	*C. sapidus*
Lesser blue crab	*C. similis*

Executive Summary

Biological monitoring of the Cape Fear Estuary at Carolina Power & Light Company's Brunswick Steam Electric Plant (BSEP) was conducted in 1997 as part of the National Pollutant Discharge Elimination System permit requirements. Monitoring results from 1997 were compared to those of previous years. Entrainment and impingement studies monitored the effectiveness of the intake modifications in reducing entrainment and impingement of fish and shellfish.

Entrainment and larval impingement comparisons indicated that utilization of fine-mesh screens reduced entrainment of larvae by approximately 4% to 80% depending upon the species present and the season. Entrainment of commercial species was reduced 18% to 80 %. In addition to reducing the total number of organisms entrained, use of fine-mesh screens also reduced the number of taxa entrained. Out of 59 larval taxa impinged, only 33 taxa were entrained. Without the use of fine-mesh screens, all 59 taxa would have been entrained. *Gobiosoma spp.* was the dominant larval organism entrained whereas the dominant larva impinged was portunid megalops.

The dominant juvenile and adult organism impinged was bay anchovy. Prior to the completion of the fish diversion structure, the dominant juvenile and adult impinged was Atlantic menhaden. Impingement data showed that nine out of eleven taxa (including total organisms) of juvenile and adult fish and shellfish exhibited significant decreases in impingement densities and a shift toward impingement of smaller individuals as a result of the installation of the fish diversion structure.

With the intake screens on slow rotation, the overall survival estimate for selected larvae returned to the estuary was 61 % during 1997 (excluding Anchoa spp. $\geq$ 13 mm). This value increased from 1996 due to an increase in the number of larval shrimp and crabs impinged. Survival estimates for the larvae of the most valuable commercial species, shrimp and blue crabs, were 80% and 86% respectively. The survival estimate for all juvenile and adult species combined was 34% (excluding bay anchovy). This was a decrease from 1996 and resulted from a substantial decrease in the number of impinged juvenile and adult shrimp. As with larvae, shrimp and crabs exhibited the highest survival rates.

Biological monitoring during 1997 continued to show that the combination of flow minimization, fine-mesh screens, and diversion structure effectively reduced the number of entrained and impinged fish and shellfish. These modifications also continued to ensure that the most valuable commercial species are returned alive to the estuary in large numbers.

1.0 INTRODUCTION

Carolina Power & Light Company (CP&L) was issued a permit in December 1974 to discharge cooling water from the Brunswick Steam Electric Plant (BSEP) into the Atlantic Ocean under a National Pollutant Discharge Elimination System (NPDES) permit. Cooling water is withdrawn from the Cape Fear River (CFR). As a stipulation of the NPDES permit, biological monitoring is required to provide sufficient information for a continuing assessment of power plant impacts on the marine and estuarine fisheries of the Cape Fear Estuary (CFE). Data are reported annually and will provide an assessment of the effectiveness of the fish diversion structure and fine-mesh screens in minimizing the entrainment and impingement of organisms.

A stipulation of the renewed 1981 NPDES permit and subsequent permits was the implementation of power plant modifications to reduce entrainment and impingement of estuarine organisms resulting from the intake of cooling water. A permanent diversion structure was constructed across the mouth of the intake canal in November 1982 to reduce impingement by preventing large fish and shellfish from entering the intake canal (Figure 1.1). To reduce entrainment, two fine-mesh (1-mm) screens were installed on each unit in July 1983 and a third was installed on each unit in April 1987. Presently three of the four intake traveling-screen assemblies on each unit are covered with fine mesh screens.

Under the current permit, a maximum intake flow of 26.1 cubic meters per second (cms) per unit is allowed from December through March, and 31.1 cms per unit is allowed from April through November. Normally only fine-mesh screens are used during these periods of maximum intake flow. The flow of one unit may be increased to 34.8 cms during July, August, and September by using a fourth intake pump operating with coarse-mesh (9.4-mm) screens.

Beginning in 1994, Carolina Power & Light Company reduced the biological monitoring program with the concurrence of the North Carolina Department of Environment, Health & Natural Resources. Because of almost two decades of operation with no adverse impact on fish and shellfish populations in the Cape Fear Estuary, the monitoring program was modified to concentrate on the impingement and entrainment of organisms (Figure 1.2). This report presents data on impingement and entrainment rates of larval, juvenile, and adult fish and shellfish and evaluates the effectiveness of the NPDES-required plant intake modifications during 1997.

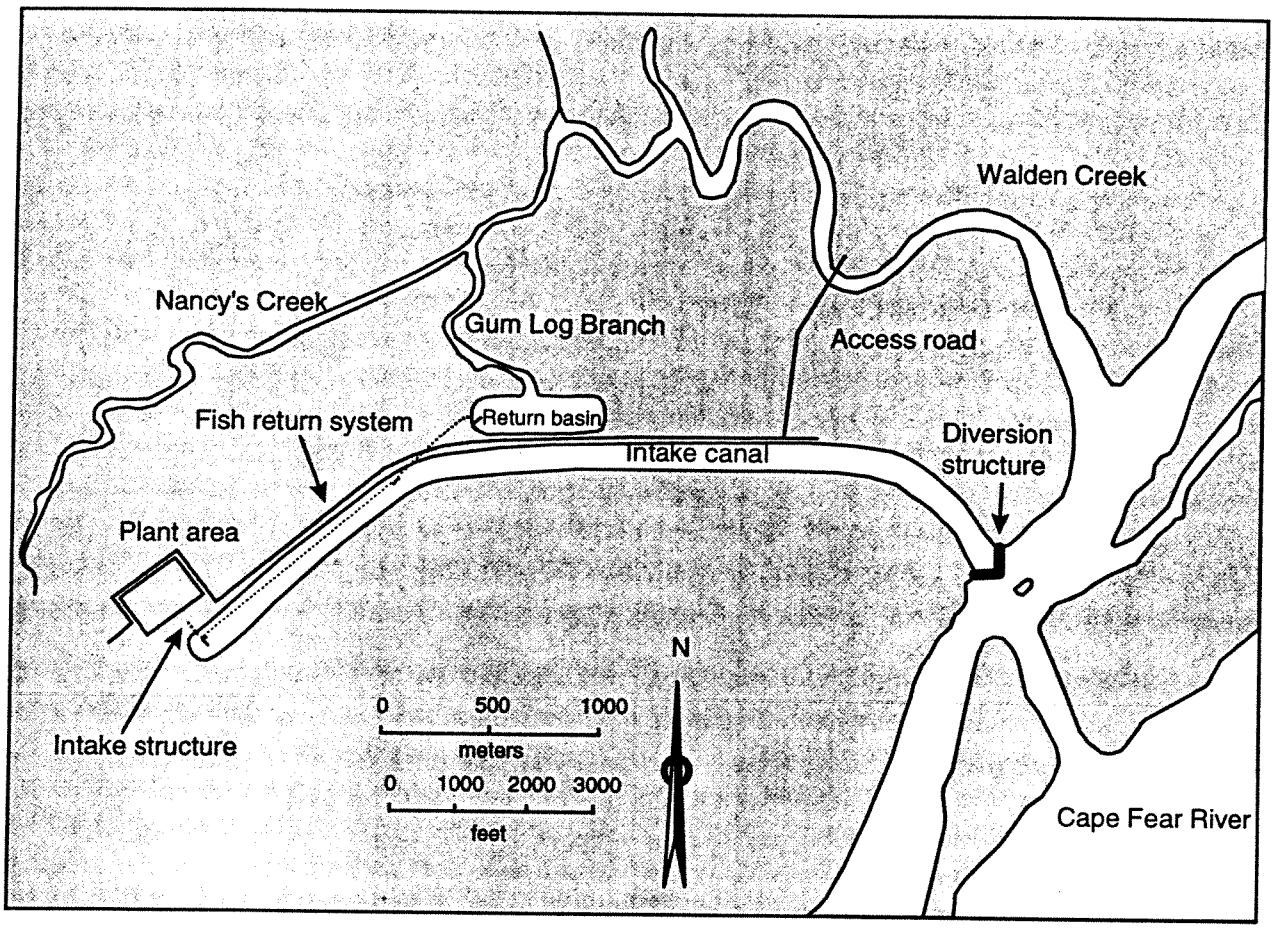


Figure 1.1 Location of fish diversion structure, fish return system, and return basin at the Brunswick Steam Electric Plant.

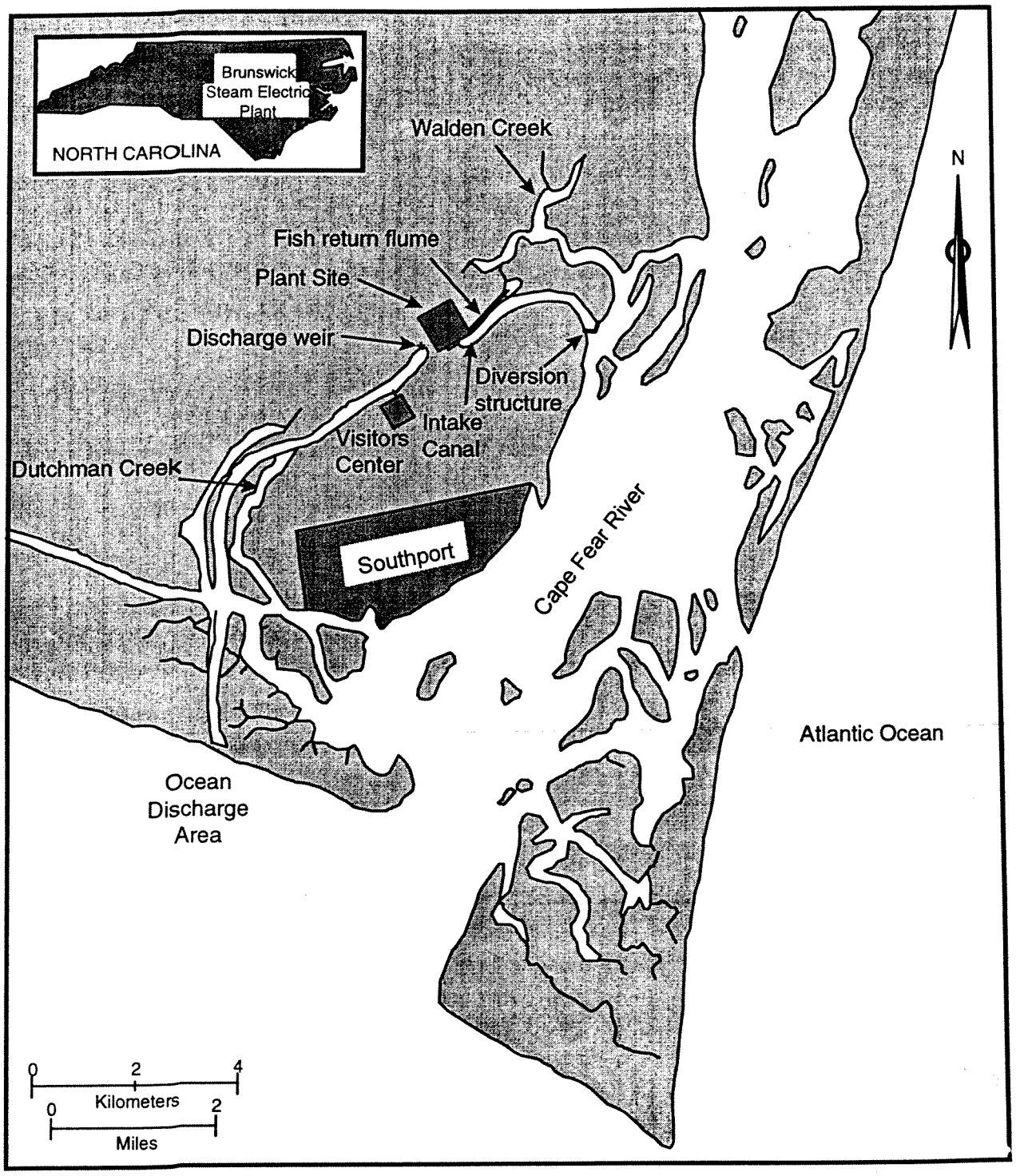


Figure 1.2 **Brunswick Steam Electric Plant biological monitoring program sampling stations for 1997.**

2.0 MONITORING PROGRAM RESULTS

2.1 Introduction

Past data indicated that the impingement of large fish and shellfish of the Cape Fear Estuary (CFE) has been reduced as a result of the 9.4-mm mesh screening on the diversion structure (CP&L 1984, 1985a, 1985b). Organisms small enough to enter the intake canal through the diversion structure may be impinged on the plant intake screens and returned to the CFE via a fish-return flume or they may be entrained through the plant. Previous studies by CP&L have documented a reduction in the entrainment of small organisms due to installation of fine-mesh screens at the intake structure and the subsequent survival of a percentage of impinged larvae returned to the CFE via the fish-return flume (Hogarth and Nichols 1981; CP&L 1989).

Entrainment sampling during 1997 documented the species composition, seasonality, and abundances of larval and postlarval organisms passing through the cooling system. Larval impingement sampling evaluated the success of the fine-mesh screens in reducing entrainment of these organisms. Juvenile and adult (J/A) impingement sampling documented species composition, densities, weights, and sizes of juvenile and adult organisms impinged during 1997 and provided evidence of the continued effectiveness of the diversion structure. Survival study results from previous years were used to determine the effectiveness of the return system at returning impinged organisms alive to the CFE (CP&L 1988).

2.2 Methods

The collection gear for entrainment and impingement has remained unchanged since 1984 (CP&L 1985a). Because sampling was conducted only once per month since 1990, results were not expanded to obtain annual estimates of organisms entrained or impinged; rather, entrainment and impingement rates, densities, and total number of organisms collected were expanded to give an estimate for 24 hours. The juvenile and adult impingement program included fish and shrimp $\geq$ 41 mm, portunid crabs $\geq$ 25 mm, and eels and pipefish $\geq$ 101 mm. Individuals smaller than these limits were included in the larval impingement program.

The densities calculated for all larval organisms from samples collected per sampling date were averaged to obtain a mean number per 1000 m^3 of water entrained through the plant. Densities for juvenile and adult organisms impinged on each sampling date were calculated by dividing the total number of organisms collected by the volume of water pumped through the plant. Densities were expressed as the number per million cubic meters of water pumped through the plant during each 24-hour sampling period.

Time-series analysis (ln [density + 1]) (CP&L 1985a) was performed on juvenile and adult impingement data from January 1977 through December 1997. Selected species included bay anchovy, Atlantic menhaden, croaker, spot, weakfish, southern flounder, brown shrimp, pink shrimp, white shrimp, and blue crabs (*Callinectes* spp.). Data from 1983 were excluded from the analysis because impingement samples were not collected during July through December of that year. One sampling trip per month was used for all years for comparable sampling effort.

2.3 Results and Discussion

2.3.1 Dominant Species

Gobiosoma spp. was the most abundant taxa collected in entrainment samples during 1997 and comprised 18.5% of the cumulative density of all organisms collected (Table 2.1). Portunid megalops (13.9%) was the second most abundant followed by *Anchoa* spp. (≥13 mm) and *Penaeus spp.* (12.1% and 11.0%, respectively). Other taxa entrained (in decreasing order of abundance) were spot, croaker, silversides, *Anchoa spp.* (< 13 mm), hardback shrimp, and weakfish. Minor taxa comprised an additional 10.5% of the total number of organisms collected. Most noticeable was the decrease in the cumulative densities of spot and croaker collected with entrainment sampling during 1997 compared to 1996. Further, the cumulative density of total organisms collected in entrainment samples was approximately 66% less than that collected during 1996.

Ten taxa accounted for 96.4% of the total larval organisms collected in impingement samples during 1997 (Table 2.2). Portunid megalops (45.8%) and Penaeus spp. (18.0%) were the most dominant taxa collected. Although the relative ranking has varied, the ten most abundant species have generally dominated larval impingement samples each year since 1984. The total number of organisms collected in larval impingement samples increased approximately 45% from the 6.9 million collected in 1996 (Table 2.2; CP&L 1997). The number of larval taxa collected in entrainment samples was consistently less than the number collected in impingement samples (Figure 2.1). Thus, use of fine-mesh screens reduced the number of taxa entrained by the plant's main cooling-water system.

Ten taxa accounted for 97.6% of the total number of organisms collected in J/A impingement samples during 1997 (Table 2.3). Bay anchovy was the most numerous species impinged accounting for 83.4% of the total number impinged during 1997. Prior to intake modifications in 1983, Atlantic menhaden had numerically dominated J/A impingement (CP&L 1980a, 1980b, 1982, 1983). Atlantic menhaden, white shrimp, star drum, spot, lesser blue crab, Atlantic silversides, blue crab, brown shrimp, and croaker combined accounted for an additional 14.2% of the total number collected. These ten most abundant taxa comprised 92.4% of the total weight collected during impingement sampling. Other taxa that contributed significantly to the biomass collected during J/A impingement sampling were Atlantic cutlassfish (4.8 kg), Atlantic stingray (1.8 kg), pinfish (1.2 kg), pink shrimp (1.2 kg), and blackcheek tonguefish (1.2 kg). The total number of organisms collected in J/A impingement samples decreased in 1997 compared to 1996 (Table 2.3; CP&L 1997).

2.3.2 Seasonality and Abundance

The seasonality for the larvae of selected species entrained in 1997 was similar to those observed in previous years and corresponded to the seasonalities of larval fish in the estuary (Tables 2.4 and 2.5; CP&L 1994). Peaks of abundance in entrainment and impingement of organisms can be influenced by operating screens without fine mesh, increasing or decreasing the flow of cooling water as determined by plant operational needs, and/or sampling period.

The typical winter and summer periods of abundance observed during 1997 in the entrainment program were also observed in the larval impingement program (Table 2.6). Atlantic menhaden, spot, croaker, and pinfish--all ocean-spawned species--were abundant during the winter and spring months. Brown shrimp was most abundant during the spring. During the late spring and summer, ocean-spawned species (such as pink and white shrimp, weakfish and hardback shrimp) and estuarine-spawned species (such as anchovy, *Gobiosoma* spp., and silversides) were abundant. The large number of anchovies collected in larval impingement samples during December represented older individuals 24 mm to 40 mm that were too small to be included with the J/A impingement samples. The periods of maximum abundance for portunid megalops and swimming crabs (portunid crabs $\leq$ 10 mm carapace width), occurred during the summer and fall. *Gobionellus spp.* was abundant during the summer, fall, and winter.

Peak densities of most of the selected species collected during J/A impingement sampling were associated with the recruitment of individuals too small to be excluded by the diversion structure. Bay anchovy was most abundant during January (Table 2.7). The peak density of croaker occurred in May. Although a relatively large number of damaged diversion screens occurred in May, the relatively small modal length of croaker collected during this month indicates that the majority of these individuals were young-of-the-year recruits rather than older fish (Table 2.8). Thus, timely repair by plant personnel minimized entry of larger fish into the canal. The peak densities of white, brown, and pink shrimp occurred during the summer and fall. Blue crab was abundant during the spring and summer.

Atlantic menhaden and spot that were abundant during the winter and spring were yearlings from 70mm to 80 mm long that may have overwintered in the intake canal since there were relatively few damaged diversion screens (Tables 2.7 and 2.8). Previous studies have indicated that the intake canal is used as nursery habitat by many species (Copeland et al. 1974, 1979; Birkhead et al. 1979).

Installation of the diversion structure has resulted in a decline in the impingement densities of most J/A organisms. Results of time-series analysis indicated that total organisms and eight of the ten selected taxa exhibited significant decreases in impingement density over the past 21 years (Table 2.9). Atlantic menhaden exhibited the greatest decline in impingement density (Figure 2.2). The density of bay anchovy impinged has also declined over the study period. Prior to the addition of 1997 data, a nonsignificant or increasing trend occurred for the density of bay anchovy (CP&L 1997). Time-series analysis of brown shrimp data indicated a nonsignificant trend in density impinged over the study period. White shrimp was the only species which exhibited a significant increase in density over the study period (Table 2.9 and Figure 2.4). The trend was most likely a result of a natural increase in white shrimp populations in the Cape Fear Estuary. Previous studies have shown that significant increases in the white shrimp population in Walden Creek coincide with increases in impingement of this species (CP&L 1994). Postlarval shrimp too small to be excluded by the diversion structure successfully recruit to the intake canal and used it as nursery habitat and were subsequently impinged (Birkhead et al. 1979; Copeland et al. 1979; CP&L 1991).

2.3.3 Flow Rates

The amount of water pumped through the plant can affect the number and weight of organisms impinged and entrained. Monthly intake flow volumes during 1997 ranged from 113.7 million m^3 in February to 178.0 million m^3 in July (Figure 2.5). The mean monthly flow volume during 1997 was higher than the mean flows of previous years including the period 1977-1982 when there were less stringent flow-minimization requirements. The greater monthly volumes during 1997 were a result of the significantly reduced time required for outages resulting in more continuous plant operation. Low monthly volumes during September through November were a result of the Unit 2 refueling and Unit 1 maintenance outages.

2.3.4 Fine-Mesh Screens

In 1997, entrainment and larval impingement rates were summed to find the total number of larvae affected. The percent effectiveness (how successfully the organisms were kept from being entrained) of fine-mesh screens was calculated as the ratio between the larval impingement rate and the total number (entrainment plus larval impingement) affected for each sampling trip. The overall effectiveness for total organisms ranged from 4% to 80% when data from all sampling trips were analyzed (Table 2.10). Previous studies have shown that the operation of three fine-mesh screens per unit versus no fine-mesh screens may reduce the total mean density of entrained organisms by 61% (CP&L 1989).

The variability of effectiveness was influenced by species composition, seasonality, organism size, and number of non fine-mesh screens operating. During November when fine-mesh screen efficiencies were highest, no coarse-mesh screens were operating and portunid megalops (taxa exhibiting high fine-mesh screen efficiency) comprised 95% of the total larvae affected (entrained and impinged) by the plant (Tables 2.5 and 2.6). Conversely, the lowest fine-mesh screen efficiencies were recorded during April and May. This resulted from the fact that silversides and *Gobiosoma spp.* (taxa exhibiting poor fine-mesh screen efficiency) dominated the larval taxa affected by the plant during those months. These two taxa comprised 74% of the total larvae affected by the plant each month (Tables 2.5 and 2.6). The larvae of these taxa can be characterized as small (< 7 mm) cylindrical forms. Body size and shape has been shown to have an effect on screening efficiency for other species of larval fish (Tomljanovich et al. 1978; EPRI 1984).

Larvae of the commercially important taxa (portunid megalops, *Penaeus spp.*, spot, croaker, Atlantic menhaden, weakfish, swimming crabs) demonstrated higher fine-mesh screen efficiencies than the larvae of noncommercial taxa (Anchovies, *Gobionellus spp.*, *Gobiosoma* spp., silversides, hardback shrimp, and pinfish). Fine-mesh screen efficiencies for larvae of the commercial taxa ranged from 18% to 80% (Figure 2.6). However, fine-mesh screen efficiencies for larvae of the noncommercial taxa ranged from 1% to 29%.

2.3.5 Survival Estimates

Survival was determined for selected size classes of the dominant organisms that have been impinged at the BSEP in past years (CP&L 1985a, 1986, 1987, 1988). Screens were operated on slow-screen rotation speed (75 cm/min) for most sampling dates in 1997. Survival estimates were calculated using survival rates determined during previous studies for slow-screen rotation (CP&L 1988). A mortality rate of 100% is used for taxa that have never been tested. Thus, the estimated survival rate for total organisms is a conservative and minimum estimate.

Six of the ten most impinged larvae were previously tested for survival (Table 2.11). These six taxa accounted for about 94% of the total larval impingement catch. Survival during slow-screen rotation ranged from 86.3% for portunid megalops to 0% for Atlantic menhaden. *Anchoa* spp. (≥ 13 mm), which were not considered commercially or recreationally important, were not included in the total survival estimate. Estimates indicated that approximately 61% of these selected larval species impinged during slow-screen rotation, excluding *Anchoa* spp. (≥ 13 mm), were returned to the estuary alive. The overall larval survival rate increased from 1996 (18%) due to the increase in the number of larval shrimp and portunid megalops impinged during 1997. Both taxa exhibit good survival rates.

Six taxa of the ten most impinged J/A organisms were previously tested for survival on slow-screen rotation (Table 2.12). These taxa accounted for 90.4% of the total number collected and 67.3% of the total weight collected. Excluding bay anchovy, survival during slow-screen rotation ranged from 53.1% for croaker to 92.1% for blue crabs. The most valuable commercial species (shrimp and blue crabs) exhibited survival rates ranging from 86.5% to 92.1%. Survival estimates indicated that 34.1% of the total number and 36.2% of the total weight of the selected J/A organisms impinged, excluding bay anchovy, were returned alive to the estuary during slow-screen rotation. These percentages are lower than reported for 1996 (65.9% and 55.5% respectively) due to the decrease in the number and weight of larger J/A penaeid shrimp impinged in 1997 (Table 2.3; CP&L 1997)

Table 2.2 **Total number of selected taxa estimated by larval impingement sampling at the BSEP during 1997, ranked by percent.**

Taxon	Total number[+]	Percent
Portunid megalops	4.8×10^6	45.8
Penaeus spp.	1.9×10^6	18.0
Croaker	9.9×10^5	9.4
Anchoa spp. (≥ 13 mm)	9.0×10^5	8.5
Spot	7.5×10^5	7.1
Gobionellus spp.	2.7×10^5	2.5
Gobiosoma spp.	2.1×10^5	2.0
Portunidae	1.4×10^5	1.3
Pinfish	9.0×10^4	0.9
Anchoa spp. (<13 mm)	8.7×10^4	0.8
Other taxa	3.8×10^5	3.6
Total[¶]	**1.0×10^7**	**100.0**

[+]Total number is a sum of the twelve sampling-day totals.

[¶]Total may vary from summation due to rounding of individual taxon.

Table 2.3 Total number, total weight, and percent of total of the ten most abundant juvenile and adult organisms collected in the BSEP impingement samples during 1997.

Taxon	Number+	Percent¶	Weight (kg)+	Percent¶
Bay anchovy	219,932	83.4	238.5	41.3
Atlantic menhaden	10,348	3.9	116.6	20.2
White shrimp	7,622	2.9	46.8	8.1
Star drum	6,376	2.4	25.5	4.2
Spot	2,808	1.1	26.2	4.5
Lesser blue crab	2,494	1.0	5.7	1.0
Atlantic silversides	2,470	0.9	5.4	0.9
Blue crab	2,030	0.8	49.5	8.6
Brown shrimp	1,789	0.7	11.4	2.0
Croaker	1,331	0.5	8.8	1.5
Other taxa	6,411	2.4	42.5	7.6
Total	**263,611**		**576.9**	

+Numbers and weights are sums of the twelve sampling day totals.

¶Percentages may not add up due to rounding.

Table 2.4 Entrainment densities (mean no./1000 m^3 per sampling day) of selected$^+$ taxa at the BSEP during 1997.

Taxa	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Portunid Megalops	0	0	6.52	17.52	0	82.76	9.98	1.52	38.89	241.05	173.02	15.14
Penaeus spp.	0	0	26.89	2.83	0	41.58	126.59	81.53	91.70	69.32	12.13	12.33
Croaker	84.02	104.27	36.00	2.94	0	0	0	0	0	19.65	18.0	62.11
Anchovies	21.69	0	6.63	2.83	22.03	309.47	16.03	8.11	8.64	0	0	331.34
Spot	148.13	183.09	47.71	5.88	0	0	0	0	0	0	0	0
Gobinellus spp.	0	0	0	0	3.21	25.28	3.52	8.05	0	17.88	0	36.95
Gobiosoma spp.	0	0	0	2.83	134.01	151.41	347.97	51.16	52.38	39.76	3.23	0
Silversides	0	0	6.61	203.64	34.34	3.18	0	0	0	0	0	0
Hardback shrimp	0	0	0	0	0	127.03	8.55	14.92	2.78	0	0	0
Swimming crabs	0	0	6.52	2.94	0	82.76	26.22	1.92	5.62	14.17	0	0
Pinfish	8.71	33.66	6.31	0	0	0	0	0	0	0	0	6.19
Atlantic menhaden	3.27	3.66	0	0	0	0	0	0	0	0	0	0
Weakfish	0	0	0	0	3.12	103.98	0	0	0	0	0	0
Total Organisms	**265.82**	**339.70**	**146.15**	**258.76**	**221.5**	**942.15**	**575.63**	**193.00**	**208.27**	**404.68**	**206.38**	**464.07**

$^+$Selected taxa comprised $\geq$ 1% of the total sampled in either entrainment or larval impingement.

Table 2.5 Entrainment rates (million per sampling day) of selected+ taxa at the BSEP during 1997.

Taxa	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Portunid Megalops	0	0	0.029	0.094	0	0.445	0.054	0.008	0.117	1.082	0.614	0.068
Penaeus spp.	0	0	0.121	0.015	0	0.224	0.681	0.439	0.276	0.311	0.043	0.056
Croaker	0.379	0.441	0.162	0.016	0	0	0	0	0	0.088	0.064	0.280
Anchovies	0.098	0	0.030	0.015	0.119	1.666	0.086	0.044	0.026	0	0	1.495
Spot	0.668	0.774	0.215	0.032	0	0	0	0	0	0	0	0
Gobinellus spp.	0	0	0	0	0.017	0.136	0.019	0.043	0	0.008	0	0.167
Gobiosoma spp.	0	0	0	0.015	0.721	0.815	1.873	0.275	0.158	0.179	0.011	0
Silversides	0	0	0.030	1.10	0.185	0.017	0	0	0	0	0	0
Hardback shrimp	0	0	0	0	0	0.684	0.046	0.080	0.001	0	0	0
Swimming crabs	0	0	0.029	0.016	0	0.445	0.141	0.010	0.002	0.006	0	0
Pinfish	0.040	0.142	0.028	0	0	0	0	0	0	0	0	0.028
Atlantic menhaden	0.015	0.015	0	0	0	0	0	0	0	0	0	0
Weakfish	0	0	0	0	0.017	0.560	0	0	0	0	0	0
Total Organisms	**1.199**	**1.436**	**0.659**	**1.393**	**1.193**	**5.672**	**3.099**	**1.039**	**0.627**	**1.817**	**0.732**	**2.094**
Volume (10^6 m^3)	**4.512**	**4.226**	**4.512**	**5.343**	**5.383**	**5.383**	**5.383**	**5.383**	**3.010**	**4.490**	**3.548**	**4.512**

+Selected taxa comprised $\geq$ 1% of the total sampled in either entrainment or larval impingement.

Table 2.6 **Total number of selected+ taxa estimated by monthly samples of larval impingement at the BSEP during 1997.**

Taxa	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Portunid megalops	0	1,584	8,929	46.656	8,640	213,696	110,016	104	144,864	599,904	2,802,872	882,720
Penaeus spp.	0	4,320	117,360	31,392	9,360	121,104	644,112	162,576	282,960	415,008	27,216	90,000
Croaker	223,920	395,424	190,944	1,584	0	0	0	0	3,456	38,736	5,040	138,816
Anchovies	24,192	1,728	3,456	3,312	9,792	370,800	6,624	10,224	4,608	3,312	4,320	548,208
Spot	219,456	435,600	89,712	7,344	0	0	0	0	0	0	0	0
Gobionellus spp.	576	1,872	576	1,872	576	46,944	864	2,304	0	29,664	2,736	178,704
Gobiosoma spp.	0	0	0	0	10,800	51,984	51,408	20,304	53,136	26,208	0	0
Silversides	0	0	0	1,152	2,736	2,736	0	0	0	0	0	0
Hardback shrimp	0	0	0	0	0	0	8,496	0	8,064	2,304	5,904	0
Swimming crabs	0	0	0	72	144	0	89,712	72	36	33,408	7,776	0
Pinfish	1,368	62,352	864	1,008	0	0	0	0	0	0	0	12,528
Atlantic menhaden	0	8,208	34,416	0	0	0	0	0	0	0	0	0
Weakfish	0	0	0	432	504	41,616	0	0	0	0	0	0
Total organisms	**488,016**	**953,856**	**456,192**	**119,520**	**52,992**	**941,760**	**927,936**	**217,872**	**512,352**	**1,155,888**	**2,864,160**	**1,881,936**

+Selected taxa comprised ≥ 1% of the total sampled in either entrainment or larval impingement.

Table 2.7 Juvenile and adult impingement densities (No./million m^3 of water entrained during each 24-hour sampling period) for selected species+ and the number of damaged diversion screens per month at the BSEP during 1997.

Month	Bay anchovy	Atlantic menhaden	Spot	Croaker	White shrimp	Brown shrimp	Pink shrimp	Blue crab	Damaged screens
Jan	28,376.1	932.1	430.6	0.4	8.8	0	0	13.3	0
Feb	6,275.8	126.8	83.1	0.5	3.5	0	1.2	2.0	4
Mar	6717.6	34.8	60.7	31.3	30.8	0	12.0	224.5	13
Apr	2,138.0	34.0	6.7	21.9	1.3	0	11.9	61.5	11
May	2,152.0	964.3	21.6	194.7	8.4	0	0	39.8	49
Jun	354.3	10.4	9.3	12.6	0.9	61.9	0	34.0	24
Jul	15.6	11.2	5.9	0	70.2	226.8	2.2	25.3	33
Aug	2.4	5.0	3.3	6.5	486.0	37.5	2.4	7.8	16
Sep	0.7	0	0.3	0.3	86.1	12.3	8.0	6.0	0
Oct	3.1	0	0	0	3.8	4.7	3.6	0.9	0
Nov	7.9	0	0	0	200.1	0.9	7.3	0.9	2
Dec	2,438.9	0.2	0.9	0.9	751.9	2.6	5.2	7.2	3

+Selected species, with the exception of bay anchovy are commercially and recreationally important species which accounted for greater than 1% of the total catch by number or weight.

Table 2.8 Modal lengths (mm) for selected[+] juvenile and adult impingement species[¶] collected by month at the BSEP during 1997.

Month	Atlantic menhaden	Spot	Croaker	White shrimp	Brown shrimp	Pink shrimp
Jan	80	70	ID[£]	ID	NC[§]	NC
Feb	80	70	ID	ID	ID	ID
Mar	70	80	40	100	NC	85
Apr	90	90	55	ID	NC	85
May	80	55	60	140	NC	ID
Jun	95	60	80	ID	90	ID
Jul	110	ID	NC	110	110	ID
Aug	ID	ID	ID	105	85	ID
Sep	NC	ID	ID	100	80	50
Oct	NC	NC	NC	115	80,90	75
Nov	NC	NC	NC	85	ID	70
Dec	ID	ID	ID	95	ID	ID

[+]Selected species are commercially and recreationally important species which accounted for greater than 1% of the total catch by number or weight.

[¶]Fish ≥ 41 mm and crabs ≥ 25 mm.

[§]NC= None Collected.

[£]ID = Insufficient number collected (< 10).

Table 2.9 Time-series analysis of BSEP juvenile and adult impingement data indicating trends in density from January 1977 through December 1997.

Taxon	Trend[+]	Slope	R^2
Atlantic menhaden	—***	— 0.00052	0.97
Weakfish	—***	— 0.00029	0.97
Blue crabs	—***	— 0.00028	0.96
Spot	—***	— 0.00027	0.97
Croaker	—***	— 0.00024	0.96
Southern flounder	—***	— 0.00018	0.96
Pink shrimp	—***	— 0.00014	0.96
Bay anchovy	— **	— 0.00005	0.98
White shrimp	+***	0.00031	0.98
Brown shrimp	NS		
Total organisms	**—*** **	**— 0.00016**	**0.96**

[+]Trends are explained with the following notation:

NS = $P > 0.05$
* = $0.01 < P \leq 0.05$
** = $0.001 < P \leq 0.01$
*** = $P \leq 0.001$
+ = Increasing trend
— = Decreasing trend

R^2 = Amount of variation explained by the dependent variable in the time-series model.

Table 2.10 Percent effectiveness of fine-mesh screens in reducing the number of selected taxa entrained per sampling day at the BSEP during 1997.

Taxa	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Portunid Megalops	NP+	100	24	33	100	32	67	62	55	36	82	93	**66**
Penaeus spp.	NP	100	49	68	100	35	49	27	51	57	39	62	**47**
Croaker	37	47	54	9	NP	NP	NP	NP	100	31	7	33	**41**
Anchovies	20	100	10	18	2	18	7	19	15	100	100	27	**22**
Spot	25	36	29	19	NP	NP	NP	NP	NP	NP	NP	NP	**31**
Gobionellus spp.	100	100	100	100	3	26	4	5	NP	79	100	52	**41**
Gobiosoma spp.	NP	NP	NP	0	1	6	3	7	25	13	0	NP	**5**
Silversides	NP	NP	0	0	1	< 1	14	NP	NP	NP	NP	NP	**< 1**
Hardback shrimp	NP	NP	NP	NP	NP	0	16	0	91	100	100	NP	**3**
Swimming crabs	NP	NP	0	4	100	0	39	7	68	84	100	NP	**17**
Pinfish	26	30	3	100	NP	NP	NP	NP	NP	NP	NP	31	**28**
Atlantic menhaden	0	36	100	NP	NP	NP	NP	NP	NP	NP	NP	NP	**59**
Weakfish	NP	NP	NP	100	23	7	NP	NP	NP	NP	NP	NP	**8**
Total Organisms	**29**	**40**	**41**	**8**	**4**	**16**	**23**	**17**	**45**	**39**	**80**	**47**	**34**

+NP = Not Present.

Table 2.11 Estimated number and percent survival of selected larval organisms collected during impingement sampling at the BSEP during 1997.

Taxon	Number collected	Percent survival[+]
Portunid megalops	4.8×10^6	86.3
Penaeus spp.	1.9×10^6	80.3
Croaker	9.9×10^5	14.4
Anchoa spp. (≥ 13 mm)	9.0×10^5	0.3
Spot	7.5×10^5	9.0
Atlantic menhaden	4.3×10^4	0.0
Total[¶]	**9.7×10^6**	
Percent survival		**61.2**

[+]Reference: CP&L 1988 (Slow-screen rotation).

[¶]Selected species excluding *Anchoa* spp. (≥ 13 mm).

Table 2.12 Estimated number, weight, and percent survival of selected juvenile and adult organisms collected during impingement sampling at the BSEP during 1997.

Taxon	Number collected	Percent survival+	Weight collected	Percent survival+
Bay anchovy	219,932	1.1	238.5	1.1
Shrimp (pink and white)	7,874	86.5	48.0	86.5
Brown shrimp	1,789	90.7	11.4	90.7
Blue crabs	4,524	92.1	55.2	92.1
Spot	2,808	57.1	26.2	57.1
Croaker	1,331	53.1	8.8	53.1
Percent survival (Selected species)		**6.6% by number**		**21.7% by weight**
Percent survival (Selected species excluding bay anchovy)		**34.1% by number**		**36.2% by weight**

+Reference: CP&L 1988 (Slow-screen rotation).

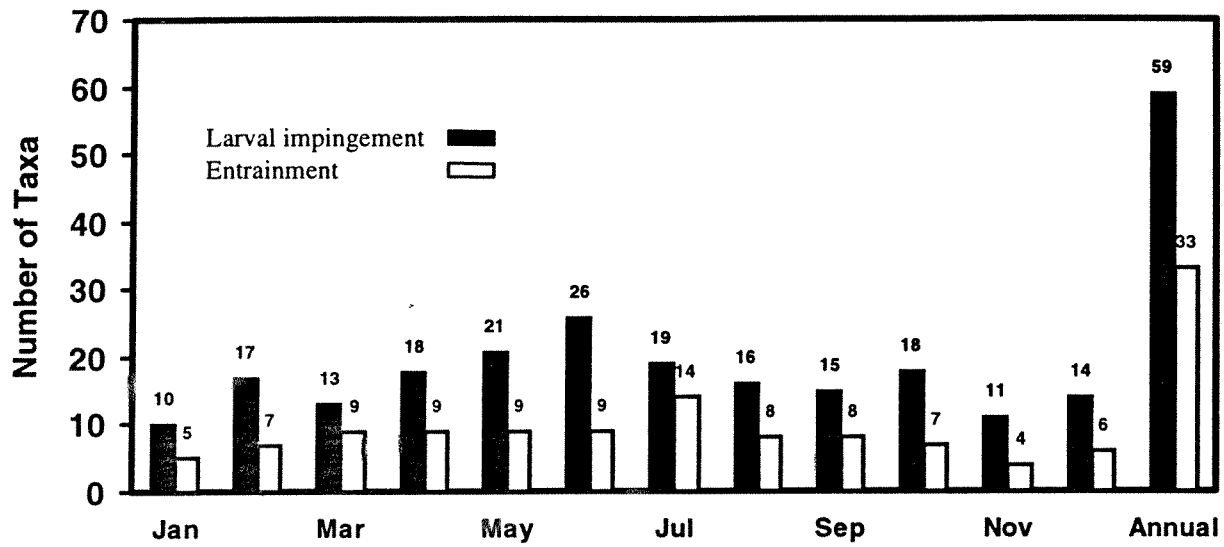


Figure 2.1 Number of taxa collected in entrainment and larval impingement samples at the BSEP during 1997.

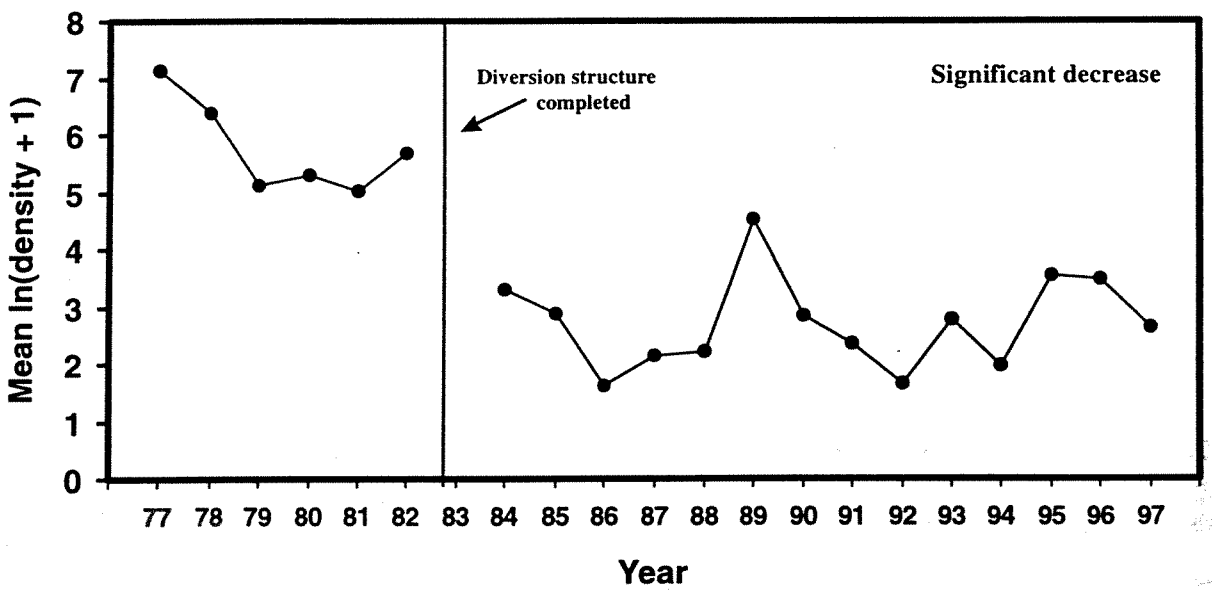


Figure 2.2 Time-series analysis of juvenile and adult Atlantic menhaden data collected during impingement sampling at the BSEP from 1977 through 1997.

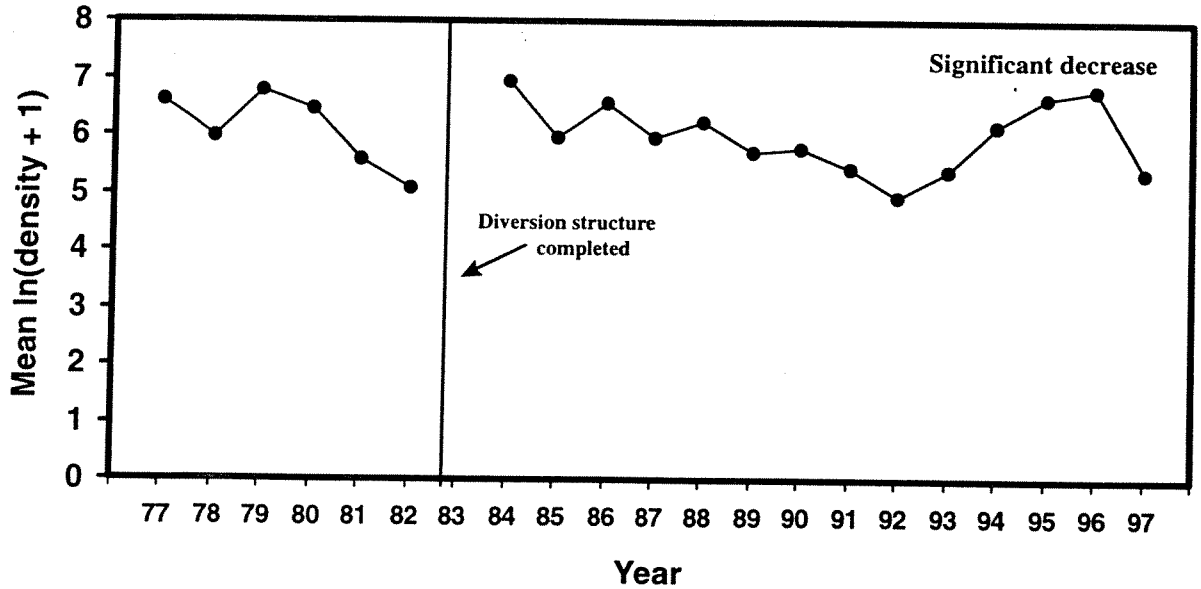


Figure 2.3 Time-series analysis of juvenile and adult bay anchovy data collected during impingement sampling at the BSEP from 1977 through 1997.

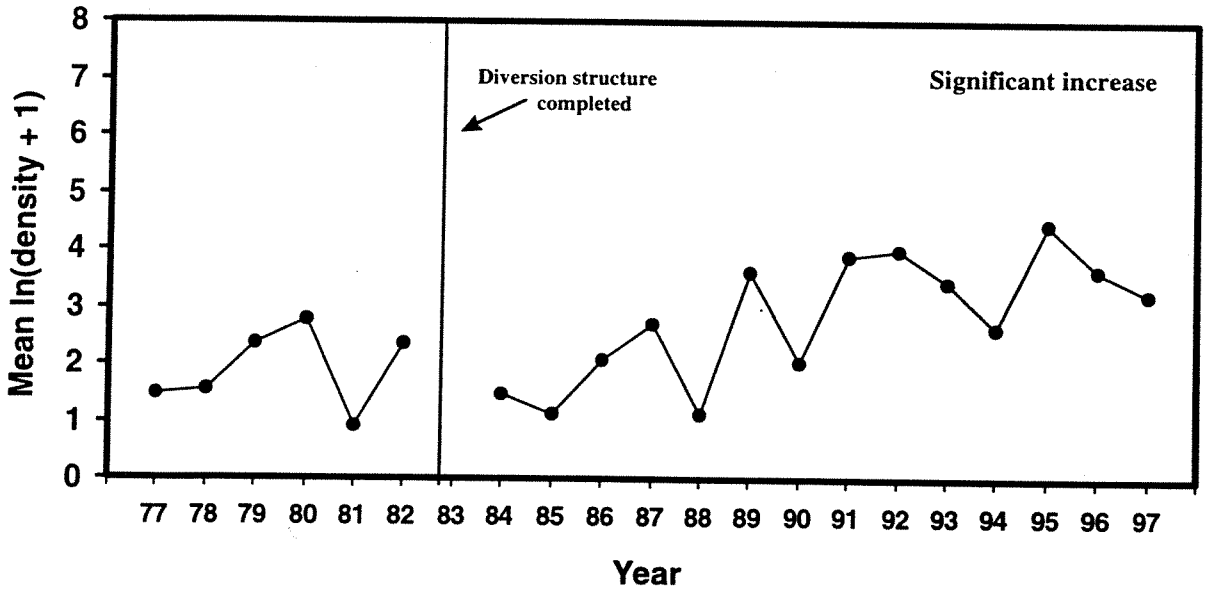
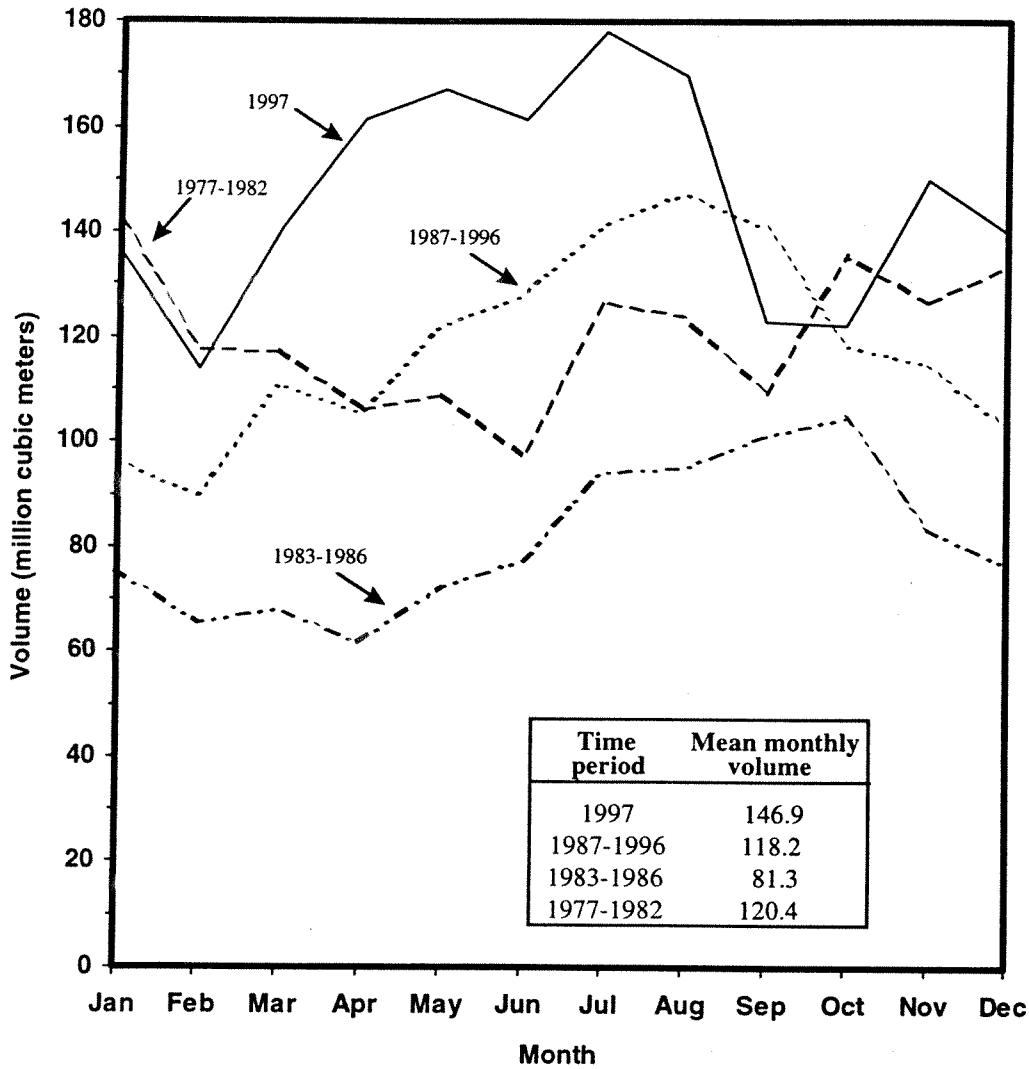


Figure 2.4 Time-series analysis of juvenile and adult white shrimp data collected during impingement sampling at the BSEP from 1977 through 1997.



Time period	Mean monthly volume
1997	146.9
1987-1996	118.2
1983-1986	81.3
1977-1982	120.4

Figure 2.5 Monthly flow of water pumped at the BSEP from 1977 through 1997.

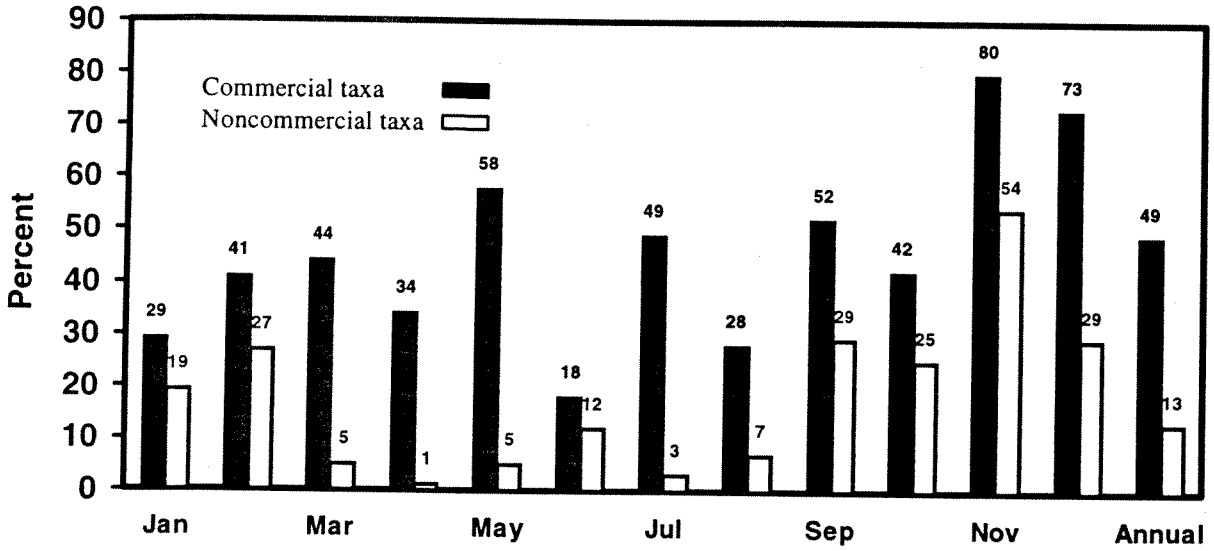


Figure 2.6 Percent effectiveness of fine-mesh screens in reducing the number of commercial and noncommercial taxa entrained per sampling day at the BSEP during 1997.

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