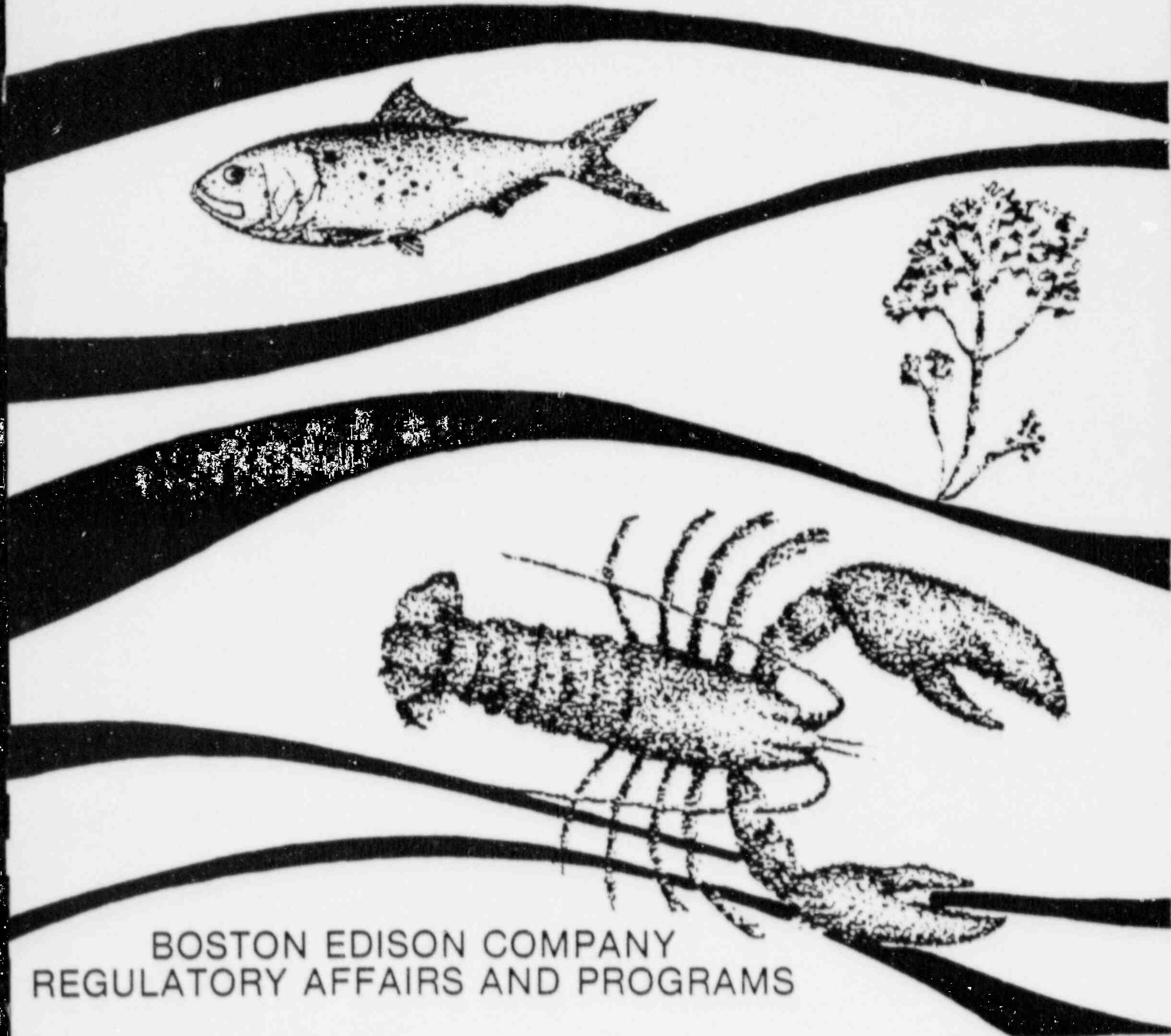
marine ecology studies

Related to Operation of Pilgrim Station

SEMI-ANNUAL REPORT NUMBER 31
JANUARY 1987 - DECEMBER 1987



BOSTON EDISON COMPANY
REGULATORY AFFAIRS AND PROGRAMS

BOSTON EDISON
800 Boylston St. Boston, MA 02199

MARINE ECOLOGY STUDIES

RELATED TO OPERATION OF PILGRIM STATION

SEMI-ANNUAL REPORT NO. 31

REPORT PERIOD: JANUARY 1987 THROUGH DECEMBER 1987

DATE OF ISSUE: APRIL 30, 1988

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SUMMARY

Highlights of the Environmental Surveillance and Monitoring Program results obtained over this reporting period (January - December 1987) are presented below. (Note: Pilgrim Station was in an outage from early April 1986 through December 1987, so data reflects a control situation for 1987, with no thermal influence on aquatic resources. For the period March - August 1987 no circulating seawater pumps were operating).

Marine Fisheries Monitoring:

1. In the April-November 1987 shorefront sportfish survey at Pilgrim Station, an estimated 1,250 angler visits accounted for 300 fishes caught. Cunner (56%), winter flounder (22%) and bluefish (11%) dominated the sportfish catch. The lack of a thermal component during the 1987 Pilgrim outage resulted in a much reduced sportfishery success rate, as occurred in 1986 and other outage years covering the shorefront angling season.

2. Pelagic fish mean CPUE (Catch Per Unit Effort) for 1987 at the gill net station (189.6 fishes/set) increased 90% from 1986 when 99.6 fishes/set were taken. Northern sea robin (35%), pollock (20%) and Atlantic herring (17%) were 72% of the total catch. Pollock catch rate was similar from 1986 to 1987 while northern sea robin and Atlantic herring increased substantially. A significant positive correlation was found for cunner catch and Pilgrim Station operational output (thermal loading to the environment) for 1973-1983, 1985. A general attraction to the thermal discharge appears to exist for tautog.

3. Shrimp trawl catch for 1987 recorded 30 benthic fish species with winter flounder (34%), little skate (30%) and windowpane (16%) composing 80% of the total. Mean CPUE for all species was 25.3 at the discharge surveillance station, 28.2 (highest) at the intake surveillance station and 22.9 (six less than in 1986) for all stations pooled in 1987. The presence of substantially larger numbers of small winter flounder caught in the intake embayment, compared to the other stations each year, suggests its attraction as a possible nursery area. Winter flounder abundance in spring, summer and fall, at the intake surveillance station, was much greater than at the discharge and reference stations. Young-of-the-year Atlantic cod were unusually abundant, being caught in greatest numbers in the PNPS intake embayment, also.

4. Adult lobster mean monthly catch rate per pot haul, in May - October 1987, was 0.33 lobsters which is 57% less than the 1986 rate (0.77). The surveillance area (thermal plume) catch rate was 0.34 while the reference area (control) was 0.20. The seasonal, legal lobster catch rate since 1970 has not been significantly lower in the thermal plume area than in control areas. A significant negative correlation was noted between legal lobster catch for thermal plume areas and mean annual Pilgrim Station output for the period from 1973 - 1983, 1985. The lobster research study, which commenced in 1986, identified two parameters to assess PNPS impact when the Station resumes operation - comparative areas for legal catch rate and size frequency comparisons.

5. In May - November 1987 fish observational dive surveys, 7 species were observed in the thermal plume area. Cunner (79%), pollock (14%) and tautog (2%) were the most numerous species seen, pollock being most abundant in the direct path of the Pilgrim discharge current. Total number of fishes observed decreased 65% from 1986 to the lowest point of the study. Most fishes were in greatest concentrations at stations in the discharge zone (45%), followed by the control zone (36%) and the stunted zone (19%). These results are similar to 1984 (also an outage year with a minimal discharge current) when most fish were observed relatively evenly divided between discharge and control zones, but unlike normal discharge current years when fish seem to greatly favor being in the path of the effluent.

6. Atlantic silverside accounted for 78% of the 1987 haul seine (shore zone) fish catch with a total of 29 species collected. The PNPS intake showed the greatest species diversity, and seine catches were highest overall in August and September. Fish captured in the PNPS intake embayment (second in CPUE to Long Point) were dominated by blueback herring and sand lance spp., and included Atlantic silverside and alewife among the more numerous species. A deeper seine net (10' compared to 6'), to more effectively sample the intake, was utilized beginning in 1984 and results have indicated this area is more similar in fish fauna attraction to an estuary than exposed coastal areas.

Impingement Monitoring:

1. The mean January - December 1987 impingement collection rate was 0.28 fish/hr. The rate ranged from 0 fish/hr (April) to 1.96 fish/hr (December) with rainbow smelt comprising 27.7% of the catch, followed by Atlantic silverside 18.2%, cunner 9.5%, lumpfish 6.8% and winter flounder 6.8%. Fish impingement rates in 1985 and 1986 were several times higher than in 1984 and 1987 when Pilgrim Station outages had both circulating water pumps off for considerable periods of time.

2. In January and December 1987, rainbow smelt impingement accounted for 85.4% of this species collected. They have been one of the most abundant species impinged on an annual basis at Pilgrim Station, predominating in 1978 and 1987.

3. The mean January - December 1987 invertebrate collection rate was 1.61/hr with the blue mussel, sand shrimp and polychaete worms accounting for 71.8%, 7.9% and 4.5% of the enumerated catch, respectively. No American lobsters were sampled, and the invertebrate impingement rates in 1985 and 1986 were similar to that recorded at Pilgrim Station during the 1987 outage year, despite lower circulating water pump availability.

4. Impinged fish, initial survival at the end of the Pilgrim Station intake sluiceway was approximately 29% during static screen washes and 43% during continuous washes. Five of the dominant species showed greater than 50% survival, overall.

Fish Surveillance:

Fish overflights in 1987 spotted four of five major species categories: herring, Atlantic menhaden, Atlantic mackerel and baitfish. Two sightings of fish in the nearfield Pilgrim vicinity were made. On June 21, 18,000 pounds of menhaden and on October 19, 105,000 pounds of Atlantic herring were observed near Pilgrim Station, but these occurrences were not reported to regulatory authorities as the Station was in an outage condition with no thermal plume present. From 1985 - 1987 there have been no observations of pollock.

Benthic Monitoring:

1. One new species of invertebrate was added to the list of biota for PNPS benthic surveys as a result of analysis of the 1987 samples. This was a bivalve, Hiatella striata.

2. A significant difference in species richness existed between the Effluent and Reference stations based on results of the fall 1987 sampling. The reference stations, which have characteristically ranked ahead of the Effluent station in species numbers, appeared more similar to each other than to discharge area.

3. Review of overall faunal community structure, via cluster analysis, showed that the Effluent Station has a low degree of similarity compared with the reference stations. Faunal clusterings and algal community overlap values, although somewhat

consistent with past observations, are beginning to show general recovery of community structure at the Effluent site when compared with reference sites.

4. The warm-water species, Gracilaria tikvahiae, decreased in the area of the Effluent station during 1986 and was completely absent in 1987, after it had normally colonized in 1985. It was also rare in 1984, indicating a direct relationship to the lack of thermal effluent in 1984, 1986 and 1987. Additional evidence of PNPS impacts in the Effluent discharge zone was the prevalent appearance of the cold-water alga, Laminaria, in the Effluent area during 1984 and 1987 transect mappings.

5. Four observations of the near-shore acute impact zones were performed during this reporting period. Some changes in the size and shape of the denuded and stunted zones were detected as a result of the 1987 surveys as a result of the PNPS shutdown. These surveys noted a greatly decreased near-field impact area in June, possibly due to a virtual stoppage in circulating water pump operation for the period March - June, resulting in negligible discharge current flow. Evidence of a lagged return to PNPS-induced scouring impacts was realized in the fall when circulating pump operation resumed in September 1987. Approximately six to nine months is the observed time frame of response to the thermal effects of PNPS operation by Chondrus in the immediate discharge vicinity (within 95 meters of the discharge canal).

Entrainment Monitoring:

1. A total of 36 species of fish eggs and/or larvae were found in the January - December 1987 entrainment collections (20-eggs, 33-larvae).

2. Seasonal egg collections for 1987 were dominated by Atlantic cod and winter flounder (winter - early spring); mackerel, rockling, labrids and searobins (late spring - early summer); hake, rockling, labrids, windowpane and cod (late summer - autumn).

3. Seasonal larval collections for 1987 were dominated by rock gunnel and sculpin (winter - early spring); winter flounder, seasnail, menhaden, tautog, rockling and silversides (late spring - early summer); hakes, windowpane, rockling and tautog (late summer - autumn).

4. No lobster larvae were collected in the entrainment samples for 1987, and only nine have been sampled from 1974-1987.

5. In 1987 an estimated 3.440×10^9 fish eggs and 4.787×10^7 fish larvae were entrained at Pilgrim Station, assuming full flow capacity of all seawater pumps. On an annual basis, eggs were dominated by the labrid - Limanda group and Atlantic mackerel, and larvae by seasnail, sculpin and rockling.

6. Total numbers of fish larvae collected for similar volumes of water sampled, in spring and summer 1984 and 1987, were lower than for the same periods in all other years. These results were shown to be significant with the fact that both Pilgrim Station circulating water pumps were offline during most of the spring/summer period 1984/1987, but at least one circulating water pump was operating during this period in other years.

INTRODUCTION

A Scope and Objective

This is the thirty-first semi-annual report on the status and results of the Environmental Surveillance and Monitoring Program related to the operation of Pilgrim Nuclear Power Station (PNPS). The monitoring programs discussed in this report relate specifically to the Cape Cod Bay ecosystem with particular emphasis on the Rocky Point area. This is the nineteenth semi-annual report in accordance with the environmental monitoring and reporting requirements of the PNPS Unit 1 NPDES Permit from the U.S. Environmental Protection Agency (#MA0003557) and Massachusetts Division of Water Pollution Control (#359). A multi-year (1969-1977) report incorporating marine fisheries, benthic, plankton/entrainment and impingement studies was submitted to the NRC in July 1978, as required by the PNPS Appendix B, Tech. Specs. Programs in these areas have been continued under the PNPS NPDES permit. Amendment #67 (1983) to the PNPS Tech. Specs. deleted Appendix B non-radiological water quality requirements, as the NRC felt they are covered in the NPDES Permit.

The objectives of the Environmental Surveillance and Monitoring Program are to determine whether the operation of PNPS results in measurable effects on the marine ecology and to evaluate the significance of any observed effects. If an effect of significance is detected, Boston Edison Company has committed to take steps to correct or mitigate any adverse situation.

These studies are guided by the Pilgrim Administrative-Technical Committee (PATC) which was chaired by a member of the Mass. Division of Water Pollution Control in 1987, and whose membership includes representatives from the University of Massachusetts, the Mass. Division of Water Pollution Control, the Mass. Division of Marine Fisheries, the National Marine Fisheries Service (NOAA), the U.S. Bureau of Sport Fisheries and Wildlife, the U.S Environmental Protection Agency and Boston Edison Company. Copies of the minutes of the Pilgrim Administrative-Technical Committee meetings held during this reporting period are included in Section V.

B. Marine Biota Studies

1. Marine Fisheries Studies

A modified version of the marine fisheries monitoring, initiated in 1981, is being conducted by the Commonwealth of Massachusetts, Division of Marine Fisheries (DMF).

The occurrence and distribution of fish around Pilgrim Station and at sites outside the area of water temperature increase are being monitored. Pelagic species were sampled using gill net (1 station) collections (Figure 1) made at monthly intervals. In 1981, shrimp trawling and haul seining were initiated to provide PNPS impact-related sampling of benthic fish and shore zone fish, respectively. Shrimp trawling was done twice/month at 4 stations (Figure 2) and haul seining twice/month during June - November at 5 stations (Figure 1).

Monitoring is conducted of local lobster stock catch statistics for areas off Rocky and Manomet Points (Figure 4). Catch statistics are collected approximately weekly throughout the fishing season (April-October).

A finfish observational dive program was initiated in June 1978. SCUBA gear is utilized on biweekly dives from May-October (weekly mid-August to mid-September) at 6 stations (Figure 2) in the PNPS thermal plume area.

In 1986, an experimental, lobster pot trawl monitoring effort was initiated to eliminate any biases associated with the collection of lobster stock catch statistics in determining PNPS effects. Ten 5-pot lobster trawls were fished in the thermal plume and control areas around PNPS during 1987 (Figure 3).

Results of the marine fisheries monitoring and impact analysis during the reporting period are presented in Sections IIIA.1 and IIIA.2.

2. Benthic Studies

The benthic monitoring described in this report was conducted by Battelle New England Marine Labs, Duxbury, Massachusetts.

The benthic flora and fauna were sampled at three locations at depths of 10 feet (MLW) (Figure 1). Quantitative (rock substratum) samples were collected, and the dominant flora and fauna in each plot were recorded. Sampling was conducted two times per year (March and

September) to determine biotic changes, if any. Transect sampling off the discharge canal to determine the extent of the denuded and stunted zones was conducted four times a year (March, June, Setpember and December). Results of the benthic surveys and impact analysis during this period are discussed in Sections IIIB.1 and IIIB.2.

3. Plankton Studies

Since August 1973, Marine Research, Inc. (MRI) of Falmouth, Massachusetts, has been monitoring entrainment in Pilgrim Station cooling water of fish eggs and larvae, and lobster larvae (from 1973-1975 phytoplankton and zooplankton were also studied). Figure 5 shows the entrainment contingency sampling station locations to be sampled should the numbers of eggs/larvae entrained greatly exceed recorded historical averages. Information generated through this monitoring has been utilized to make periodic modifications in the sampling program to more efficiently address the question of the effects of entrainment. These modifications have been developed by the contractor, and reviewed and approved by the Pilgrim A-T Committee on the basis of program results. Plankton monitoring in 1987 emphasized consideration of ichthyoplankton entrainment. Results of the ichthyoplankton entrainment monitoring and impact analysis for this reporting period are discussed in Sections IIIC.1 and IIIC.2.

4. Impingement Studies

The Pilgrim I impingement monitoring and survival program speciates, quantifies and determines viability of the organisms carried onto the four intake traveling screens. Since January 1979, Marine Research, Inc. has been conducting impingement sampling with results being reported on by Boston Edison Company.

A new screen wash sluiceway system was installed at Pilgrim in 1979 at a total cost of approximately $150,000. This new sluiceway system was required by the U.S. Environmental Protection Agency and the Mass. Division of Water Pollution Control as a part of NPDES Permit #MA0003557. Special fish survival studies conducted from 1980-1983 to determine its effectiveness in protecting marine life were terminated in 1984, and a final report on them appears in Marine Ecology Semi-Annual Report #23.

Results of the impingement monitoring and survival program, as well as impact analysis, for this reporting period are discussed in Section IIID.

C. Fish Surveillance Studies

March - November, weekly fish spotting overflights were conducted as part of a continuing effort to monitor the times when large concentrations of fish might be expected in the Pilgrim vicinity. Regularly from May-October since 1978, dive inspections have been conducted of the Pilgrim discharge canal in order to evaluate fish barrier net durability, and effectiveness in excluding fishes from the discharge canal.

The annual summary report on fish overflights for 1987 is presented in Section IVA. Barrier net inspections were not performed in 1987 as Pilgrim Station was in an outage the whole year, and the net has been removed from the discharge canal since August, 1986.

D. Station Operation History

The daily average, reactor thermal power levels from January through December, 1983-1987 are shown in Figure 6. As can be seen, PNPS was in an outage during the 1987 reporting period; however, environmental monitoring programs were performed to obtain control data for impact comparison with past and future high operational years.

E. 1988 Environmental Programs

A planning schedule bar chart for 1988 environmental monitoring programs related to the operation of Pilgrim Station, showing task activities and milestones from December 1987 - June 1989, is included as Figure 7.

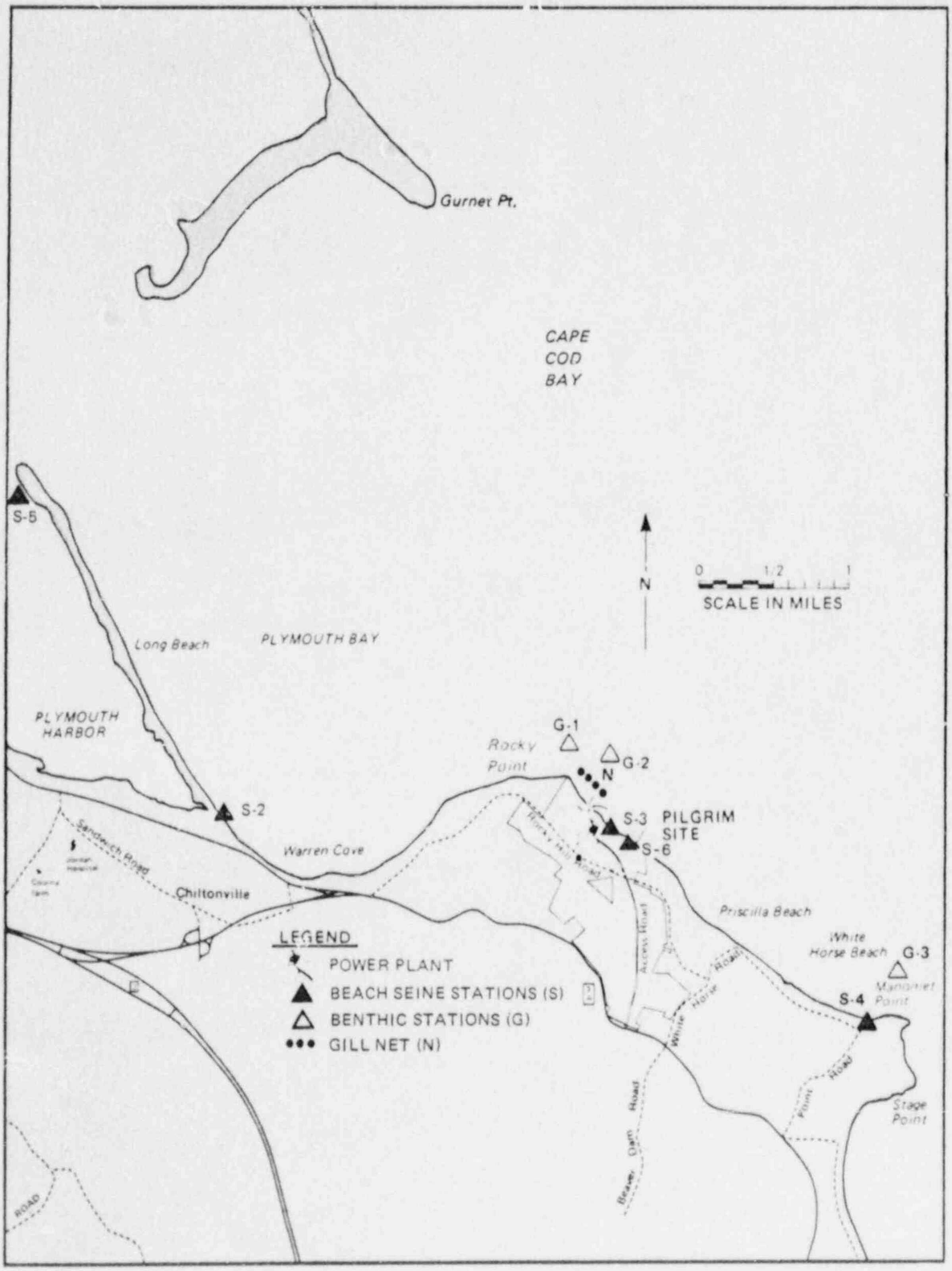


Figure 1. Location of Beach Seine and Gill Net Sampling Stations for Marine Fisheries Studies, and Benthic Studies Sampling Stations

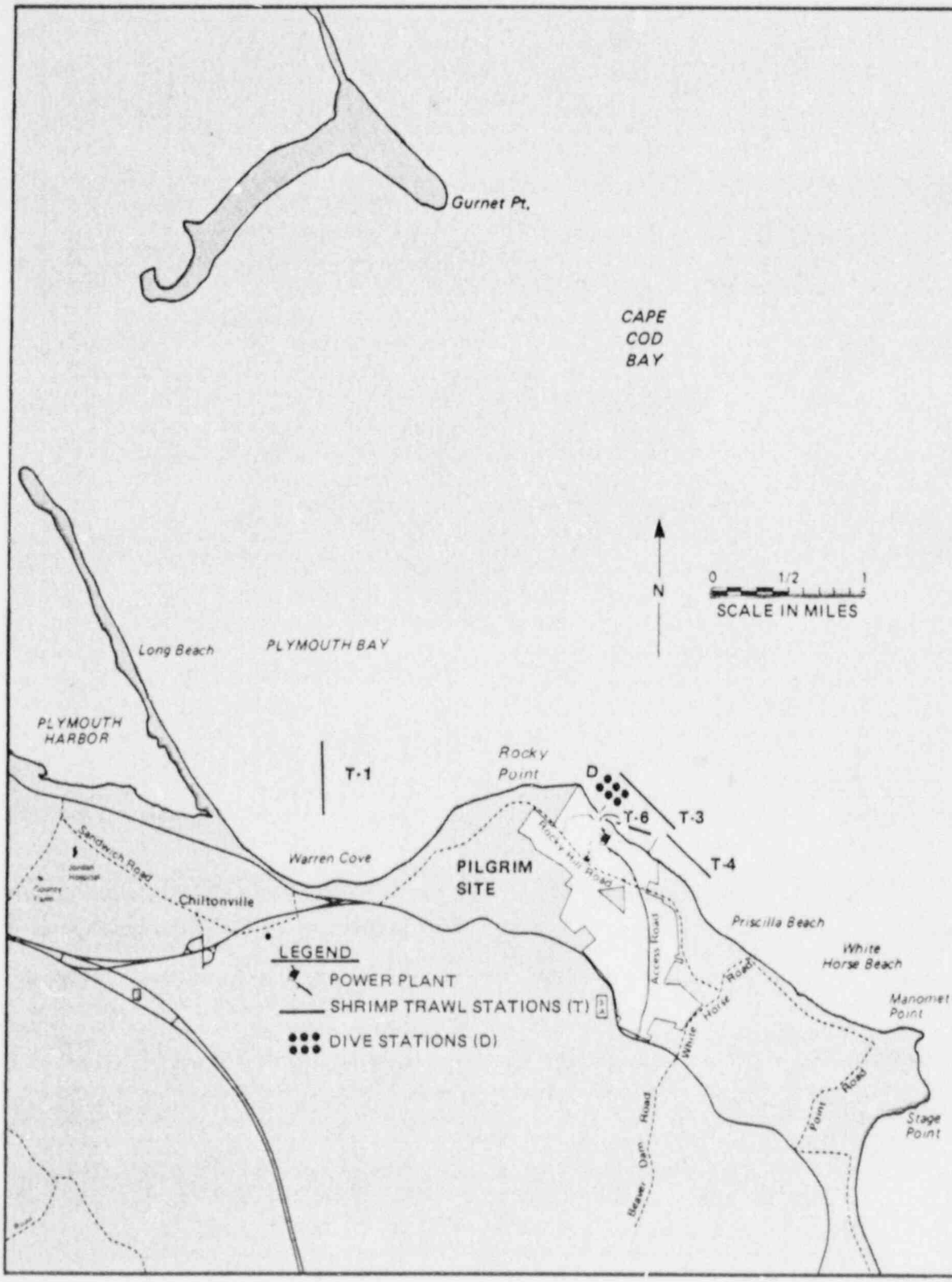


Figure 2. Location of Shrimp Trawl and Dive Sampling Stations for Marine Fisheries Studies

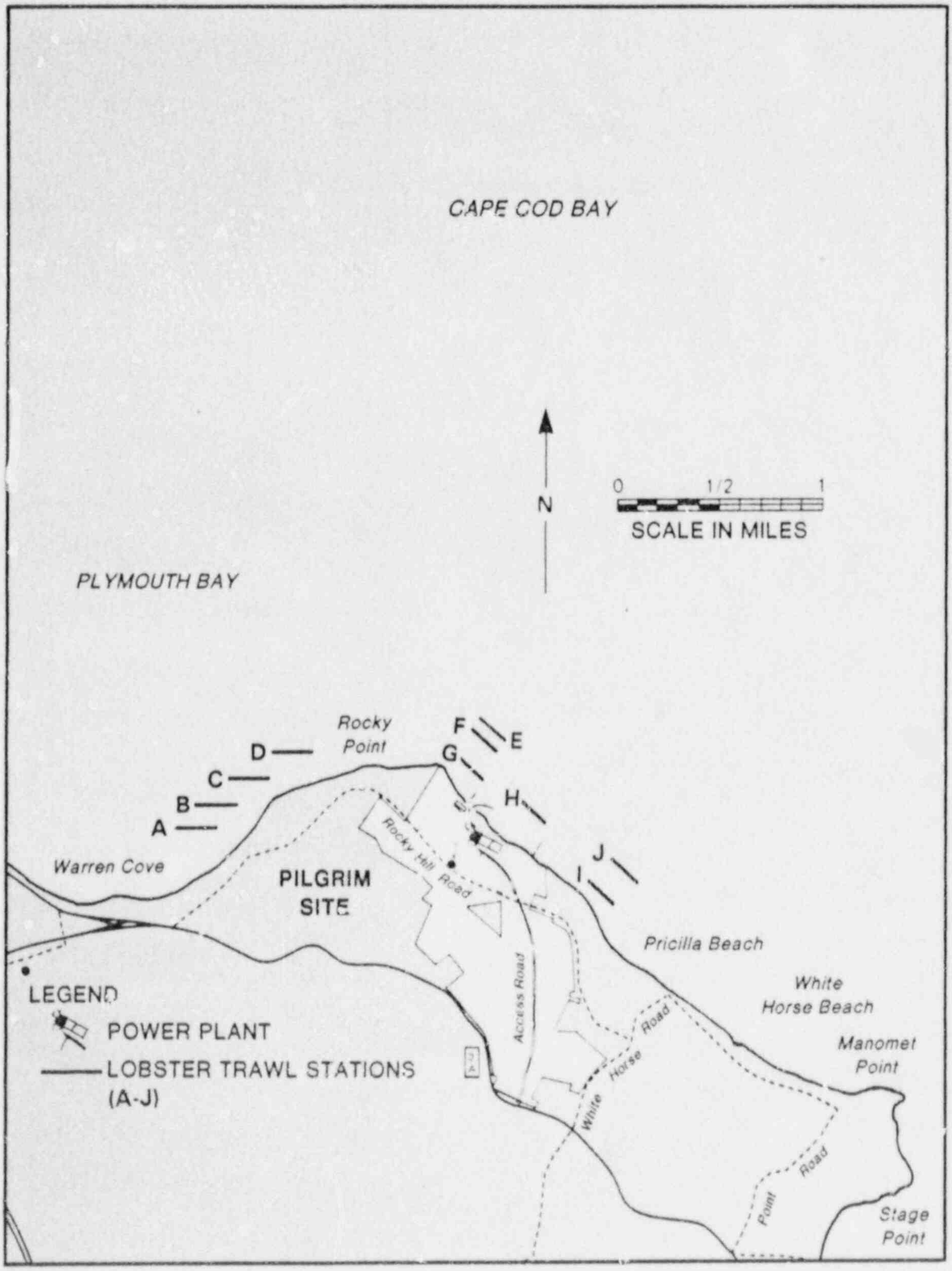


Figure 3. Location of experimental lobster gear (5-pot trawls) for Marine Fisheries Studies.

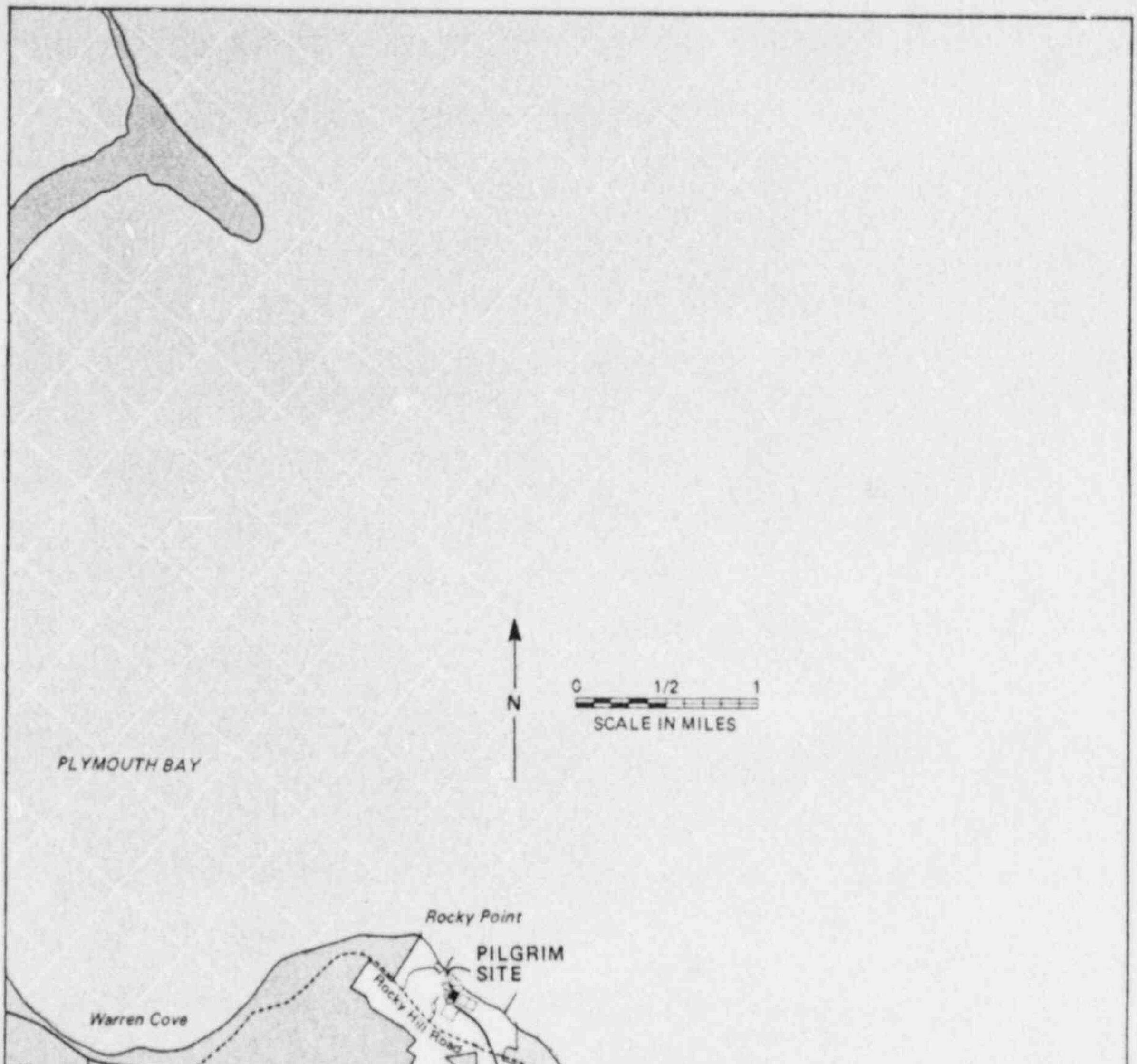


Figure 4 Lobster Pot Sampling Grid for Marine Fisheries Studies.

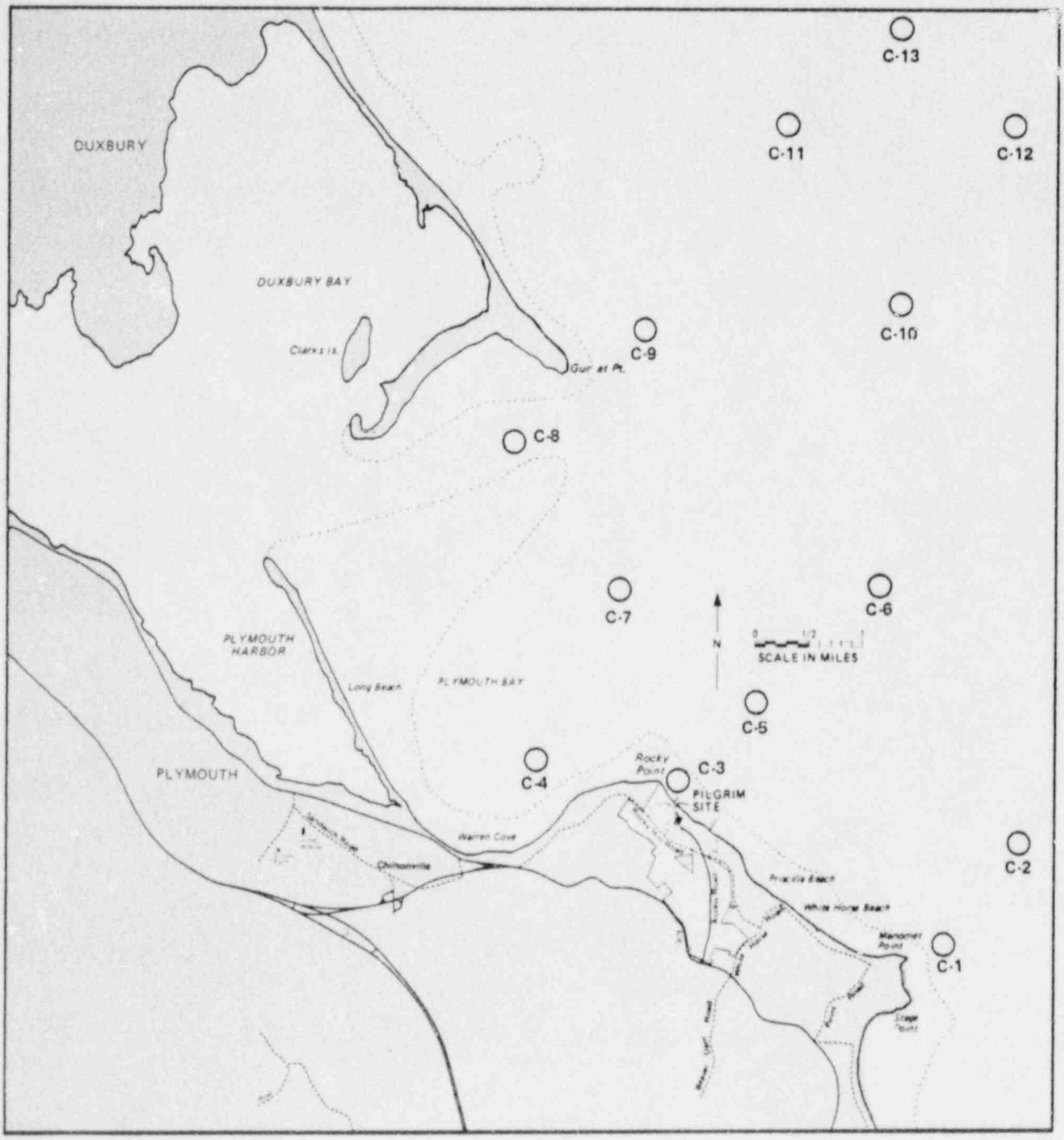
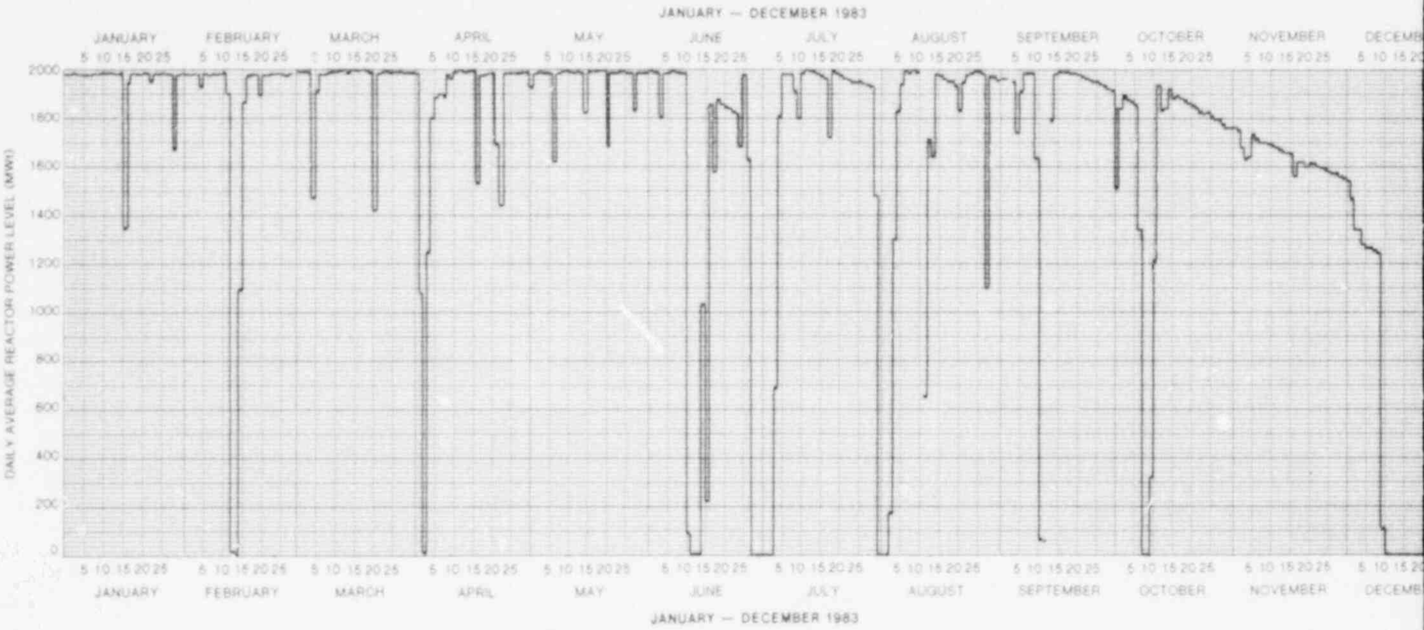


Figure 5 Location of Entrainment Contingency Plan Sampling Stations, C.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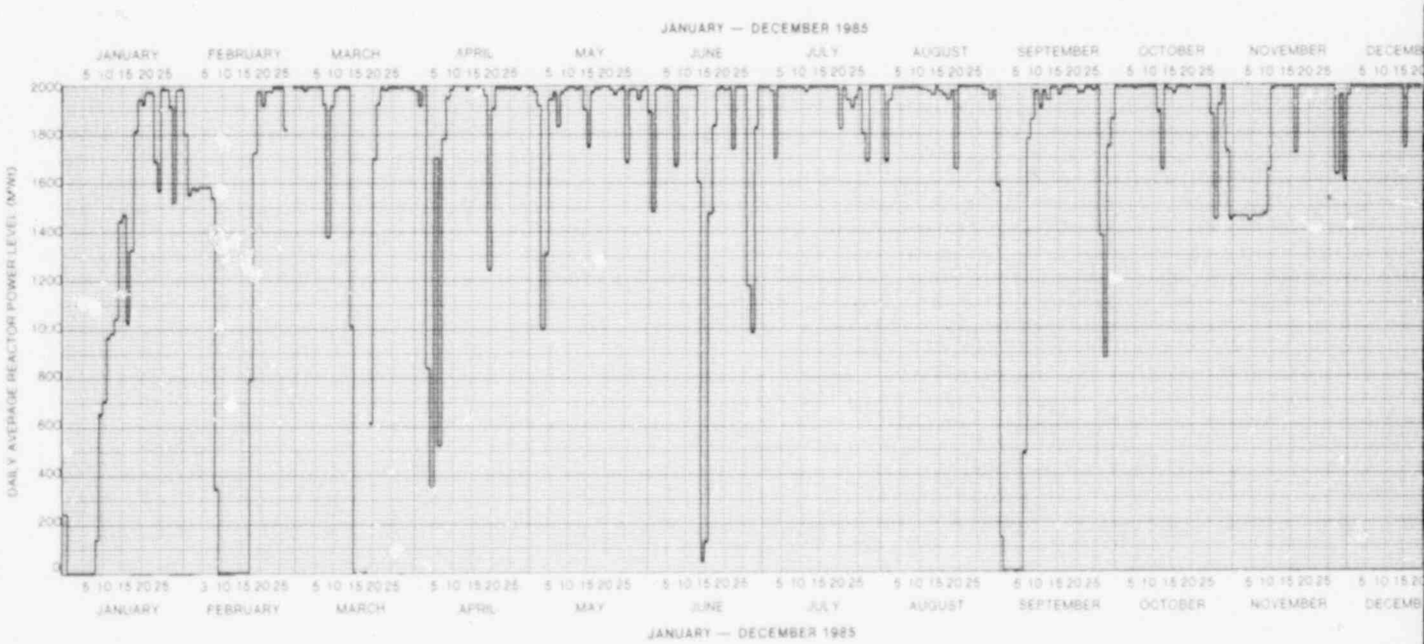
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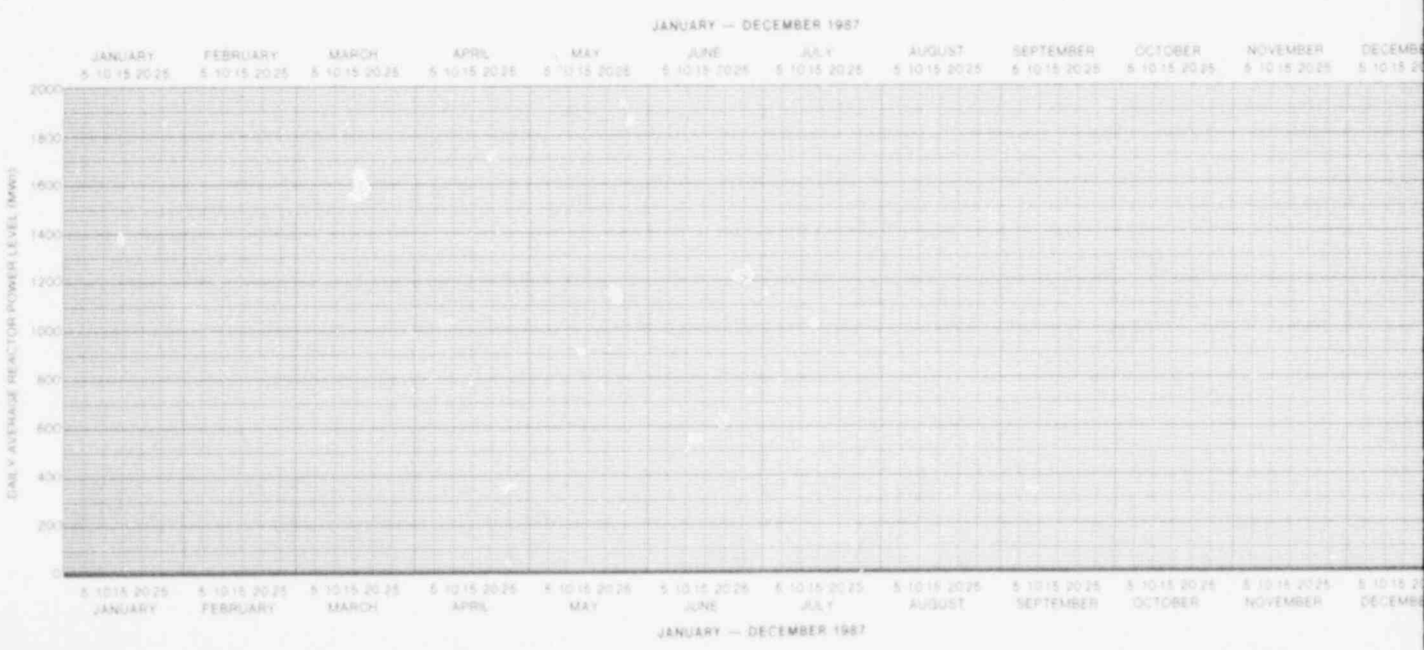
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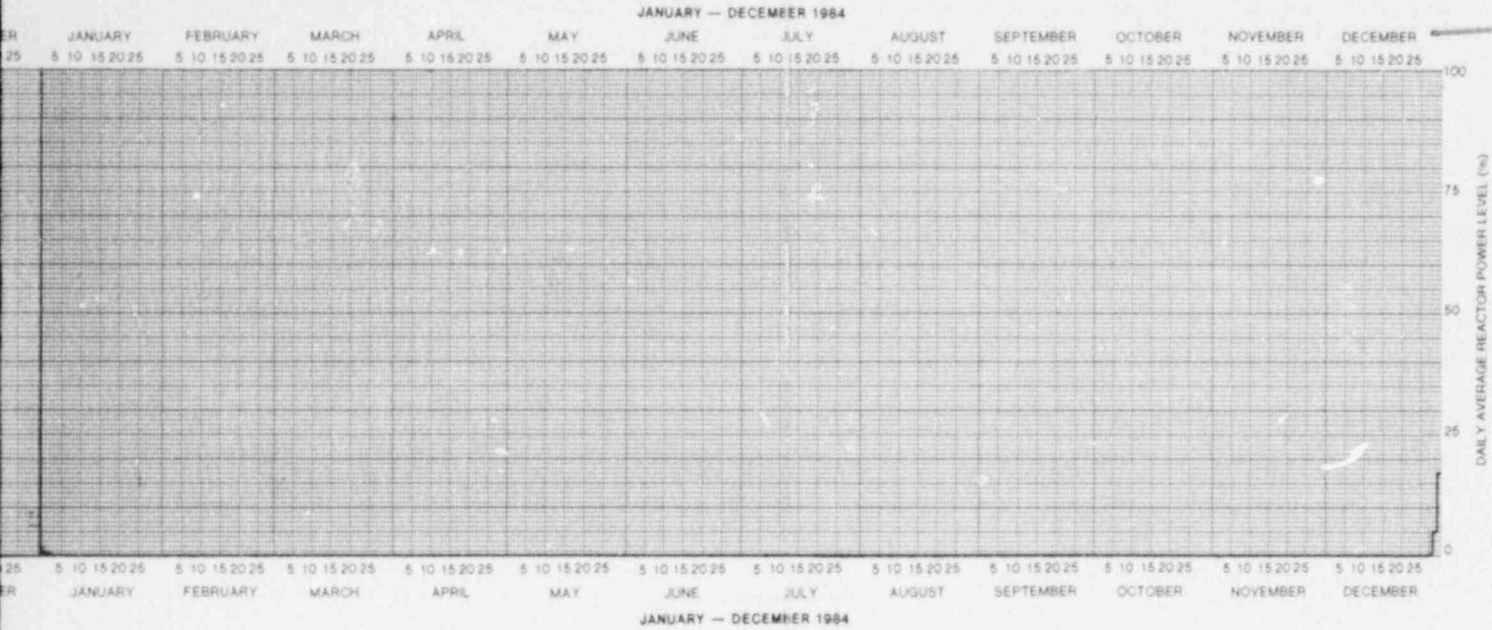

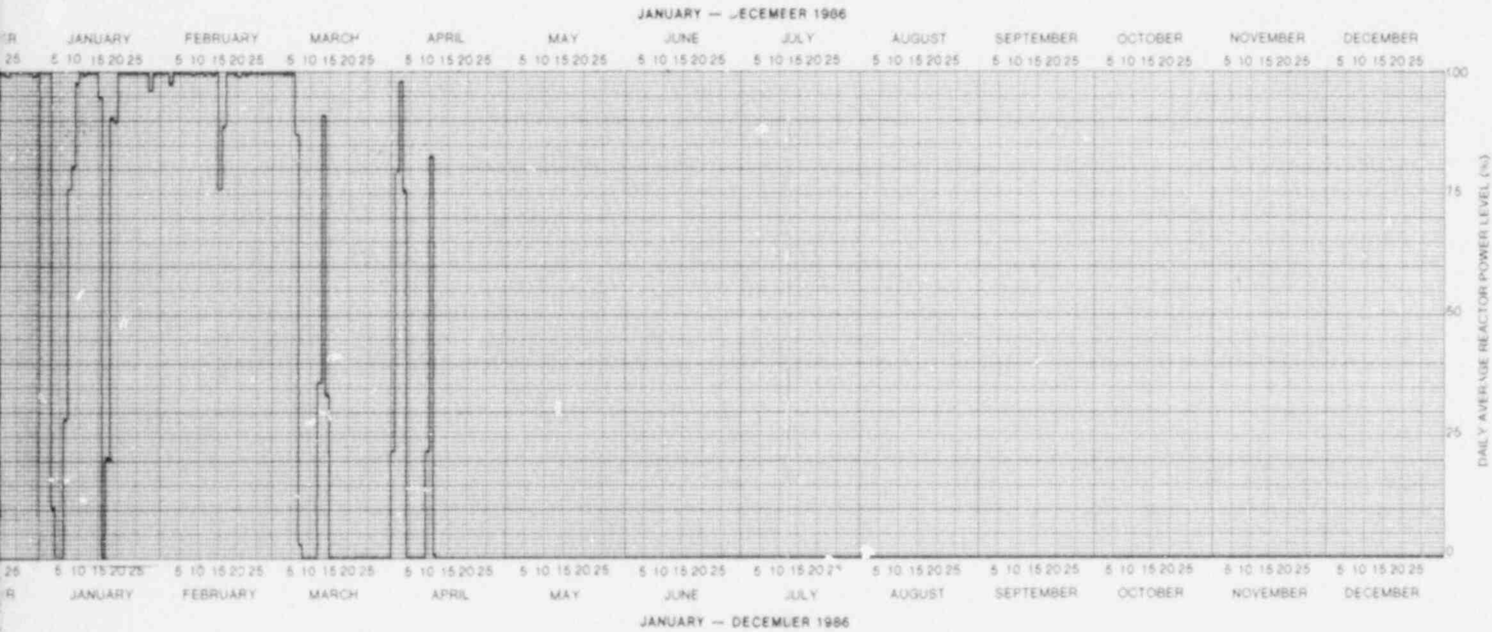

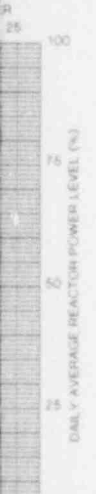

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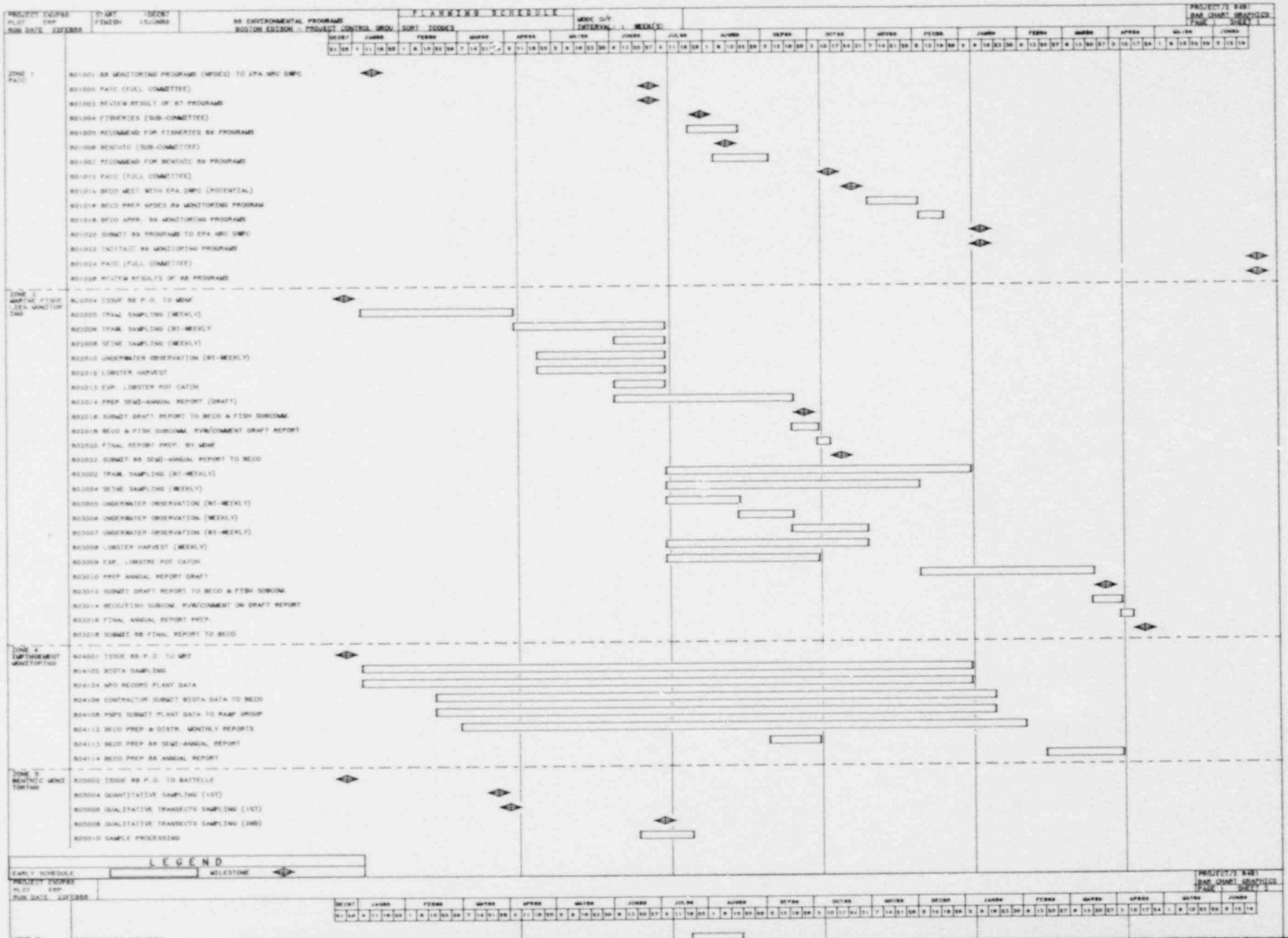
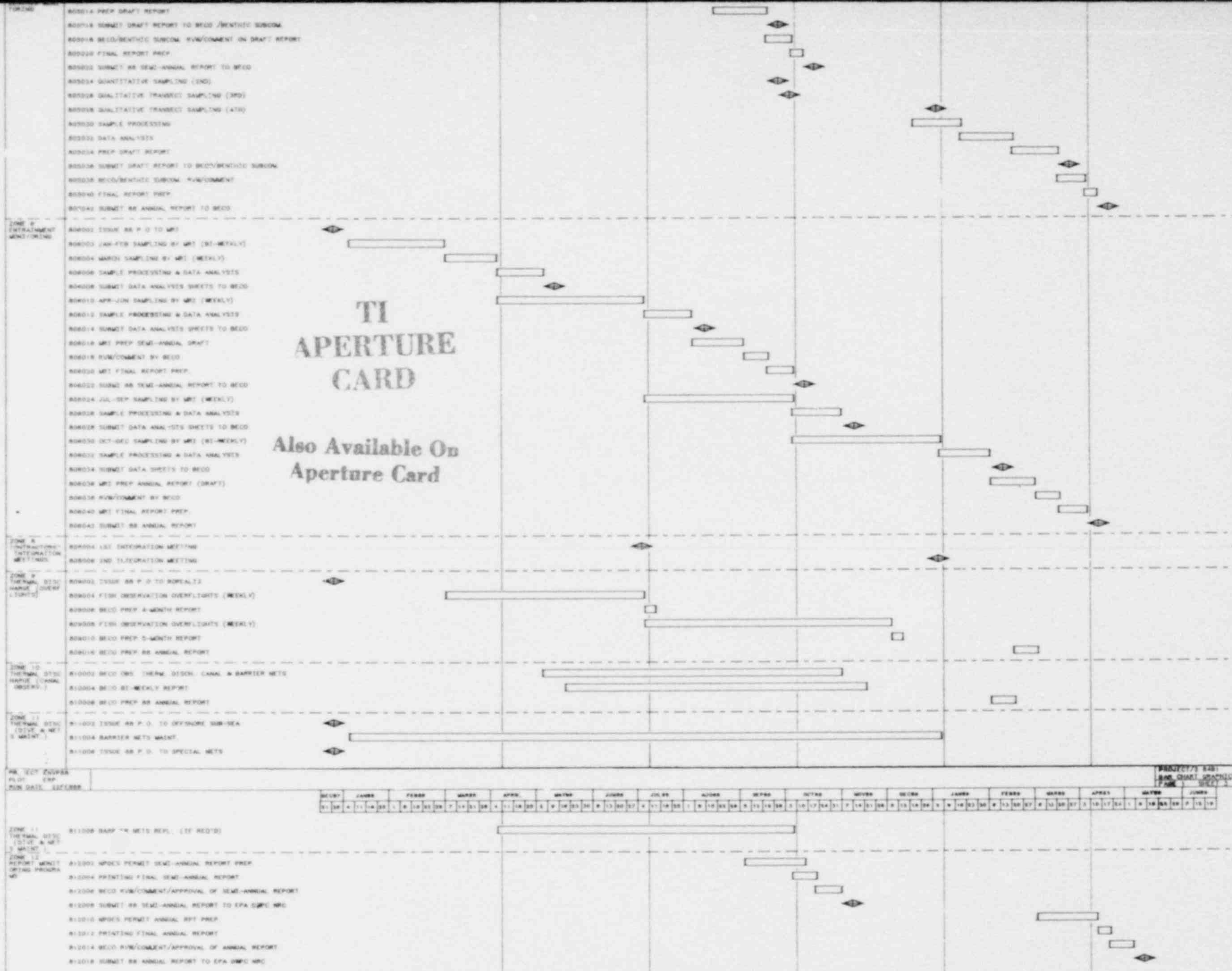
FIGURE 6. Daily Average Reactor Thermal Power Level (MW_t and %) from January 1983-December 1987 for Pilgrim Nuclear Power Station.

Figure 7. Schedule for Pilgrim Station 1988 Environmental Monitoring Programs (NPDES Permit).





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ANNUAL REPORT
ON
MONITORING TO ASSESS IMPACT
OF
PILGRIM NUCLEAR POWER STATION
ON MARINE FISHERIES RESOURCES
OF WESTERN CAPE COD BAY

(CHARACTERIZATION OF THE FISHERIES RESOURCES)

Project Report No. 44 (January-December, 1987)

(Volume 1 of 2)

By

Brian C. Kelly, Vincent J. Malkoski,
Robert P. Lawton and Mando Borgatti

April 1, 1987

Massachusetts Department of Fisheries,
Wildlife, and Environmental Law Enforcement
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I. EXECUTIVE SUMMARY

A modified version of marine fisheries monitoring, initiated in 1981, was conducted by the Massachusetts Division of Marine Fisheries. Data on the occurrence, distribution, and relative abundance of finfish and lobster were collected according to a standardized sampling scheme to identify trends and relationships in the study area over time. We directed our efforts to commercially and recreationally important fisheries resources. Pelagic finfish were sampled using gill net collections. Near-shore bottom trawling and haul seining sampled benthic and shore zone fish, respectively. Monitoring of the local commercial lobster stock catch statistics for areas off Rocky Point was conducted during the inshore lobster season. Experimental lobster pot trawling, also conducted, eliminated any biases associated with the collection of lobster stock catch statistics. A finfish observational dive program and a sportfishing creel survey rounded out the investigations.

Catch rates in the Pilgrim area declined from 1986 to 1987 for the top three groundfish (winter flounder, little skate, and windowpane) trawled. The gill net catch of cunner was at its lowest level of the entire survey, while pollock catch has been quite similar for the last four years. By contrast, the seine catch rates of Atlantic silverside, juvenile river herring (blueback herring and alewife), and sand lance were up from last year. Overall, fish sighted in the diving study was at its lowest point of the study. Sportfish catches were extremely low relative to past records.

II. INTRODUCTION

Environmental monitoring was conducted in 1987 by the Massachusetts Division of Marine Fisheries in an ongoing effort to assess plant-related impact of the Pilgrim Nuclear Power Station on marine resources in western Cape Cod Bay, under Purchase Order No. 63644 to Boston Edison Company. Data on the occurrence, distribution, and relative abundance of finfish and lobster were collected throughout the year following a standardized sampling scheme. Analyses included measurements, counts, percentages, and indices which were used to identify trends and relationships in the data throughout the study area over time. Volume 1 is a characterization of fisheries' resources in the Pilgrim area.

This report highlights results of pertinent findings and discernments in a reduced overview of sorts, departing from the former format. Detailed analyses including statistical information and supportive data with complete results are available from the Division of Marine Fisheries and will be supplied upon request. Only essential information is presented in order that the volume of material be substantially reduced. The reporting of environmental studies has evolved in a series of steps from a progress report which included much raw data to an exhaustive scientific report, to the present condensed format. Our intent was to condense subject matter but maintain clarity and precision of data reporting and interpretation. We have endeavored to convey technical information in a more readable report.

III. METHODS AND MATERIALS

Commercial Lobster Pot Catch

Many lobstermen trap lobster (*Homarus americanus*) in the waters off Pilgrim Nuclear Power Station, and there are numerous landing sites along the coast. Consequently, it was impractical to monitor the entire local lobster fishery; instead, prior to 1987, we opted to sample the trap-catch of two commercial lobstermen of the area to obtain an index of harvest. However, in 1987, we terminated sampling with one fisherman, as he had progressively moved his gear offshore and out of the immediate vicinity of the power plant. Instead, we devoted more time to fishing our own traps at prescribed locations.

We sampled the entire day's commercial catch of our second lobsterman biweekly from May-October, which is the height of the inshore lobster season. To facilitate data collection, the study area was partitioned into a grid (0.8 km^2) quadrats), and catch recorded by quadrat (Figure 1), with quadrats later grouped to identify reference and surveillance areas. Catch data included: catch (number) of lobster per pot-haul; pot location (quadrat); and for each lobster - carapace length (CL) in mm, sex, presence/absence of eggs on females, and molt condition.

Research Lobster Trap Fishing

In June 1987, we began the second year of an experimental lobster study which was implemented to measure the impact of the thermal discharge from Pilgrim Power Station on the local lobster population. We conducted research trap fishing from June-September in the discharge area (surveillance) and at two comparable reference (control) locations using a uniform

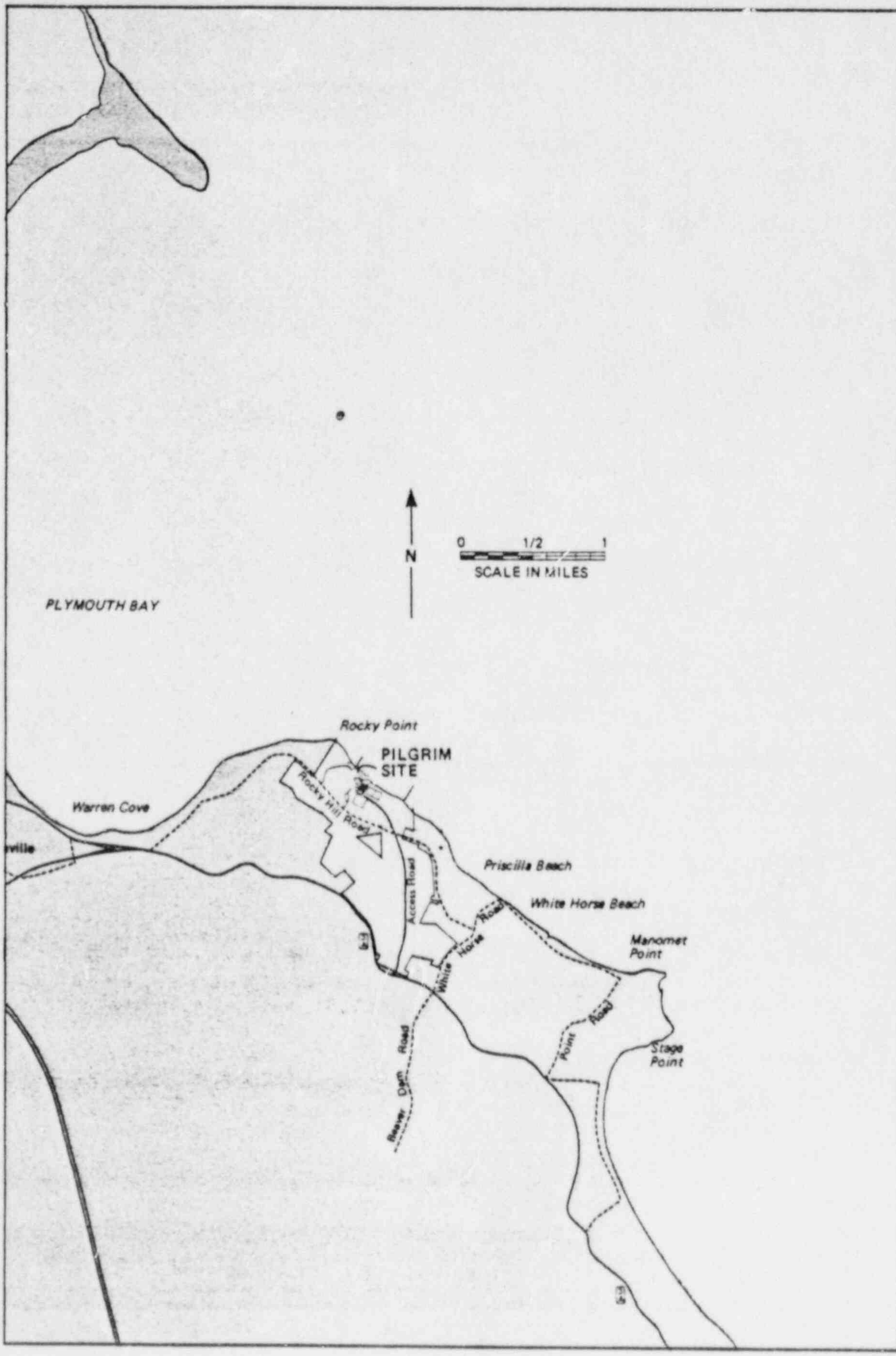


Figure 1. Lobster Pot Sampling Grid for Marine Fisheries Studies.

experimental technique to reduce sampling variability as natural populations are rarely ever uniform over space. Ten stations were monitored: four (E-H) at the surveillance location and six (A-D; I-J) at the two controls (Figure 2).

Because of the extended power plant outage, the discharge was monitored for a second year without the influence of waste heat. However, this year, current was reduced further to a minimal flow of water out of the discharge canal. This allowed us to collect two seasons of base line data under essentially prestress conditions to compare temporally the potentially impacted/treatment stations with the non-impacted/control stations before the plant resumes operation.

Our sampling design included standardized gear and methods to maximize data precision and accuracy. Fifty (10 more than in 1986) vinyl coated wire lobster traps (91 x 51 x 30 cm) were fished in trawls. Randomization was applied in our selection of stations from within an area. Ten trawls each having five traps per trawl with traps spaced about 30 m apart and buoyed at each ends were employed, one trawl at each of the 10 stations. A station location was permanently marked with an anchor-buoy arrangement and was sampled methodically to standardize the distribution of effort.

Pots were hauled every other day in the morning, weather permitting, with soak-time (duration of a set) recorded. Water temperatures (bottom and surface) were measured approximately weekly. At each sampling, traps were emptied of their contents, rebaited, and relocated on station. Flounder racks were used

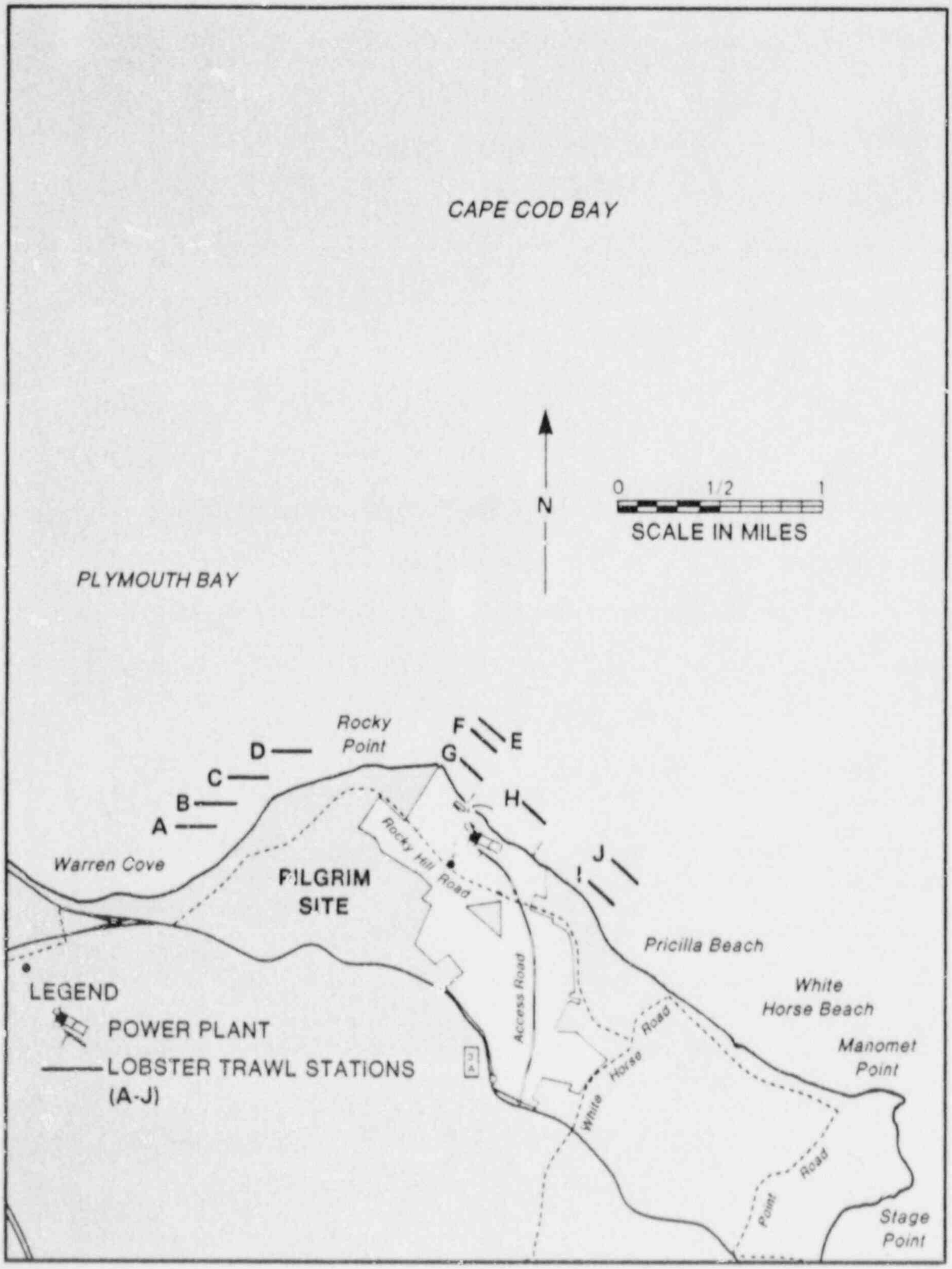


Figure 2. Location of experimental lobster gear (5-pot trawls) for Marine Fisheries Studies.

exclusively as bait to standardize any effect of bait on catchability. For each pot-haul, lobster were counted, measured, sexed, and examined for missing claws, presence of eggs, shell hardness, and disease. We released all lobster in the area of capture except for a sub-sample retained for radiological analysis. To address the recapture rate of sublegal lobster (<81 mm CL) we tagged a percentage of the sublegals each sampling trip rotating between the three sampling areas. We tagged legals (≥ 81 mm CL) last year and found very few were recaptured in our pots; none were tagged this year. We used a coded yellow cinch tag placed proximal to the dactyl portion of the lobster's left claw.

Bottom Trawling

To monitor the nearshore groundfish community in the Pilgrim area, we continued small vessel (5 m) bottom trawling. Four permanent stations were sampled biweekly during the daytime (Figure 3). Trawling in the impact areas was conducted at surveillance stations T-3 (Discharge) and T-6 (Intake). The primary reference station was T-1 in Warren Cove, while the other reference site was T-4, northwest of Priscilla Beach. Station selection was based on availability of suitable substrate for trawling, depth, sediment type, and known patterns of the thermal plume.

We opted for duplicate 15-minute tows at each station to obtain fish catch/effort data on groundfish using a 9.8 m Wilcox trawl (9.8 m sweep; 7.0 m headrope; wings of 11.4 cm stretch mesh; fitted with a 6.4 mm stretch mesh cod-end liner). Catch (number) of fish per standard 15-minute tow was our sampling unit

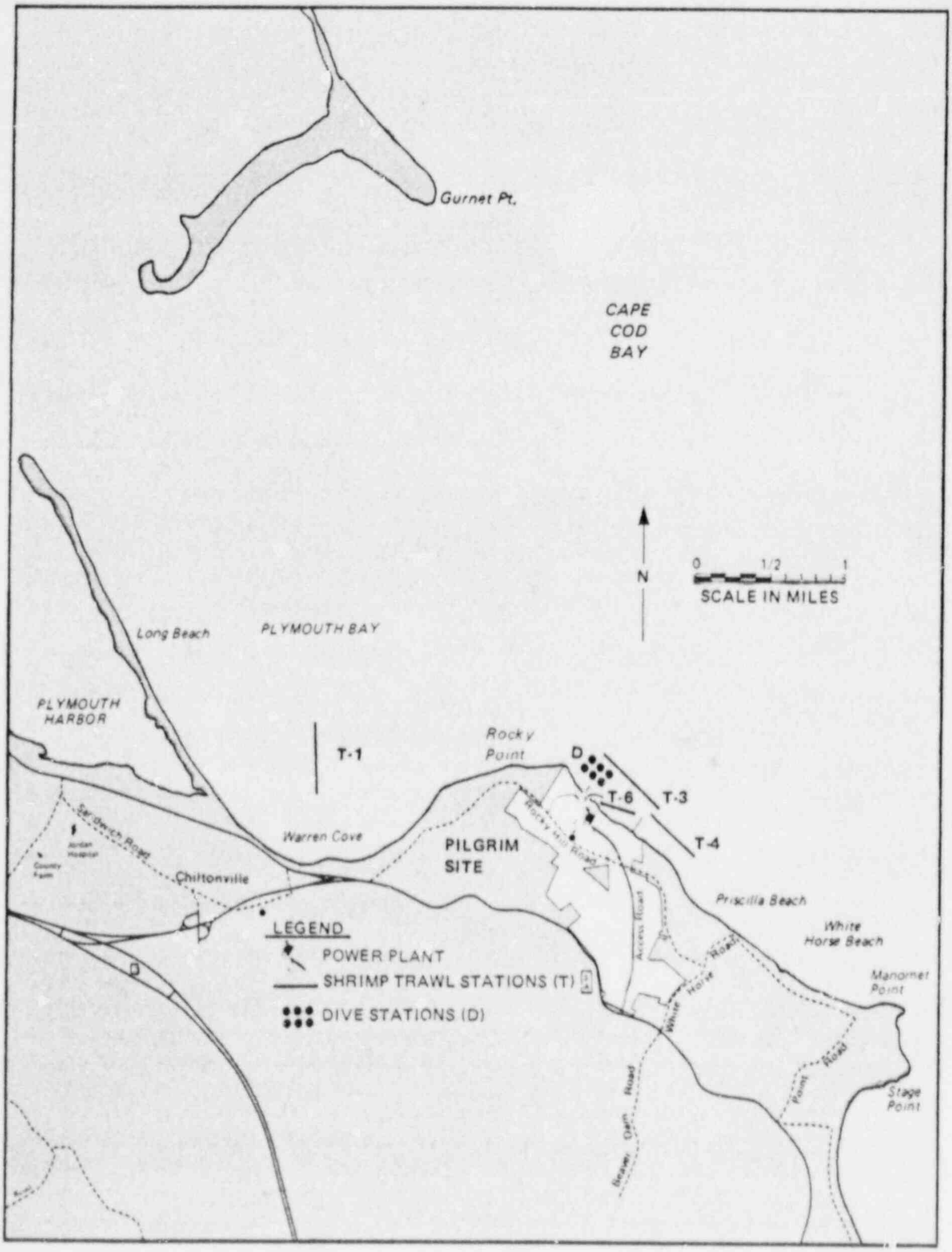


Figure 3. Location of Shrimp Trawl and Dive Sampling Stations for Marine Fisheries Studies.

or catch-per-unit-effort (CPUE), which was used as the index of relative abundance. When uncontrollable factors prevented completion of a standard tow, catch values were extrapolated by using a weighting function.

In processing the catch, standard survey techniques and trawl log sheets were employed. All fish were identified, enumerated, measured, and then returned to the water. Invertebrates were identified and counted; lobster were gauged as to being legal or sublegal in size. Surface and bottom water temperatures were taken during sampling operations at each station.

Gill Net Sampling

Gill net sampling for pelagic and benthi-pelagic fish was conducted at a site located parallel to shore at a depth of 3 m (MLW) near a ledge extending north from the mouth of the discharge canal (Figure 4). The site is located partially within the discharge impact area. An overnight set was made approximately once a month throughout the year. The net was set at sunset and retrieved the next day at sunrise to take advantage of the greater sampling efficiency at night.

A sinking monofilament gill net, 213.4 m long and 3.0 m deep, was anchored and fished the entire water column at low tide. To counter gear selectivity, we fished an experimental net consisting of a single "gang" of seven 30.5 m panels of the following mesh sizes: 3.8, 5.1, 6.4, 7.6, 8.9, 11.4, and 15.2 cm - stretch measure. To further reduce sampling bias, the end of the net positioned to the discharge canal was reversed on

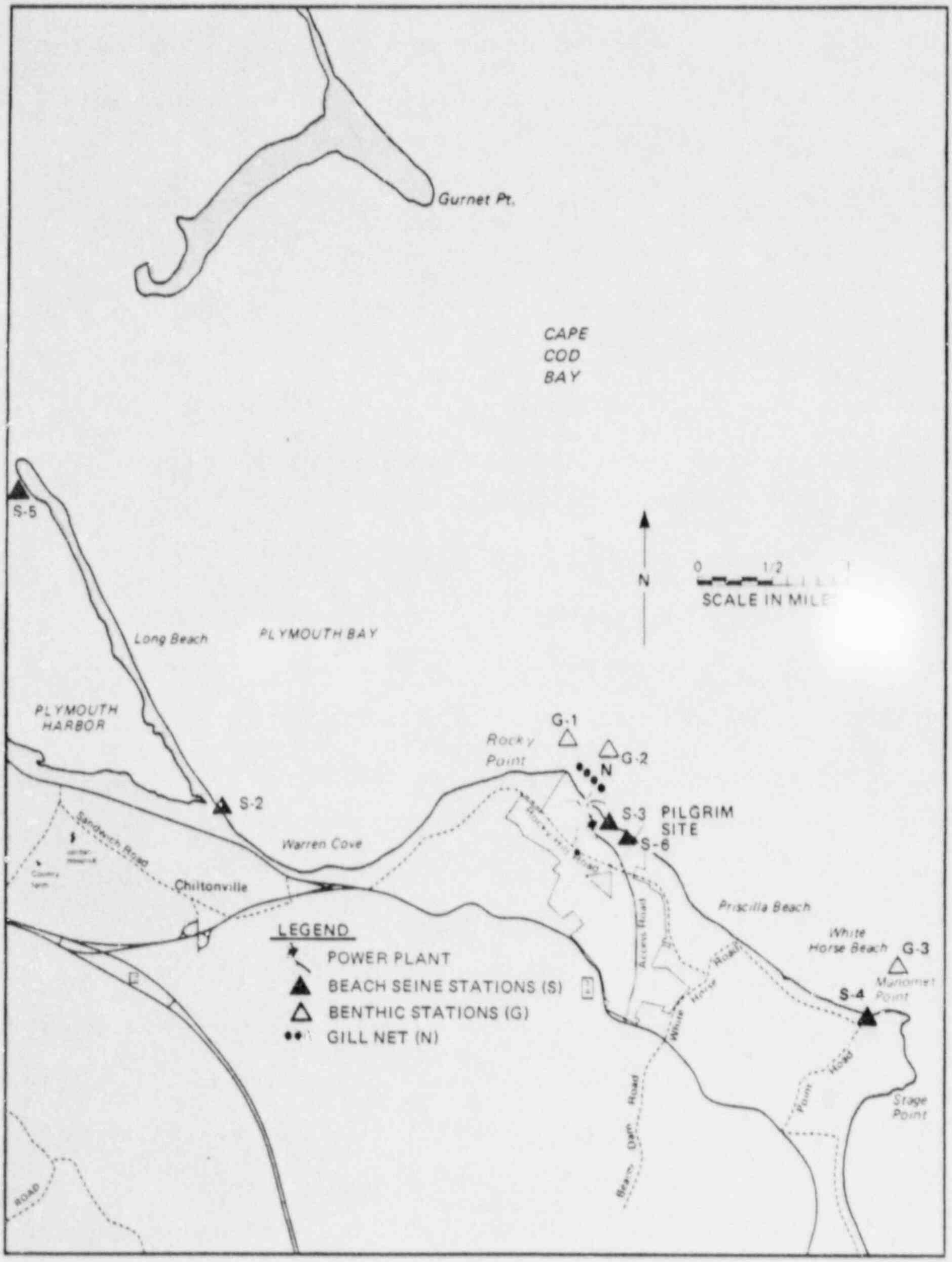


Figure 4. Location of Beach Seine and Gill Net Sampling Stations for Marine Fisheries Studies.

alternate sets. Surface and bottom water temperatures were taken when the net was set and hauled.

Our objectives were to provide collections of fish for radiation analysis and to obtain records of relative abundance for correlation analysis with plant operation.

Haul Seining

To countervail the selectivity of bottom trawling and gill netting, we sampled shallow water habitats, i.e., the intertidal and shallow subtidal zones, by haul seining. Fishes occurring along the shoreline included forage species and the juveniles of many important sport and commercial species. Six stations were seined during the daytime on a weekly schedule from June-November (Figure 4). Winter/early spring sampling was omitted because cold water temperatures reduce fish distribution in shoal waters.

We adopted a standardized quantitative seining technique, modified after Conover and Ross (1982). The net used at Stations 2, 4, and 5 was a 45.7 x 1.8 m haul seine with a 1.8 x 1.8 x 1.8 m bag of 0.48 cm square mesh (twine #63). Duplicate hauls were usually made at each site. Sampling was conducted within ± 2 hours of low tide. Surface water temperature and salinity were measured at the time of sampling.

At the surveillance site (Station 3 - Intake), sampling was constrained by the limited sampling area and by depth. To alleviate this problem, we are sampling this location with a deeper seine set from a small outboard-powered skiff; the net measures 45.7 x 3.0 m with a 3.0 x 3.0 x 3.0 m pocket of 0.48 cm square mesh (twine #63). Sampling was carried out within ± 2 hours of low tide.

Using a smaller seine (6.1 x 1.8 m with no bag of 0.48 cm square mesh), we sampled Stations 1-6 at both high and low tides. The larger seines are effective sampling pelagic fish, while the smaller seine with a double lead weighted line was designed to capture demersal fish.

At the beginning of each set, area (m^2) and volume (m^3) of water seined was estimated from the depth and linear distance of the net from shore. Fish were enumerated and measured; length data were obtained by measuring up to 50 individuals of each species caught. Unusually large catches were subsampled to reduce mortality. An estimate of the total number of individuals caught was made by multiplying the subsample ratio (individuals per unit volume) by the total number of volume-units in the catch. Mean catches were calculated for numerically dominant species at each station.

Observational Diving

The underwater finfish observational program included standardized inspection of six permanent stations undertaken by biologist-divers using SCUBA (Figure 3). Two stations were in the area denoted as 'denuded', two in the 'stunted' zone, and two were control sites as defined by Boston Edison Company (1980). Dives were made at 2-week intervals from May through mid-August, weekly from then until mid-September, and then biweekly through October. During each dive, two divers descended to the bottom and occupied each station consecutively, recording visual observations of marine biota, with major emphasis on fish identification, numbers, and approximate sizes. Bottom water temperatures were taken with a hand-held thermometer, and visibility estimates were made with a Secchi disk. This study provided direct visual observations of fish numbers, location, behavior, and condition just outside the discharge canal.

Creel Survey

Sportfish catch at Pilgrim Station's Shorefront recreational area in 1987 was monitored by security personnel at the waterfront in a cooperative effort with us to maintain a database on the recreational fishery of the area. A questionnaire was employed daily to record data on number of anglers, location of fishing, weather conditions, and catch by species.

IV. RESULTS AND DISCUSSION

A. HYDROGRAPHY

1. WATER TEMPERATURE

In the inshore area of western Cape Cod Bay, we have recorded ambient water temperatures ranging from -1 C in February to 23 C in August at the surface and -1 C in February to 21 C in September on the bottom. Surface waters begin warming in March or April, and a thermocline forms at between 5 and 10 m in June. Surface to bottom temperature differentials have ranged from 0.5 C to 4.7 C. The highest monthly average water temperature (ambient) for western Cape Cod Bay between 1970 and 1987 was 18.8 C, obtained in September 1974. The maximum surface temperature was recorded in August of both 1973 and 1984 at 23 C. Ambient water temperatures for spring and summer were higher in the nearby estuary - Plymouth, Kingston, Duxbury Bay - reaching 25 C in the shallows during summer. Temperatures in Pilgrim Station's thermal plume, with the plant fully operational, have peaked at 32 C (surface and bottom).

During the last five years (1983-1987), surface water temperatures, overall, were highest in 1983 and 1985; on the whole, temperatures were somewhat lower in 1986. Most noteworthy was the markedly lower temperatures found during all seasons of 1984 in the Pilgrim area. A plot of bottom water temperatures for the spring is especially insightful (Figure 5). Cooler springs are indicated for 1984 and 1987. It is likely that lower commercial lobster catch rates in western Cape Cod Bay in 1984 and 1987 were related to reduced molt probability and resultant lower recruitment caused by these cooler spring temperatures.

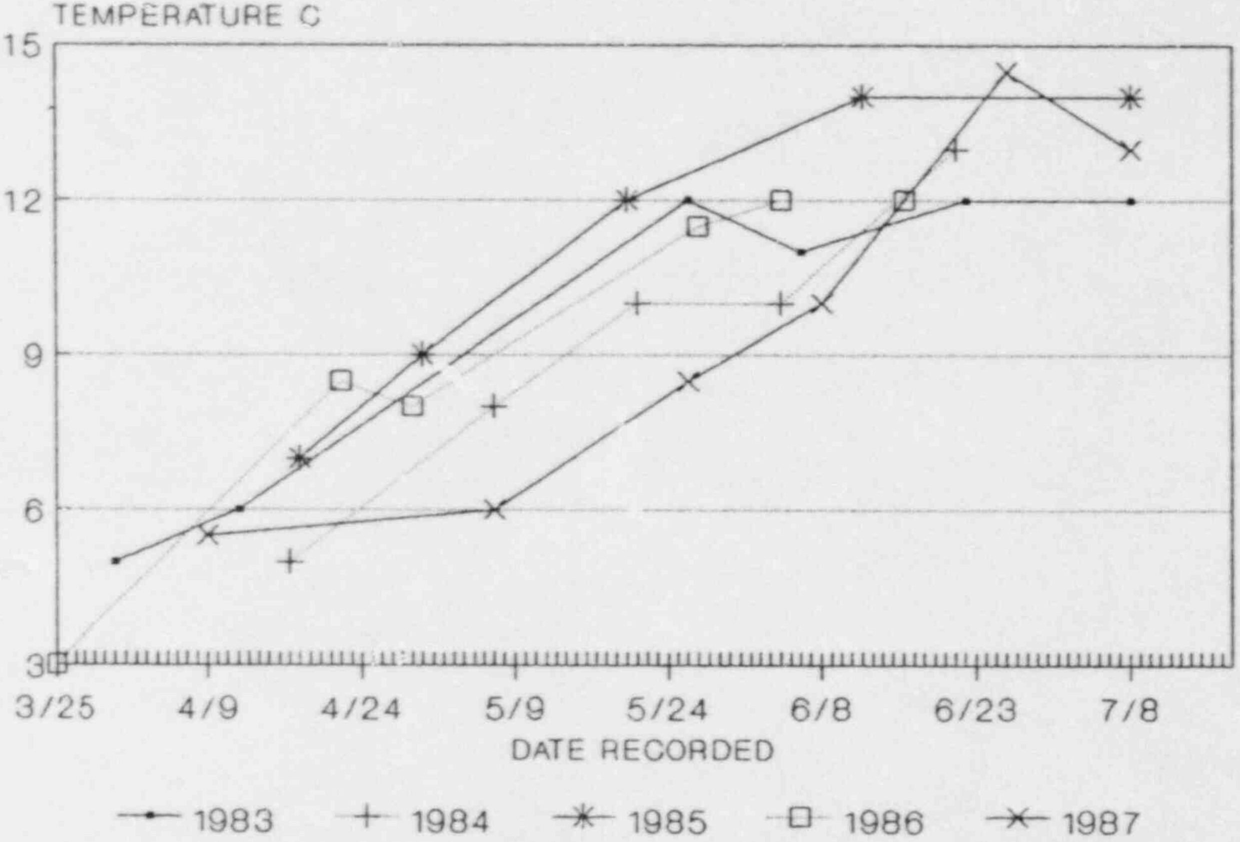


Figure 5. Bottom water temperatures (ambient) recorded in the environs of Pilgrim Station during spring, 1983-1987.

2. SALINITY

Surface salinities in the Pilgrim area ranged from 29 to 32 ‰ indicating minimal influence of freshwater drainage from watersheds. There was little variation among stations sampled with the average salinity being 31‰. Efficient tidal flushing in Cape Cod Bay accounts for the small salinity variation within the Bay as is true with the waters of Massachusetts Bay and the Gulf of Maine (Davis 1984).

B. FISHERIES

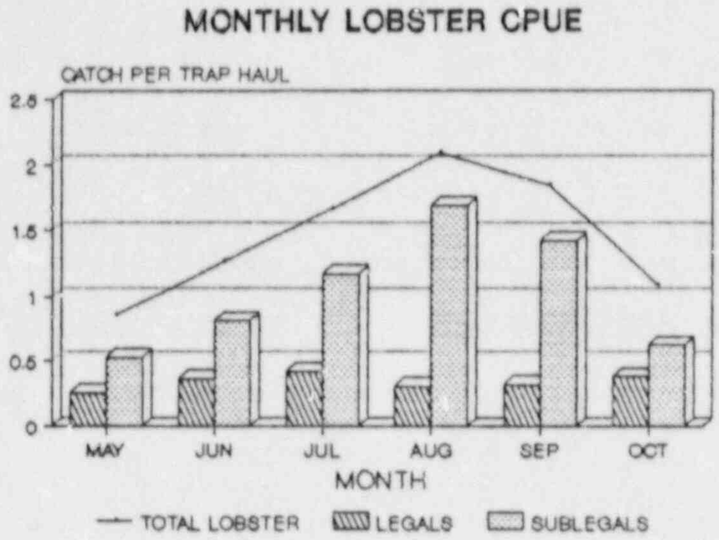
1. COMMERCIAL LOBSTER POT-CATCH FISHERY

Monitoring the commercial American lobster (*Homarus americanus*) fishery in the Pilgrim study area began 15 May and concluded 27 October, 1987. Lobster catch statistics and biological data (i.e., length, sex, shell hardness) were collected for the 6-month investigation during 11 sampling trips aboard a commercial lobster boat. Data were recorded for 2,658 lobster taken from 1,818 lobster pot-hauls.

Overall catch per pot for all lobster (legal, sublegal, and ovigerous females ≥81 mm) for the Pilgrim area was 1.5, down from last year's CPUE of 2.2. This decrease in catch rate was due in part to our change in sampling strategy in 1987. We no longer monitor the catch of a second lobsterman, who fished deeper waters in the Pilgrim area and traditionally has caught more lobster than the individual whose catch we are still sampling.

Twenty-three percent (609) of the total catch were legal lobster for an annual legal catch rate of 0.33 lobster/trap-haul. The lowest monthly legal catch rate occurred in May (0.26), and the highest of 0.42 in July (Figure 6). This atypical trend in monthly legal CPUE is attributed to the unusually cold bottom water temperatures in the spring of 1987 (Figure 5), which potentially effects inshore lobster abundance. The monthly catch rate of sublegal lobster paralleled that of the overall lobster CPUE, while monthly legal CPUE appeared independent of total catch.

Females comprised 54% of the annual catch (1.2 female to 1.0 male) and dominated in every month of the study. There were 65



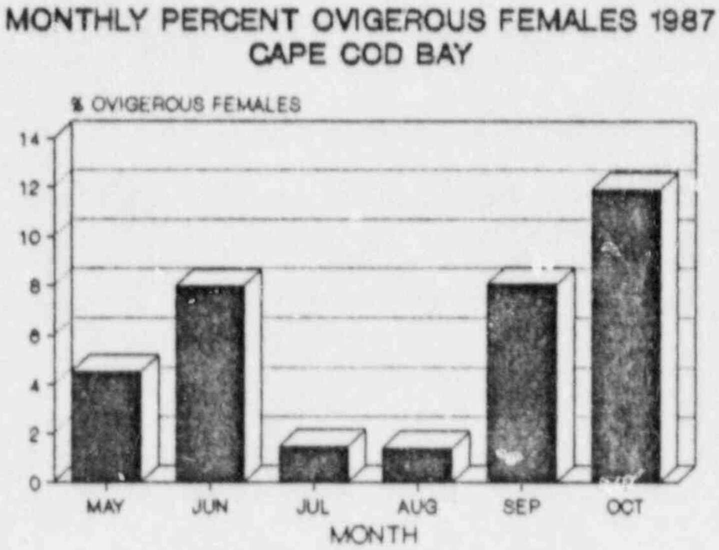


Figure 6. Monthly lobster catch per trap haul and percent ovigerous females in the Pilgrim area, 1987.

ovigerous (egg-carrying) females sampled (2.4% of the entire catch), of which 30 (2.1% of all females) were less than 81 mm in carapace length. The overall percentage of ovigerous females was greatest in June (7.9%) and October (11.9%) and lowest in summer (1.4% in July and August) (Figure 6). The seasonality of ovigerous females is typical of the two-year reproductive cycle of the American lobster (Aiken and Waddy 1982). Female lobster generally breed after the summer molt, but do not extrude fertilized eggs until fall of the following year. The eggs are then carried throughout the winter and hatch out in the spring.

2. <u>RESEARCH LOBSTER TRAP FISHING</u>

During the period 20 June through 29 September, 1987, we conducted controlled research lobster fishing in the environs of Pilgrim Station (Figure 2). Forty-six sampling days were completed, during which 5449 lobster were sampled from 2282 trap hauls. The samples were predominantly composed (86.9%) of sublegals (< 81 mm carapace length - CL). Of the total catch, only 712 lobster were legal-sized (≥ 81 mm CL), with a ratio of sublegal to legal of 6.7:1. The number caught per trap-haul ranged from 0 to 15, with legals ranging from 0 to 4 and sublegals, 0 to 8; in 19% of the trap-hauls no lobster were caught.

In 1986, we tagged legal-sized lobsters in order to determine their recapture rate in our pots; recaptures could then be discounted and an unbiased estimate of catch obtained. In 1987, we tagged sublegal lobsters to assess the magnitude of recapture. A total of 488 sublegals (10% of the sublegal catch) were tagged and released over the course of the summer. Only four (0.8%) of the sublegals tagged were recaptured in our gear. Although, we did not solicit returns from other lobstermen, a few tags were returned, all from the immediate area of the study. As a result of the two years of tagging data, we feel that catch rate need not be adjusted for recapture.

The overall mean CTH (catch-per-trap-haul) for lobster of all sizes and both sexes in 1987 was 2.1, somewhat higher than last year's 1.2. The mean catch rate for sublegal lobster (1.9) was also up from 1986 (0.2);CTH of legal lobster was 0.3 in 1987 and 1.0 in 1986.

Males comprised 52.3% of the research catch with an overall sex ratio of 1.1:1 (males to females). In the commercial catch for western Cape Cod Bay , conducted primarily in deeper waters further from shore, females (60.5%) dominated (Bruce Estrella, personal communication)[1] at a ratio of 1.5:1 (females to males). Our finding of a higher percentage of males in the inshore experimental program parallels research in Long Island Sound (Briggs and Muschacke 1979), where males were found to predominate in shoal waters. We captured 20 egg-bearing (ovigerous) females, only 0.4% of the total catch of females; of these, 8 (40%) were sublegal. The percent females ovigerous in the commercial catches of the area was 2.4%, with 46% sublegal.

Carapace lengths of the lobster sampled in the experimental study ranged from 22 -123 mm. Mean carapace length was 72.9 mm, nearly identical to the 1986 value of 72.7. Further, comparison of length-frequency histograms from 1986 and 1987 (Figure 7) reveals that size composition of the catch for both years also

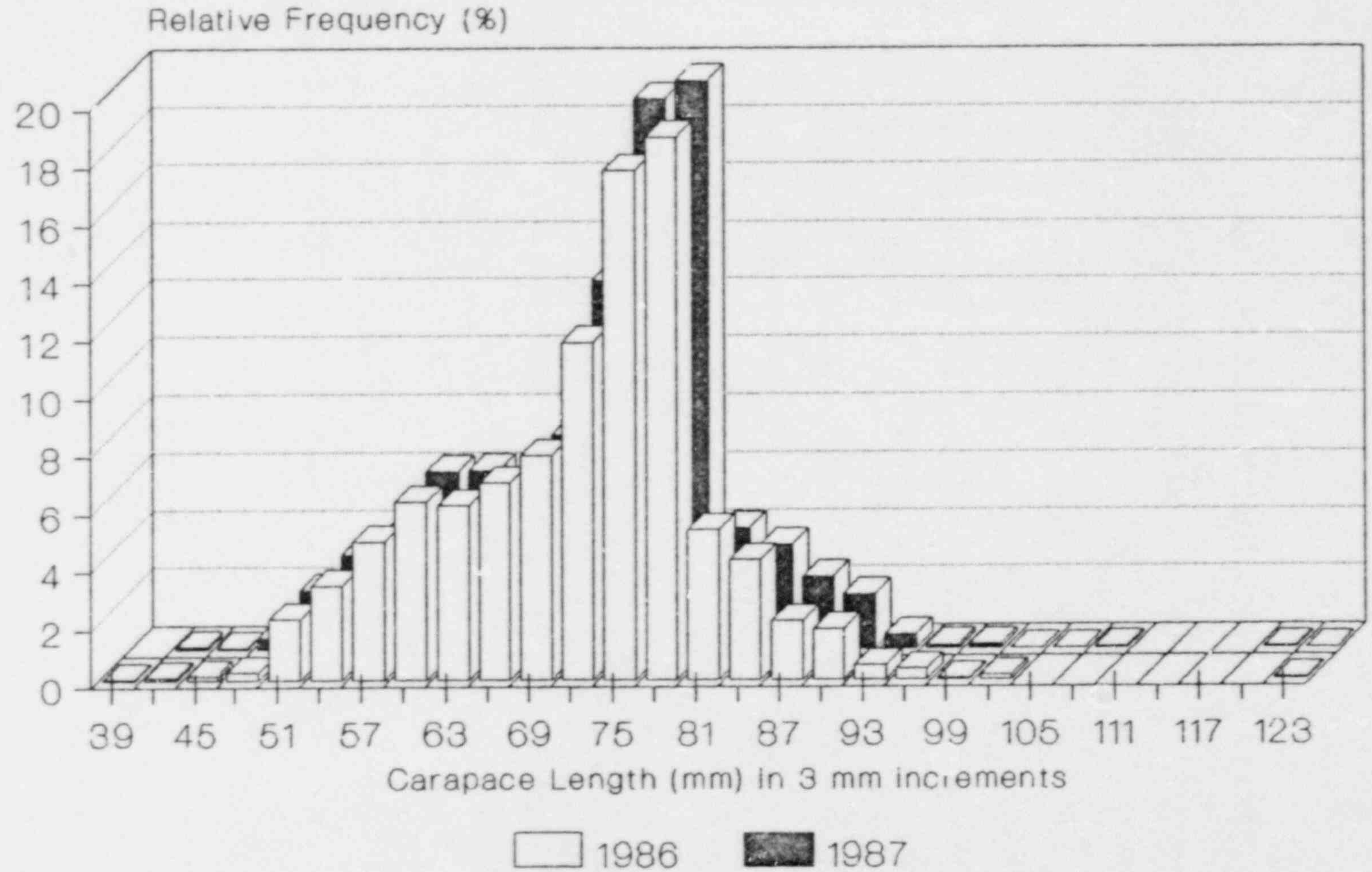


Figure 7. Size distribution of lobster captured in the research trap fishery off Pilgrim Station in 1986 and 1987.

was nearly identical. Kelly et al. (1987) reported that some of the characteristics that may influence size composition were pot design, fishing pressure, and habitat characteristics. With these factors held constant between 1986 and 1987, the closely matched size compositions suggest good precision in our sampling program.

The percentage of culls (this category includes lobster with both missing and regenerating claws) sampled in research fishing was 20%, which is representative of region in that the cull rate in the commercial catches was 21.4%. Both of these estimates are identical to 1986 values (Kelly et al. 1987), suggesting a leveling off of the trend for increasing numbers of culls reported for coastal Massachusetts by Estrella and McKeirnan in 1986.

3. NEARSHORE BENTHIC FINFISH

We completed 107 bottom trawls in the study area in 1987. No samples were collected in February and April due to adverse weather conditions. A total of 2,450 fish, representing 30 species, was collected in 1987 (Table 1). A species check list (Robins et al. 1980) with scientific names is found in Table 2, which includes all fish observed or collected by all gear types in the study area in 1987. Four groundfish - winter flounder, little skate, windowpane, and northern searobin - comprised 86% of the 1987 trawl catch. The average catch per tow (CPUE) for all species and stations pooled was 22.9. The surveillance stations -

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[1]B. Estrella, Senior Marine Fisheries Biologist, Coastal Lobster Investigations. Massachusetts Division of Marine Fisheries, Sandwich, MA.

Table 1. Expanded catch[1] and percent composition of groundfish captured by bottom trawling at four stations in the vicinity of Pilgrim Station, January-December, 1987.

Species	1 Warren Cove	3 Pilgrim Discharge	4 Priscilla Beach	6 Pilgrim Intake	Totals	% catch
Winter flounder	159.9	212.5	184.6	266.7	823.9	33.6
Little skate	165.6	273.6	210.1	100.3	749.7	30.5
Windowpane	123.7	106.8	102.5	60.3	393.5	16.0
Northern searobin	8.0	30.7	114.0	2.0	154.7	6.3
Yellowtail flounder	1.0	40.5	16.0	10.3	67.9	2.7
Atlantic cod	18.0	14.0	12.0	21.0	65.0	2.6
Winter skate	9.0	16.2	6.5	10.9	42.6	1.7
Butterfish	17.5	1.5	2.0	4.1	25.1	1.0
Atlantic silverside	4.0	5.4	10.1	2.6	22.2	0.9
Longhorn sculpin	1.0	8.2	3.0	3.0	15.2	0.6
Other spp.[2]	23.1	27.1	14.2	26.1	90.5	4.1
Number of species	19	20	19	18	30	
Number of tows	29	29	31	18	107	
Total fish	530.8	736.5	675.0	507.9	2450.3	
Catch/tow	18.3	25.3	21.7	28.2	22.9	
Percent catch	21.6	30.0	27.5	20.7		

[1]Catch rates were expanded for tows less than the standard 15-minute duration.

[2]Represents pooled totals from 20 species of low catch.

Shaded columns are data collected at surveillance stations.

Table 2. Checklist of finfish species (following classification of Robins et al. 1980) collected or observed in the adjacent waters of Pilgrim Station, 1987.

Class: Chondrichthyes
- Order: Squaliformes
  - Family: Carcharinidae - requiem sharks
    - _Mustelus canis_ (Mitchill) - smooth dogfish
  - Family: Odontaspididae - sand tigers
    - _Odontaspis taurus_ (Rafinesque) - sand tiger
  - Family: Squalidae - dogfish sharks
    - _Squalus acanthias_ (Linnaeus) - spiny dogfish
- Order: Rajiformes
  - Family: Rajidae - skates
    - _Raja erinacea_ (Mitchill) - little skate
    - _Raja ocellata_ (Mitchill) - winter skate

Class: Osteichthyes
- Order: Clupeiformes
  - Family: Clupeidae - herrings
    - _Alosa aestivalis_ (Mitchill) - blueback herring
    - _Alosa sapidissima_ (Wilson) - American shad
    - _Alosa pseudoharengus_ (Wilson) - alewife
    - _Brevoortia tyrannus_ (Latrobe) - Atlantic menhaden
    - _Clupea harengus harengus_ (Linnaeus) - Atlantic herring
  - Family: Engraulidae - anchovies
    - _Anchoa mitchilli_ (Valenciennes) - bay anchovy
- Order: Salmoniformes
  - Family: Salmonidae - trouts
    - _Oncorhynchus kisutch_ (Walbaum) - coho salmon
  - Family: Osmeridae - smelts
    - _Osmerus mordax_ (Mitchill) - rainbow smelt
- Order: Gadiformes
  - Family: Gadidae - codfishes
    - _Gadus morhua_ (Linnaeus) - Atlantic cod
    - _Melanogrammus aeglefinus_ (Linnaeus) - haddock
    - _Merluccius bilinearis_ (Mitchill) - silver hake
    - _Microgadus tomcod_ (Walbaum) - Atlantic tomcod
    - _Pollachius virens_ (Linneaus) - pollock
    - _Urophycis chuss_ (Walbaum) - red hake
    - _Urophycis tenuis_ (Mitchill) - white hake
  - Family: Zoarcidae - eelpouts
    - _Macrozoarces americanus_ (Bloch and Schneider) - ocean pout

Order: Gasterosteiformes

Family: Gasterosteidae - sticklebacks

Gasterosteus aculeatus (Linnaeus) - 3-spine stickleback

Family: Syngnathidae - pipefishes and seahorses

Syngnathus fuscus (Storer) - northern pipefish

Order: Atheriniformes

Family: Atherinidae - silversides

Menidia menidia (Linnaeus) - Atlantic silverside

Family: Scomberesocidae - sauries

Scomberesox saurus (Walbaum) - Atlantic saury

Family: Cyprinodontidae - killifishes

Fundulus majalis (Walbaum) - striped killifish

Order: Perciformes

Family: Percichthyidae - temperate basses

Morone saxatilis (Walbaum) - striped bass

Family: Serranidae - sea basses

Centropristes striata (Linnaeus) - black sea bass

Family: Pomatomidae - bluefishes

Pomatomus saltatrix (Linnaeus) - bluefish

Family: Scombridae - mackerels and tunas

Scomber scombrus (Linnaeus) - Atlantic mackerel

Family: Sparidae - porgies

Stenotomus chrysops (Linnaeus) - scup

Family: Sciaenidae - drums

Menticirrhus saxatilis (Bloch and Schneider) northern kingfish

Family: Labridae - wrasses

Tautoga onitis (Linnaeus) - tautog

Tautogolabrus adspersus (Walbaum) - cunner

Family: Pholidae - gunnels

Pholis gunnellus (Linnaeus) - rock gunnel

Family: Stromateidae - butterfishes

Peprilus triacanthus (Peck) - butterfish

Family: Triglidae - searobins

Prionotus carolinus (Linnaeus) - northern searobin

Family: Cottidae - sculpins

Hemitripterus americanus (Gmelin) - sea raven
Myoxocephalus aenaeus (Mitchill) - grubby
Myoxocephalus octodecemspinosus (Mitchill) - longhorn sculpin
Myoxocephalus scorpius (Linnaeus) - shorthorn sculpin

Family: Cyclopteridae - lumpfishes and snailfishes

Cyclopterus lumpus (Linnaeus) - lumpfish
Liparis atlanticus (Jordan and Evermann) - seasnail

Family: Ammodytidae - sand lances

Ammodytes sp.

Order: Pleuronectiformes

Family: Bothidae - lefteye flounders

Paralichthys dentatus (Linnaeus) - summer flounder (fluke)
Paralichthys oblongus (Mitchill) - fourspot flounder
Scophthalmus aquosus (Mitchill) - windowpane

Family: Pleuronectidae - righteye flounders

Limanda ferruginea (Storer) - yellowtail flounder
Pseudopleuronectes americanus (Walbaum) - winter flounder

Order: Lophiiformes

Family: Lophiidae - goosefishes

Lophius americanus (Valenciennes) - goosefish

Order: Tetraodontiformes

Family: Tetraodontidae - puffers

Sp.?

the Intake embayment (Station 6) and by the power plant discharge canal (Station 3) - yielded the highest CPUE's of 28.2 and 25.3 (pooled species), respectively.

Winter flounder

Winter flounder ranked first in catch (34%, all stations pooled) for the study area, but was second to little skate at three of the four stations. The mean CPUE for all stations combined declined slightly from last year's value of 9.0 to 7.7. Station 6 ranked first in winter flounder catch abundance with an annual mean CPUE of 14.8; Station 1 (reference) was last with an annual mean CPUE of 5.5 (Table 3).

Winter flounder seasonal trawl catch rates at each station (Figure 8) followed a similar pattern of lowest catches in winter, peak catches in spring, fairly high summer catches, followed by reduced catches in the fall (with the exception of Station 1, when the nadir occurred in fall). Station 6 was highest in CPUE for every season except winter.

Little skate

Little skate ranked second, comprising 30% of the overall total catch. Mean annual catch per tow of little skate for all stations pooled was 7.0, as compared with 9.6 in 1986. As in 1986, this species was the dominant finfish trawled at all stations except in the Intake embayment. The highest annual station catch rate of 9.4 occurred at the Discharge site , while the Intake had the lowest annual CPUE of 5.5 (Table 3).

Catch rates for little skate exhibited a similar overall seasonal pattern at each station: very low values in winter, peak catches in spring, the beginning of a decline in summer, followed

Table 3 . Bottom trawl catch data for dominant groundfish in the vicinity of Pilgrim Station, January-December, 1987.

	Winter flounder	Little skate	Windowpane
STATION 1			
Mean catch/tow*	5.5	5.7	4.2
Mean size (cm)	28.7	39.9	25.7
Size range (cm)	11-40	14-51	15-31
STATION 3			
Mean catch/tow *	7.3	9.4	3.6
Mean size (cm)	28.7	35.2	22.0
Size range (cm)	8-40	12-54	13-31
STATION 4			
Mean catch/tow*	5.9	6.7	3.3
Mean size (cm)	30.1	37.9	21.5
Size range (cm)	11-44	19-55	11-31
STATION 6			
Mean catch/tow*	14.8	5.5	3.3
Mean size (cm)	27.6	37.9	21.4
Size range (cm)	4-45	18-54	11-35

*Catch rates were expanded for tows less than the standard 15-minute duration.

Shaded rows are data collected at surveillance stations.

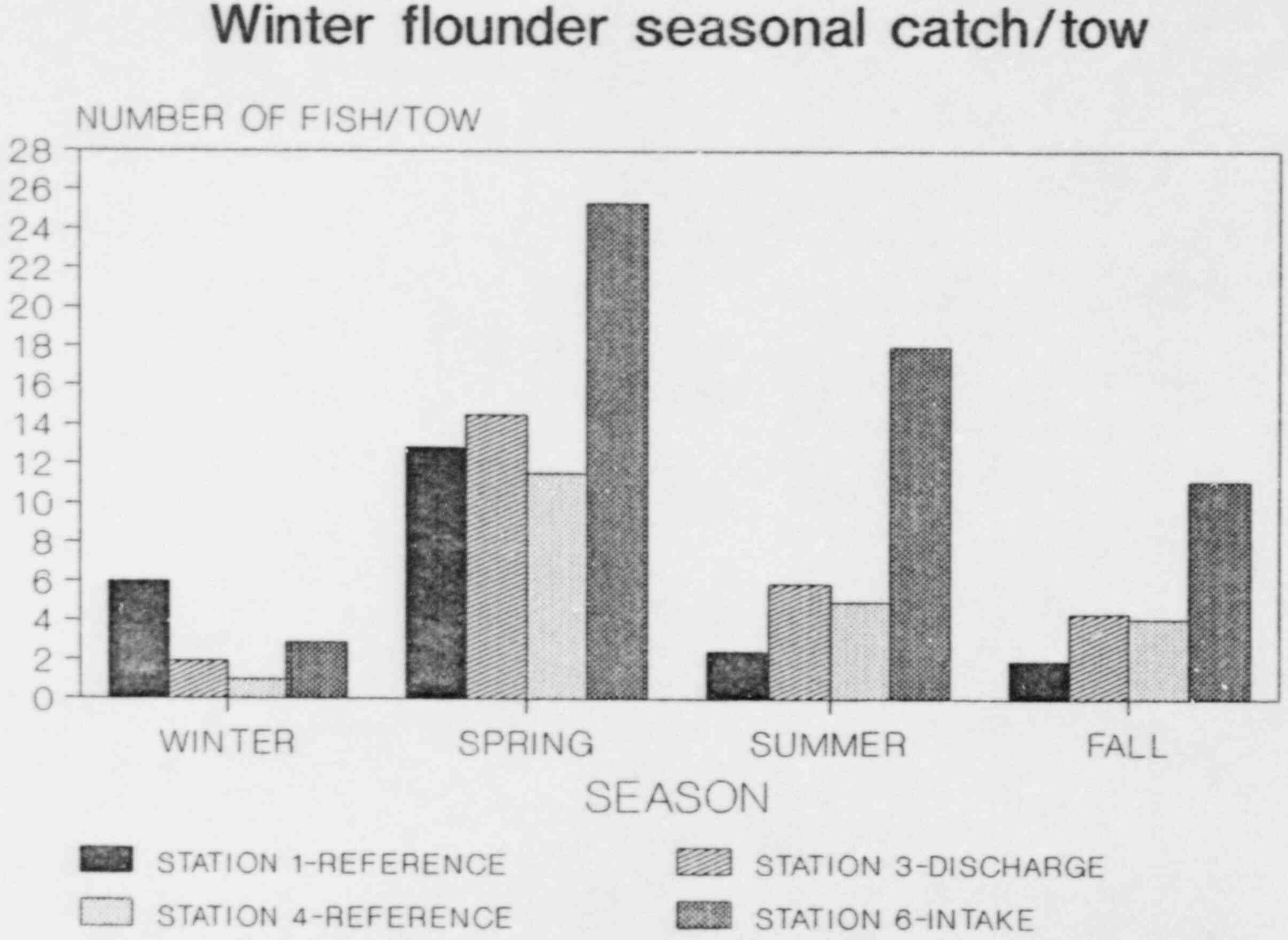


Figure 8. Seasonal mean trawl catch rates for winter flounder by station in Pilgrim area, 1987.

by a marked decline in fall (Figure 9). In the spring, little skate were most abundant in the Intake (18.5), but in the summer relative abundance was highest in the Discharge area (14.5).

Windowpane

Windowpane was third overall in annual trawl catch (16%) for the fifth consecutive year. The mean annual CPUE for all stations combined was 3.7, down from 4.6 in 1986. The highest annual CPUE for windowpane (4.2) was recorded at Station 1 in Warren Cove for the fifth consecutive year. The indices at the other stations ranged from 3.3 - 3.6 (Table 3). Seasonally, windowpane were generally absent from winter groundfish catches (Figure 10). Catches were by far the highest in spring, followed by reduced abundances in summer/fall.

Northern sea robin

Northern sea robin was fourth in trawl catch, with an overall CPUE of 1.4. However, 86% of the total harvest was captured during one day in May. The occurrence of this species was extremely sporadic.

Yellowtail flounder

Yellowtail flounder ranked fifth in annual relative abundance for the fourth consecutive year. The annual mean CPUE (0.6) for all stations pooled was similar to last year's rate. This flatfish was slightly more abundant at Station 3 than at the other sites sampled.

Atlantic cod

Young-of-the-year Atlantic cod (Gadus morhua) of 3-6 cm length were unusually abundant in this year's catch, comprising 2.6% of the annual trawl total. These small cod were captured in

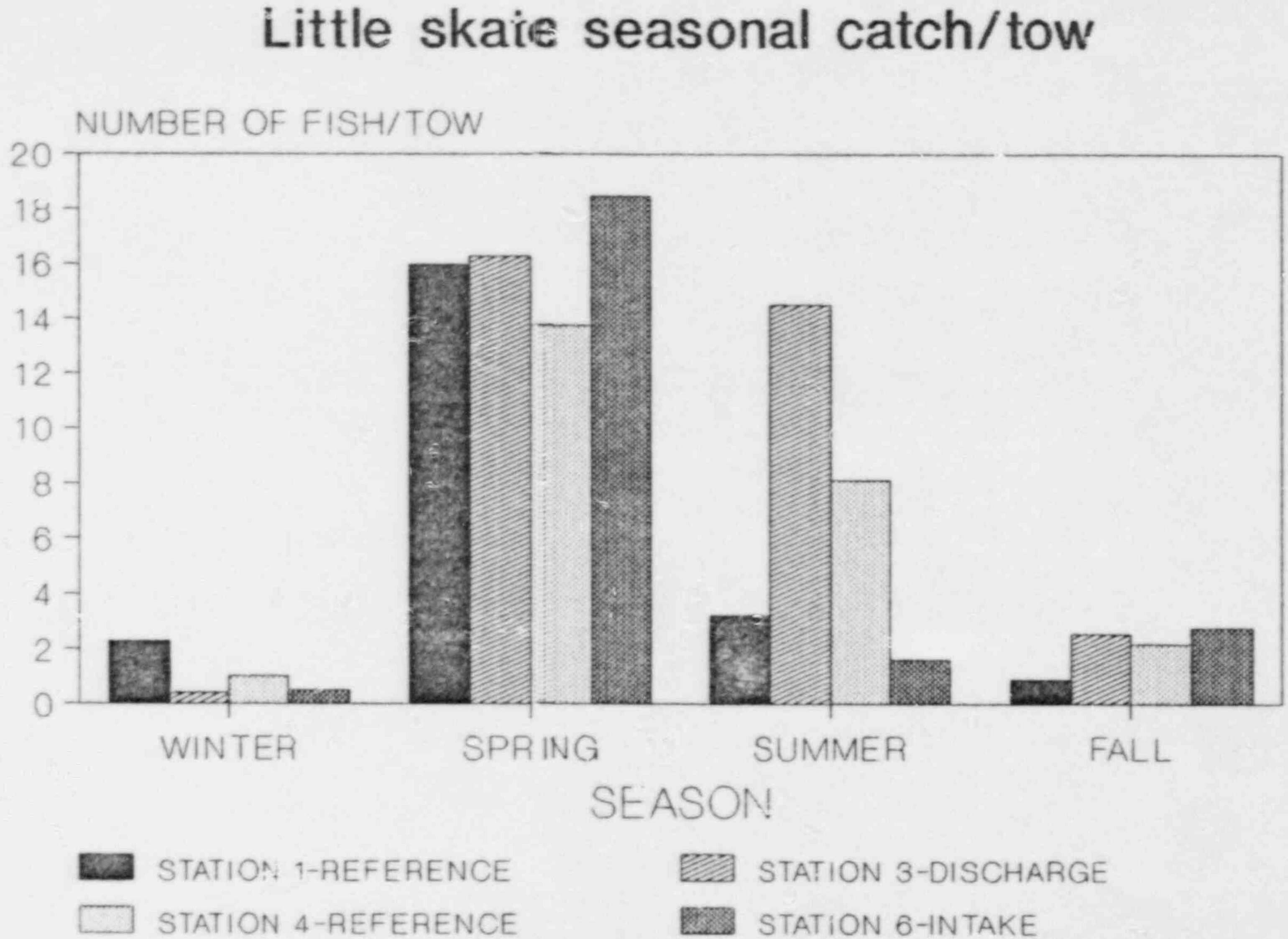
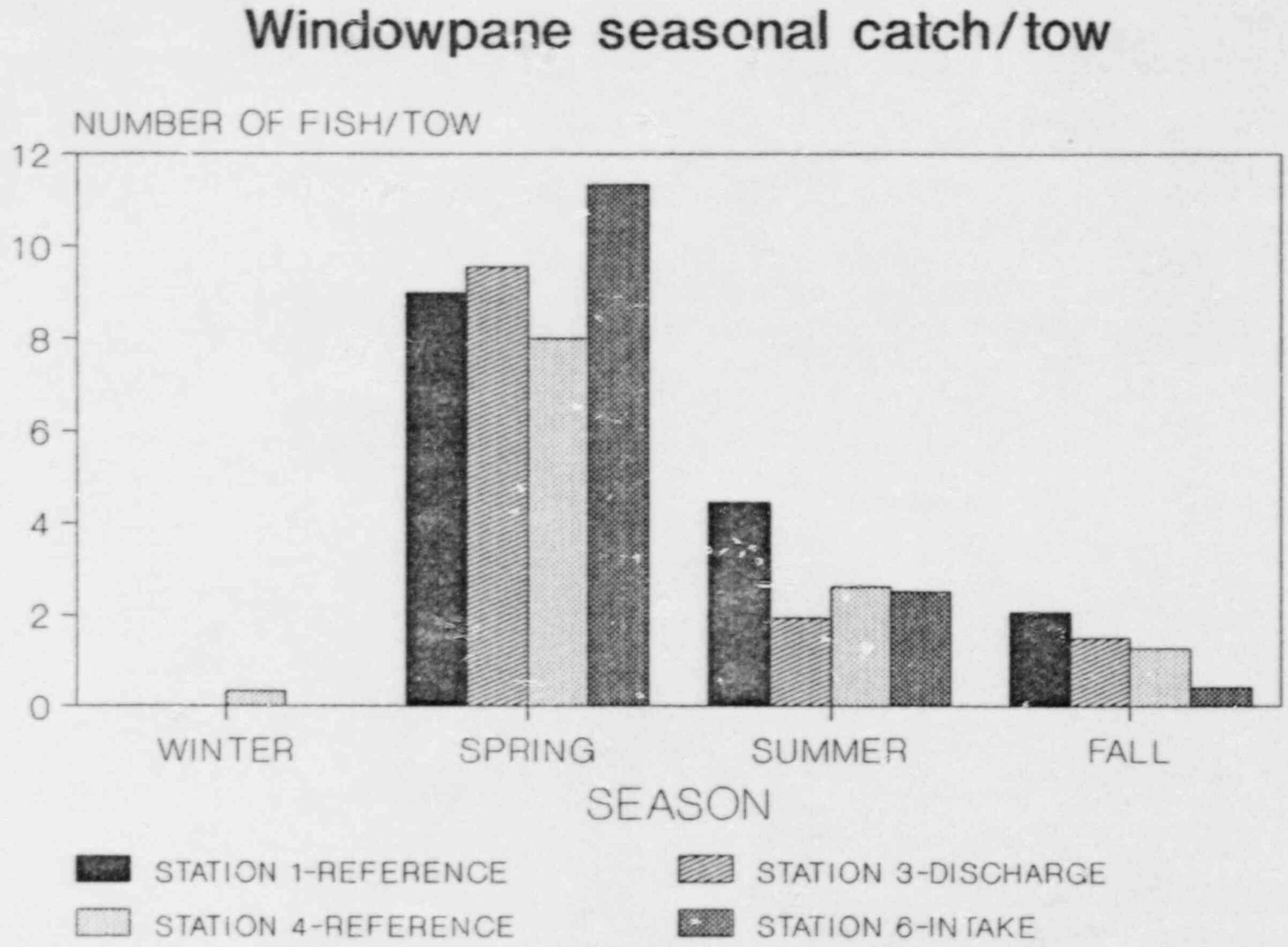


Figure 9. Seasonal mean trawl catch rates for little skate by station in Pilgrim area, 1987.



Figue 10. Seasonal mean trawl catch rates for windowpane by station in Pilgrim area, 1987.

September and October at all stations.

4. PELAGIC AND BENTHI-PELAGIC FISHES

A total of 2578 fish, comprising 32 species was gill-netted during 12 sets made in 1987 (Table 4). No sampling was conducted during January and February due to inclement weather. A sudden storm in December caused the destruction of the net with subsequent loss of data. Annual mean CPUE for pooled species was 189.6 fish/set (Figure 11), a notable increase over last year's 99.6 fish/set. This high rate may be partially the result of the absence of data from January, February, and December, months when colder water temperatures generally result in smaller catches. When averaged into annual catch statistics, the low CPUE's (catch-per-unit-effort) of these months usually cause a lowering of the overall estimate. The unusually large pulse of northern sea robin in May and June undoubtedly also contributed to the higher overall catch rate.

Table 4. Number and percentage composition of selected finfish species captured by gill net (7 panels of 3.8-15.2 cm mesh) in the vicinity of Pilgrim Nuclear Power Station, January-December, 1987.

Species		Number	Percent of total catch
Northern sea robin		904	35.1
Pollock		521	20.2
Atlantic herring		456	17.1
Cunner		166	6.4
Alewife		84	3.3
Tautog		80	3.1
Bluefish		66	2.6
Other*		301	12.2
Total	32 species	2,578	

* The remaining species were not found in abundance.

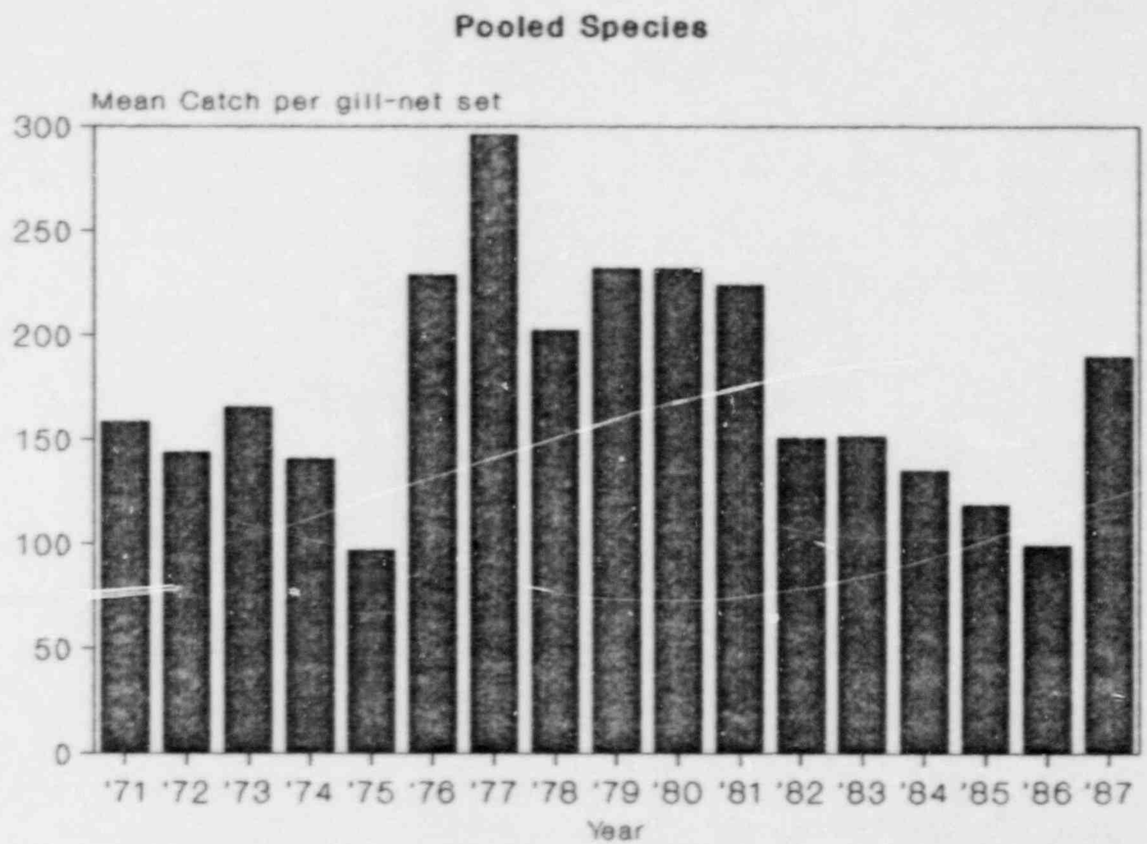


Figure 11. Indices of relative abundance (catch-per-unit-effort) for pooled finfish species captured in Western Cape Cod Bay near Pilgrim Station based on standardized gill net gear.

A new species was added to the project check-list - a sand tiger shark measuring 101 cm, was captured on 16 September. Castro (1983) reports that this species is a common summer visitor to the inshore waters of southern New England.

The dominant species was northern sea robin, comprising 35% of the total catch. Pollock, Atlantic herring, and cunner were the next most abundant species (Table 4), with 20%, 17% and 6% of the total catch, respectively.

Northern sea robin

Although a common component of project gill-net and trawl catches, the extremely large numbers taken by both gear types, gill net in particular, during May (428 fish) and June (391 fish) of this year are best viewed as being an anomaly. During the spring and summer, northern sea robin are commonly taken in the gill-net, but generally in much smaller numbers than in 1987. Bigelow and Schroeder (1953) report that northern sea robin are common visitors to inshore waters during the warmer months. However, beyond basic life history, little appears to be known about their stock size or trends in abundance over time.

Pollock

Comprising 20% of the total catch, pollock was the second most abundant species captured by gill net. Seasonal estimates of abundance using the index of CPUE, were 45.3 and 41.8 fish/set in the spring and summer and 57.7 fish/set in the fall, suggesting a stable, if seasonal, local population during 1987. Comparison of annual trends in CPUE over time (Figure 12), reveal that the 1987 value, 39.6, represents a slight decrease

Pollock

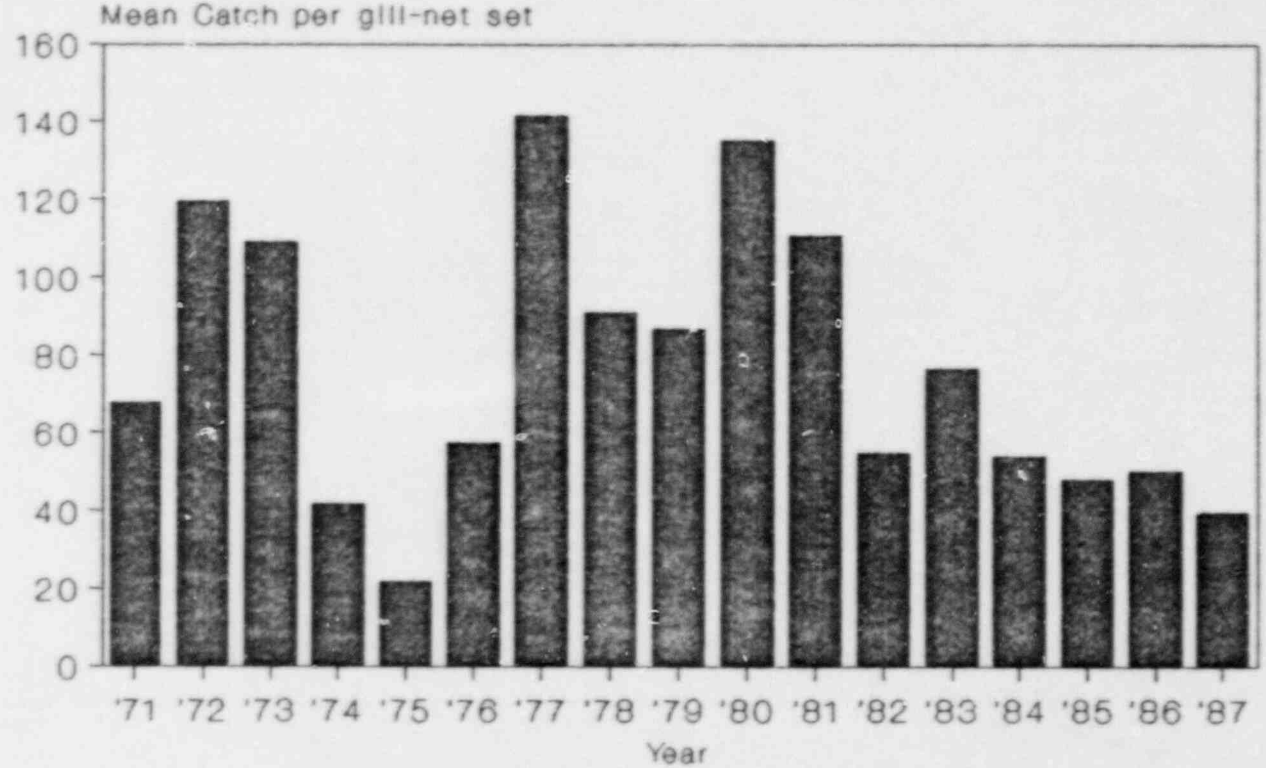


Figure 12. Indices of relative abundance (catch-per-unit-effort for pollock captured in Western Cape Cod Bay near Pilgrim Station based on standardized gill net gear (5 panels of 3.8-8.9 cm mesh) and procedures, 1971-1987.

from previous years' levels. As can be clearly seen, however, fluctuations in local abundance are common and given the migratory nature of this species (Bigelow and Schroeder 1953) are probably reflective of year-class strength (Lawton et al. 1985).

Atlantic Herring

Atlantic herring was third in the dominance hierarchy, comprising nearly 18% of the total catch. With pollock and cunner, herring are a traditional dominant in project gill net records. Like pollock, Atlantic herring are highly migratory (Bigelow and Schroeder 1953) and undergo wide variation in local abundance (Figure 13).

Cunner

Ranked fourth (6.4% of the total), relative abundance of cunner as measured by CPUE was at its lowest point (13.5 fish/set) of the entire study (Figure 14). This level is a continuation of a downward trend noted by Lawton et al. in 1986. As decreased local abundance in the Pilgrim Station area was also noted by project divers, it seems apparent that this trend represents a decline in the local population, perhaps the result of a shift in distribution.

Other species

The remaining species captured by gill net in 1987 were taken in relatively low numbers, with no single species comprising more than 4% of the total catch. Some, such as tautog, are regular visitors to the Pilgrim Station area but have experienced a recent decline in local abundance. Others, such as striped bass and bluefish, have a known affinity for the thermal effluent (Lawton et al. 1978) and generally are more scarce when

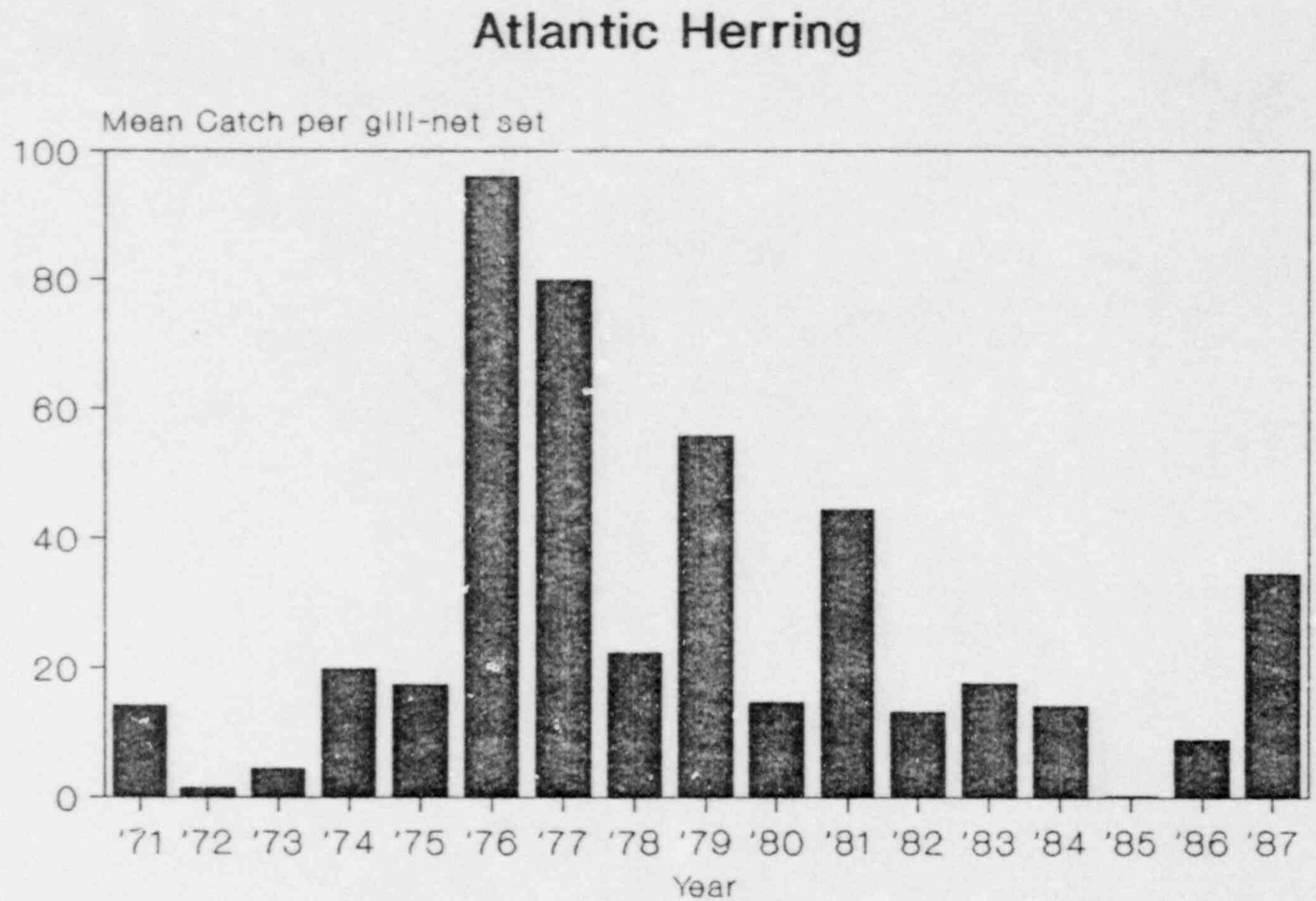


Figure 13. Indices of relative abundance (catch-per-unit-effort) for Atlantic herring captured in Western Cape Cod Bay near Pilgrim Station based on standardized gill net gear (5 panels of 3.8-8.9 cm mesh) and procedures, 1971-1987.

Cunner

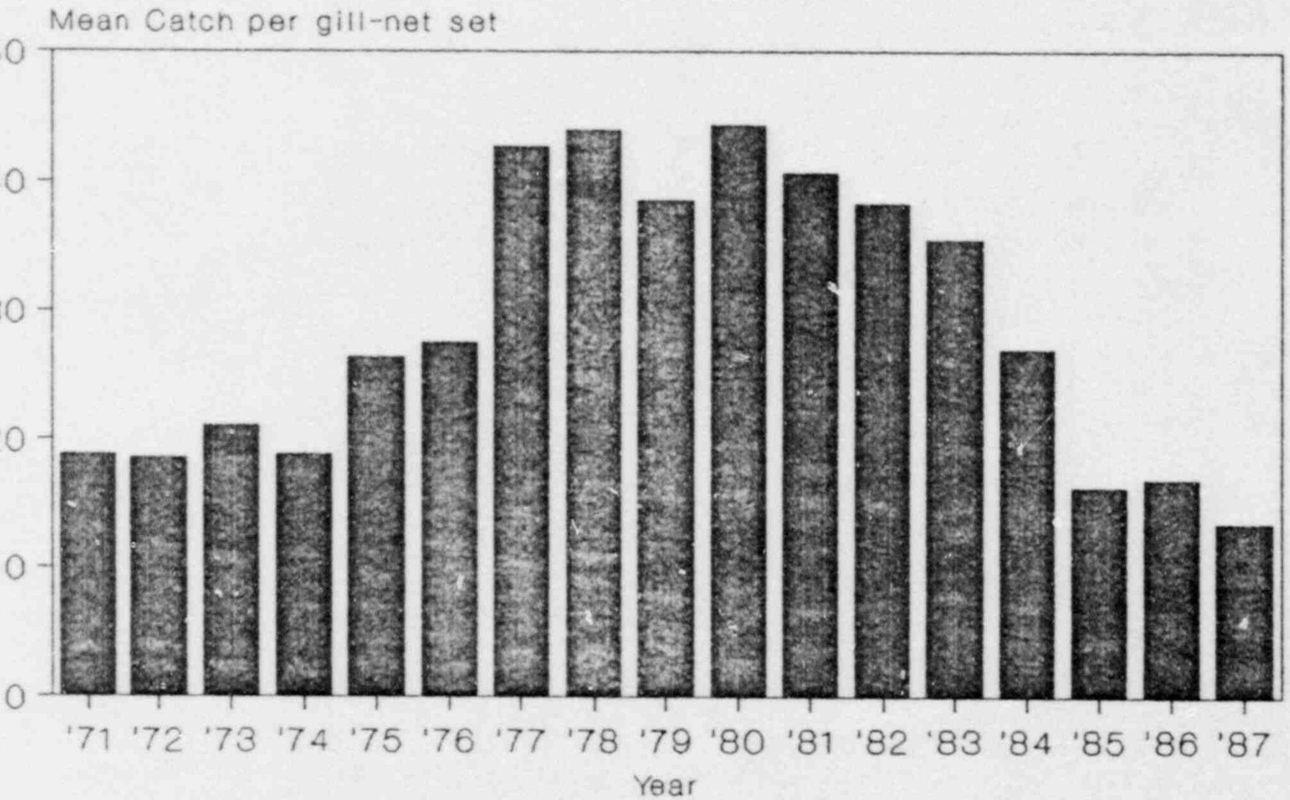


Figure 14. Indices of relative abundance (catch-per-unit-effort) for cunner captured in Western Cape Cod Bay near Pilgrim Station based on standardized gill net gear (5 panels of 3.8-8.9 cm mesh) and procedures, 1971-1987.

the plant is not operational. Most are captured only sporadically and have never occupied positions of dominance in gill-net records.

5. SHORE-ZONE FISHES

A total of 30,146 finfish representing 29 species was captured in the 45.7 meter haul seines from June-November, 1987 (Table 5). The mean catch of finfish per standard seine set for all stations and species pooled increased by a magnitude of 2.4 from 1986. An increase in catch rates (pooled stations) of Atlantic silverside, blueback herring, alewife, and sand lance contributed greatly to the overall increase. Station catch rates pooled by species increased at all sites from last year, with the largest gains at Warren Cove (3.2 fold) and Manomet Point (4.6 fold).

Seine catches were highest overall at Long Point where over 60% of the total was obtained (Table 5). This was primarily a result of the abundance of silversides there. Overall, catches again were relatively low at Manomet Point and Warren Cove. In terms of total fish caught, the Intake station was for the second consecutive year more similar to Long Point, an estuarine location, than to the exposed coastal beach stations at Warren Cove and Manomet Point.

Atlantic silverside

Five taxa - Atlantic silverside, blueback herring, sand lance spp., alewife, and winter flounder - comprised 98% of the overall catch. The Atlantic silverside dominated the catches again as it has every year since the study's inception in 1981,

Table 5. Shore-zone fishes captured by haul seine at four stations in the vicinity of Pilgrim Nuclear Power Station, June-November, 1987. (Shaded column is data from surveillance station).

Species Abundance

pecies	Warren Cove	Pilgrim Intake[1]	Long Point	Manomet Point	Total Number	Percent of total catch
		Station				
tlantic silverside	2602	1416	18433	1117	23568	78.2
lueback herring	25	2515	2	8	2550	8.5
and lance spp.	2	2056	0	4	2062	6.8
lewife	1	1055	22	1	1079	3.6
inter flounder	13	180	25	53	271	0.9
tlantic herring	5	142	2	0	149	0.5
tlantic tomcod	20	64	45	0	129	0.4
orthern pipefish	17	51	37	3	108	0.4
tlantic menhaden	0	53	0	0	53	0.2
indowpane	15	5	20	3	43	0.1
inner	14	19	10	0	43	0.1
ther spp.[2]	14	18	44	15	91	0.3
otal number of fish	2728	7574	18640	1204	30146	
umber of sets	21	20	22	19	82	
atch/set	129.9	378.7	847.3	63.4	367.6	
tal number of species	16	20	19	16	29	
rcent of total catch	9.0	25.1	61.8	4.0		

Species percent frequency of occurrence

Species	Warren Cove	Pilgrim Intake[1]	Long Point	Manomet Point	All Stations Pooled
		Station			
Atlantic silverside	38.1	65.0	68.2	52.6	56.1
Blueback herring	23.8	15.0	9.1	21.1	17.1
Sand lance spp.	4.8	35.0	0.0	10.5	12.2
Alewife	4.8	15.0	13.6	5.3	9.8
Winter flounder	23.8	75.0	54.5	57.9	52.4
Atlantic herring	9.5	10.0	9.1	0.0	7.3
Atlantic tomcod	19.0	10.0	31.8	0.0	15.9
Northern pipefish	14.3	45.0	40.9	10.5	28.0
Atlantic menhaden	0.0	5.0	0.0	0.0	1.2
Windowpane	38.1	15.0	45.5	15.8	29.3
Cunner	9.5	25.0	31.8	0.0	17.1

[1] 45.7 m x 3.0 seine; other sites sampled with 45.7 m x 1.5 m seine

[2] Represents pooled total for 18 species of infrequent occurrence in haul seine.

accounting for 78% of the fish caught. Of the total silverside catch, 78% came from the Intake. This species dominated in both catch-per-unit-effort and percent frequency of occurrence (Table 5) at all sites except Manomet Point, where it ranked second to winter flounder in the latter category. Catch rates for Atlantic silverside were up from 1986 throughout the study area, with the greatest increases at Long Point and the Intake embayment at Pilgrim Station.

<u>Blueback herring</u>

Blueback herring comprised 8% of the total and were captured at all stations. Ninety-eight percent were caught, however, on two sampling days (August 14 and September 15) in the Intake embayment. Although this schooling fish ranked second in numerical abundance, it was fifth in frequency of occurrence; this species' aggregated distribution affects its availability to capture in any year.

<u>Sand lance spp.</u>

Ranked third, sand lance spp. were caught almost exclusively (> 99%) in the Intake, with 94% of the total study catch captured on one June day. Sand lance spend a substantial portion of their time burrowed in sand bottoms, and may undertake seasonal migrations to deeper waters in Cape Cod Bay in winter and summer (Bigelow and Schroeder 1953). The mean catch rate of sand lance at the Intake increased 42% from 1986.

<u>Alewife and winter flounder</u>

Alewife and winter flounder ranked fourth and fifth, respectively, in catch abundance. Alewives were infrequently caught, with the largest catch made in August in the Intake, netting 93% of the year's tally. Winter flounder was second overall in frequency of occurrence, which reflects a relatively ubiquitous distribution. Catch rate for this flatfish was highest at Pilgrim Intake, where it ranked first in percent frequency of occurrence.

Seine catches were highest in August and September, concomitant with the highest water temperatures of the year. This relationship has occurred every year of our seine study. In November, moderate catches were made at the Intake and Long Point stations, with silversides, winter flounder and windowpane still inhabiting the cooler shallow waters of late fall.

Annual species diversity was highest at Pilgrim Intake (20 species) and Long Point (19 species). In terms of percent frequency of occurrence of dominant species, Pilgrim Intake was most like Long Point. Of the 29 species seined in this study, 7 were taken at all stations; by contrast, 12 species were taken only at one station.

In summation, Pilgrim Intake was similar to Long Point in total catch and finfish diversity. Both stations share two characteristics which may account for these similarities in abundance and diversity: they are in semi-enclosed embayments which offer protection from heavy surf, and both possess some degree of vegetation which provides suitable habitat for small fishes. This contrasts with the exposed coastal stations, Warren Cove and Manomet Point, which have little cover and are periodically subject to heavy surf and where species diversity and abundance were lower.

Additional Small Seine Sampling

Using a smaller foot-seine (6 m), and sampling mostly the high tide, a total of 5,317 fish representing 15 taxonomic groups was captured in the shore zone from June-November (Table 6). With little salinity variation (range 29-32‰) amongst stations, temperature was a more important factor governing the seasonal occurrence and abundance of fish along the shoreline.

Overall, catches with the small seine were highest at Long Point (Station 5), including total fish, number of species, and catch per effort. For the entire study area, four taxa contributed over 97% of the catch: Atlantic silverside, sand lance spp., Atlantic menhaden, and blueback herring which each contributed at least three percent to the total percent species composition. The first three taxa were reported as dominants in the shore zone of Long Island Sound at Millstone Point, Connecticut (Birely 1984).

The Atlantic silverside was by far the dominant fish of the shore zone in the Pilgrim area; over three-quarters of the fish captured by all seining operations were silversides. Collected at all seining stations, this species comprised 96% or more of the catch at four of the six sites. Catch per standard seine haul (index of relative abundance) was highest at Long Point (Station 5) at 69 silversides/haul, followed by Long Beach (Station 1) at 39 per haul. The relative abundance of silversides was similar at Warren Cove (Station 2 - 27.3 and the Pilgrim Station intake ramp (Station 6) - 29.2.

All menhaden and most of the blueback herring were captured at the head of the intake embayment (Station 3). The majority of

Table 6. Shore-zone fishes captured by foot-seine at six stations in the environs of Pilgrim Nuclear Power Station, June-November, 1987.

Species	1 Long Beach	2 Warren Cove	3 Pilgrim Intake Beach	4 Manomet Point	5 Long Point	6 Pilgrim Intake Ramp	Total Number	Percent of Total Catch
Atlantic silverside	1012	656	156	324	1793	175	4116	77.4
Sand lance spp.	0	0	2	553	0	0	555	10.4
Atlantic menhaden	0	0	357	0	0	0	357	6.7
Blueback herring	0	2	150	0	0	1	153	2.9
Winter flounder	1	6	2	18	15	0	42	0.8
Windowpane	7	4	0	3	21	0	35	0.7
Northern pipefish	0	0	0	2	25	0	27	0.5
Others[1]	0	1	2	3	23	3	32	0.6
Total no. of fish	1020	669	669	903	1877	179	5317	
No of sets	26	24	26	26	26	6	134	
Catch/set	39.2	27.9	25.7	34.7	72.2	29.8	39.7	
No. of species	3	6	8	7	11	5	15	
Percent total catch	19.2	12.6	12.6	17.0	35.3	3.4		

[1] Represents pooled totals for eight species of low catch abundance, including mummichog, alewife, Atlantic tomcod, grubby, cunner, longhorn sculpin, seasnail, and tautog.

Shaded column is data from surveillance station.

sand lance, however, were taken at Manomet Point (Station 4), while winter flounder catches were highest at the latter location and at Long Point.

6. UNDERWATER FINFISH OBSERVATIONS

Observational diving began in early May, with a total of 13 dives made through mid-November. Over 500 fish, comprising 7 species (Table 7) were observed in the study area (Figure 3). Invertebrates noted included blue mussels (*Mytilus edulis*), lobster, starfish (*Asterias* spp.), and rock and jonah crabs (*Cancer borealis* and *C. irroratus*). As in 1986, we continued qualitative observation of Irish moss (*Chondrus crispus*) growth and distribution along a transect used by Battelle researchers in the discharge area.

Table 7. Abundance and distribution of all species observed during underwater observations, May -November, 1987.

Species	Number observed by divers	% of total	Station where most abundant
Cunner	422	78.7	$D_1 + C_2$
Pollock	93	17.4	D_1
Tautog	10	1.9	$D_2 + C_1$
Rock gunnel	8	1.5	D_1
Other*	3	0.6	

* Longhorn sculpin, Striped bass, winter flounder

Estimates of visibility in the water column (obtained laterally with a diver-held secchi disk and metered line) ranged from 2.5 - 10 m (average 6.3 m), depending on sea condition and incident light. Average visibility in 1985 and 1986 (outage year) was 2.5 and 7 m, respectively, further evidence of enhanced water clarity during periods of outage as noted by Kelly et al. (1987) in 1986.

Overall abundance (536 fish) was at its lowest point since the inception of the diving study, due primarily to greatly reduced numbers of cunner and tautog. The majority of fish (45%) were observed in the discharge area (D), with 36% sighted in the control area (C), and 19% in the stunted area (S).

Cunner remained the finfish species most often seen by project divers, comprising 78.7% of all sightings (Table 7). Cunner were found at all stations, but were most commonly found in the control area and at Station D_1. The total number observed, 422, is the lowest of the study, an apparent continuation of the downward trend noted in 1986 by Kelly et al. (1987).

Found primarily in the discharge zone (83% of all sightings), pollock was the second most abundant species observed (Table 7). The 1987 total, 93, represents a decrease from the 1986 total of 130. However, as this species is highly active, occurrence in diver observations is more a matter of chance than a true representation of local pollock abundance.

Tautog ranked third in number of fish sighted (Table 7). Their abundance, like that of cunner, was at its lowest level of the dive program. Occurrence was evenly spread throughout the discharge and control areas.

Rock gunnel, found primarily under and around the large erratic at Station D_1, was fourth in abundance. This small benthic species is a common inhabitant of the subtidal area (Bigelow and Schroeder 1953) and is most often sighted under rocks or beneath clumps of algae. Because of its small size (generally around 15 cm), the rock gunnel is easily over-looked unless specifically sought. Though commonly found by divers and in the trawl, relative abundance of this species in the Pilgrim Station area is largely unknown.

The remaining species comprised less than 1% of the total sightings, each represented by a single individual (Table 7).

7. SPORTFISHING

During the 1987 informal creel survey, conducted from April - November, reportedly only 1,250 angler trips were made to the Shorefront, and seven species of fish were caught. Of the sportfish catch (approximately 300 fish), cunner - 56%, winter flounder - 22%, and bluefish - 11%, comprised 89% of the total, while tautog, pollock, skate, and striped bass accounted for the remainder. This is the same rank order of abundance as reflected in last year's sportfish catch at Pilgrim Shorefront.

Fishing occurred from the two discharge jetties, the outer intake breakwater, and the head of the intake embayment. Still-fishing with natural bait was by far the most popular method from the breakwater. Casting artificial lures was the predominant technique from the discharge jetties.

Fishing pressure increased over the spring and was highest in July and August, when over 50% of the fishing trips took place, declining thereafter. Over 50 percent of the angling trips in 1986 also occurred in the summer period - June and July. This seasonal distribution of fishing activity has been consistent over the years (Lawton et al. 1984). Favorable weather conditions and the traditional summer vacation period are obvious contributing factors to this pattern of fishing effort.

Highest sportfish catches in number of species and total fish were recorded in July, followed by August. Cunner was numerically dominant, being angled June-August; peak fishing occurred in July, when 88% of the cunner were taken. Winter flounder ranked second in sportfish catch and were caught May-November. Highest catches of winter flounder were made in June, July, and August. Taken August-October, bluefish were most frequently caught in August. Overall, catches were extremely low relative to records from past years.

V. CONCLUSIONS

Lobster - Commercial Fishery

Catch statistics and biological data for the commercial lobster fishery in the Pilgrim area were collected from over 2,600 lobster taken from mid-May through October 1987. Catch per unit effort (CPUE) of total lobster decreased from 1986. Legal catch rate was also down, averaging 0.33 for the study period; the range was from 0.26 in May to 0.42 in July. This decline was partly a function of the change in our sampling regimen (we now sample the commercial catch of only one lobsterman). Unusually cold bottom water temperatures in the spring liekly depressed the commercial catch. Females outnumbered males in monthly catches. The seasonality of percent ovigerous females has been similar the last three years.

Lobster - Research Study

Catches from controlled trap fishing (late June-September) were predominantly sublegal lobster (87%). Catch rates (mean catch per trap haul) of legals and sublegals were higher in 1987 than in 1986. The legal catch rate (0.3) for our research study matched up well with that from the commercial lobsterman sampled in the area (0.33). Mean carapace lengths and size compositions of catches were nearly identical in 1986 and 1987. Males slightly outnumbered females (1.1:1) in research trapping, which contrasts slightly with commercial trap data (1 male:1.5 females). Only 0.4% of the research catch of females were ovigerous females as compared to 2.4% of the commercial catch. The percentage of culls in the research catch (20%) approached that of the commercial catch (21.4%) and was identical to the

1986 level. Only 0.8% of the sublegal lobster we tagged were recovered in our gear, obviating the need to adjust our sublegal catch rates.

Groundfish

Thirty fish species were collected by bottom trawling in the nearshore area in the environs of Pilgrim Station. Four species comprised 86% of the catch. The average catch per standard trawl (CPUE) for all species and stations combined was 22.9, with the two surveillance stations yielding the highest overall CPUE's. Winter flounder ranked first in total catch (34%) due to ist abundance in the Intake embayment. Although little skate dominated trawl catches at the other sampling stations, it ranked second in total catch (30%). Little skate were most abundant in the Discharge area. Over the last 4-5 years, windowpane and yellowtail flounder have ranked third and fifth, respectively, in trawl catch. Catch rates in the Pilgrim area declined from 1983 to 1987 for the top three species but remained at a similar level for yellowtail flounder. Young-of-the-year Atlantic cod captured in September and October were unusually abundant at all sampling sites.

Pelagic and Benthi-pelagic Fishes

Thirty-two fish species were netted in monthly gill net sampling. Annual mean CPUE of pooled species was up from last year. Northern searobin led all species in catch for the first time, comprising 35% of the total. Although this species is common to our inshore waters in warmer months, the reason for the large catches in 1987 is unknown. Pollock ranked second (20%), with their numbers being quite similar to the last four years. Atlantic herring was third (18%), and cunner, fourth (6%) in catch abundance. The latter was at its lowest relative abundance of the entire survey, suggesting a decline in the local population. The remaining species were taken in relatively low numbers. A sand tiger shark was captured for the first time in the Pilgrim area since studies began in 1969.

Shore Zone Fish

Twenty-nine fish species were captured in the 45.7 m haul seine study from June-November 1987. An increase in the catch rates, of Atlantic silverside, blueback herring, alewife, and sand lance greatly contributed to increase the overall 1987 mean catch per seine haul in the study area for all species combined. Station catch rates for pooled species also increased from 1986 to 1987. Five species comprised 98% of the total catch. The Atlantic silverside continued to dominate catches, as it has since the beginning of the study in 1981, comprising 78% of the total catch and ranking first in both overall CPUE and overall percent frequency of occurrence. Blueback herring were second in numerical abundance (8.5%) but fifth in frequency of occurrence. Sand lance numerically ranked third (6.8%). They were, however, caught almost exclusively at the Intake Station, with 94% of their total catch occurring in June. Alewives ranked fourth in relative abundance (3.6%), with 93% of their total catch occuring in August. Winter flounder were fifth in catch abundance (0.9%) but second in overall frequency of occurrence. Highest seine catches continued to occur in August and September when area water temperatures peak. Annual species diversity was highest at the Pilgrim Intake Station (20 species) followed by the Long Point Station (19 species). Relative abundance, due primarily to the large number of silversides, was highest at Long Point.

In conjunction with the larger haul seines, a 6 m seine was used to sample finfish in the study area June-November 1987. Fifteen species were collected. Four species (Atlantic silverside, sand lance, Atlantic menhaden, and blueback herring) comprised 97% of the catch with Atlantic silversides again dominating. Total number of fish, CPUE, and diversity were highest at Long Point. All the menhaden and most of the blueback herring were captured in the Intake.

Underwater Finfish Observations

Seven finfish species were observed by divers in the study area from early May to mid-November. The overall number of fish recorded was at its lowest point since the inception of diving observations, primarily due to the decline in sightings of cunner and tautog. The majority of fish (45%) were observed in the discharge area followed closely by the control area (36%). Although apparently continuing a decline noted in 1986, cunner remained the predominant species seen (79% of the sightings). Pollock ranked second (14%) but declined in numbers from 1986. This decline, however, may be more a result of fish activity than a decrease in population abundance. Tautog was third in numerical abundance (2%) and, like cunner, was at its lowest level of the study. Rock gunnel was fourth in abundance (1.5%). The remaining fish species comprised less than 1% of the total sightings. Periods of plant outage generally increased visibility as noted in 1986.

Sportfishing

An informal creel survey was again conducted at Pilgrim Shorefront from April-November. An estimated 1,250 angler trips were made to the area and an estimated 300 fish caught representing seven species. Cunner (56%), winter flounder (22%) and bluefish (11%) comprised almost 90% of the landings. Fishing activity was greatest in June and July. Highest catches were garnered in July and August; with cunner predominating in July and bluefish in August. Overall catches were extremely low relative to past records.

VI. ACKNOWLEDGMENTS

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ANNUAL REPORT
ON
MONITORING TO ASSESS IMPACT
OF
PILGRIM NUCLEAR POWER STATION
ON MARINE FISHERIES RESOURCES
OF WESTERN CAPE COD BAY

(<u>IMPACT ON FISHERIES RESOURCES</u>)

Project Report No. 44 (January-December, 1987)

(Volume 2 of 2)

By

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Plate 11. Pictured is the thermal effluent discharging into Cape Cod Bay and anglers fishing off the discharge jetties and from boats in the plume which is visible in the background by the calm water. Striped bass and bluefish, which are attracted to and concentrate in the thermal current, are the dominant species sought by sport fishermen at this location.

Plate 12. Anglers seeking sportfish at the mouth of the discharge canal. Casting artificial lures is the most popular method of fishing the discharge current which attracts a variety of species.

I. EXECUTIVE SUMMARY

In accordance with the operational monitoring and reporting requirements of the U.S. Environmental Protection Agency and the Massachusetts Division of Water Pollution Control, marine ecological studies were continued at Pilgrim Nuclear Power Station in 1987. Marine Fisheries studies were recommended and approved by the Pilgrim Administrative-Technical Committee, an oversight committee established to insure that Pilgrim Station marine studies have the benefit of qualified scientific input and are responsive to regulatory agency concerns. Fisheries' sampling data were collected from reference and surveillance stations to assess plant impact. Emphasis was placed on comparing data from from 1983 and 1985, years of high power plant thermal output (>80% capacity), with 1984 (outage), 1986 (low output), and 1987 (outage).

Results this year confirmed that the power plant outage has resulted in localized environmental differences from when the plant was operating. Sportfish catches of striped bass and bluefish were markedly reduced without the thermal discharge. It was more evident that cunner area attracted to the current component of the Station discharge. Like cunner, tautog data support some attraction for this species to the discharge current. There appears to be an inverse relationship between the commercial legal lobster catch rate in the discharge area and the PNPS cooling water discharge.

II. INTRODUCTION

Monitoring studies were conducted by the Massachusetts Division of Marine Fisheries to assess environmental impact induced by Pilgrim Nuclear Power Station. Ecological investigations of fisheries resources in the surrounding waters of Western Cape Cod Bay for 1987 were funded by Boston Edison Company under Purchase Order No. 63644. Sampling data were collected from reference and surveillance stations during January-December, 1987; analysis included a summarization of the data and a discussion in relation to past findings. It is noted that the plant did not operate the entire year of 1987. This outage negated waste heat discharge, and current flow was reduced or nil. Measurements, counts, percentages, and indices of abundance are used in this report to identify trends and/or relationships in the data both spatially and temporally. Volume 2 is an assessment of power plant impact on the marine environment. Emphasis was placed on comparing data from 1983 and 1985, years of high power plant thermal output (> 80% capacity), with 1984 (outage year), 1986 (low output year: 17.5% capacity) and 1987 (outage year).

Plates 1-12 (found on the next several pages) depict sampling program operations to assess power plant impact on fisheries resources in the western inshore region of Cape Cod Bay.

Plate 1. Biologist collecting length-frequency data from the catch of a commercial lobsterman in the proximity of Pilgrim Station. Lobsters constitute the area's most valuable fishery resource.

Plate 2. Operations aboard a fishing vessel used during the 1986 experimental lobster study. This investigation is designed to better assess the impact on lobsters of the thermal effluent at Pilgrim Station.

Plate 3. Retrieval of the experimental gill net after a standardized overnight set in the thermal plume area. Caught in the net is a smooth dogfish, a common summer migrant in the Pilgrim area.

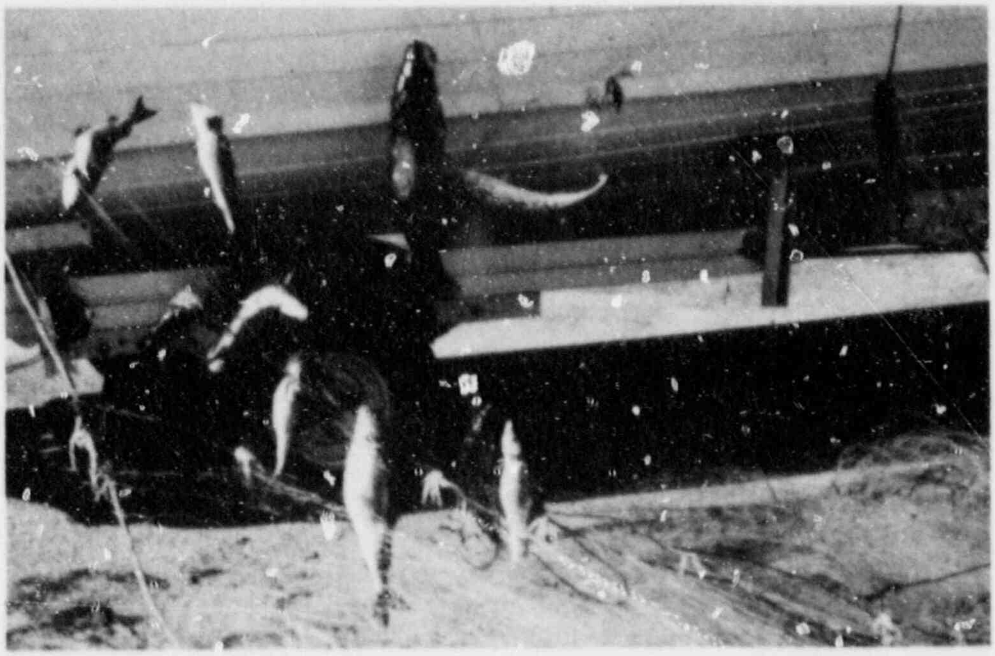


Plate 4. Fishes caught by gill net in the area of the thermal plume at Pilgrim Station. Gill-net catches include commercially important species, e.g., Atlantic cod, pollock, Atlantic mackerel, striped bass, and winter flounder.

Plate 5. Bottom trawl being set to sample groundfish in the inshore waters of western Cape Cod Bay. Catches are used to measure potential impacts of Pilgrim Station on the benthic fish community.

Plate 6. Typical trawl catch is processed which includes identifying enumerating, and measuring the different species for environmental assessment. Catches of winter flounder have been consistently largest at the Pilgrim Station intake trawl station.

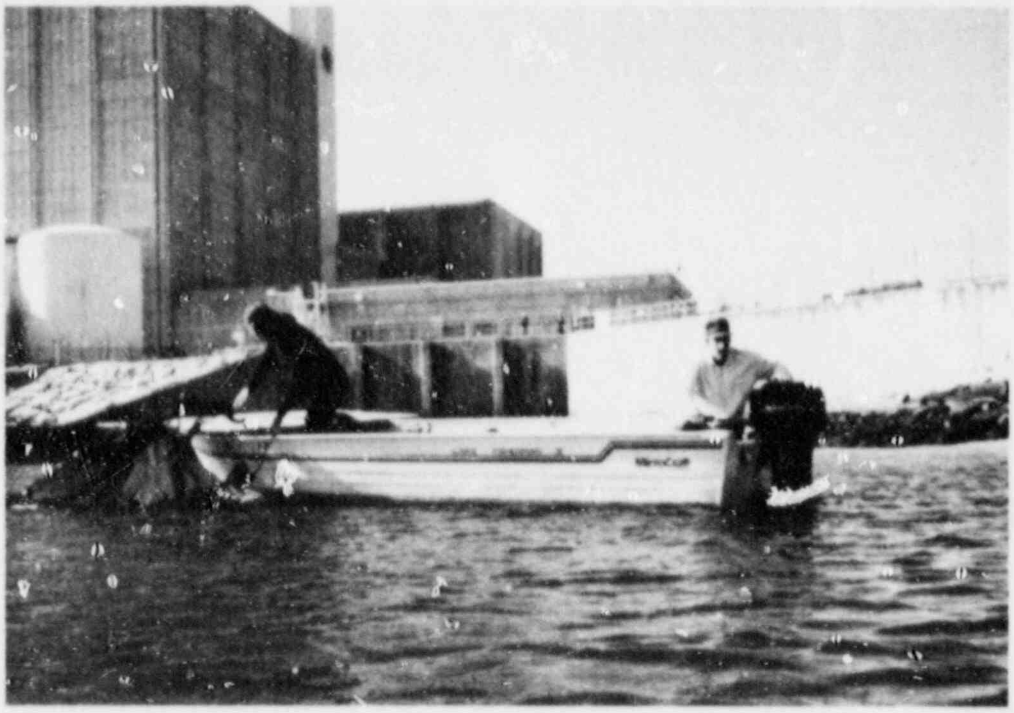


Plate 7. Haul seining in the intake embayment at Pilgrim Station: the net is being set from a powered-skiff to enclose a rectangular area. Seine catches can be integrated with impingement data for a more comprehensive evaluation of potential impact on shorezone fishes.

Plate 8. Haul seine catch processed on the beach near the Pilgrim Station intake (fish are enumerated and measured). Among the shorezone fishes are important forage fish such as the Atlantic silverside and sand lance, and the juvenile stages of several commercial species such as the winter flounder and Atlantic menhaden.

Plate 9. Biologist-diver deploying a transect line between observational stations. Diving observations have recorded the greatest number of fishes in the "denuded" zone directly off the discharge canal.

Plate 10. A tautog foraging at the mouth of the discharge canal (Station D) at Pilgrim Station. A popular catch of recreational fishermen, tautog are in the Pilgrim area from spring through autumn and have been used as an "indicator" organism to assess stress imposed by the release of the heated effluent.

Plate 11. Pictured is the thermal effluent discharging into Cape Cod Bay and anglers fishing off the discharge jetties and from boats in the plume which is visible in the background by the calm water. Striped bass and bluefish, which are attracted to and concentrate in the thermal current, are the dominant species sought by sport fishermen at this location.

Plate 12. Anglers seeking sportfish at the mouth of the discharge canal. Casting artificial lures is the most popular method of fishing the discharge current which attracts a variety of species.

III. RESULTS AND DISCUSSION

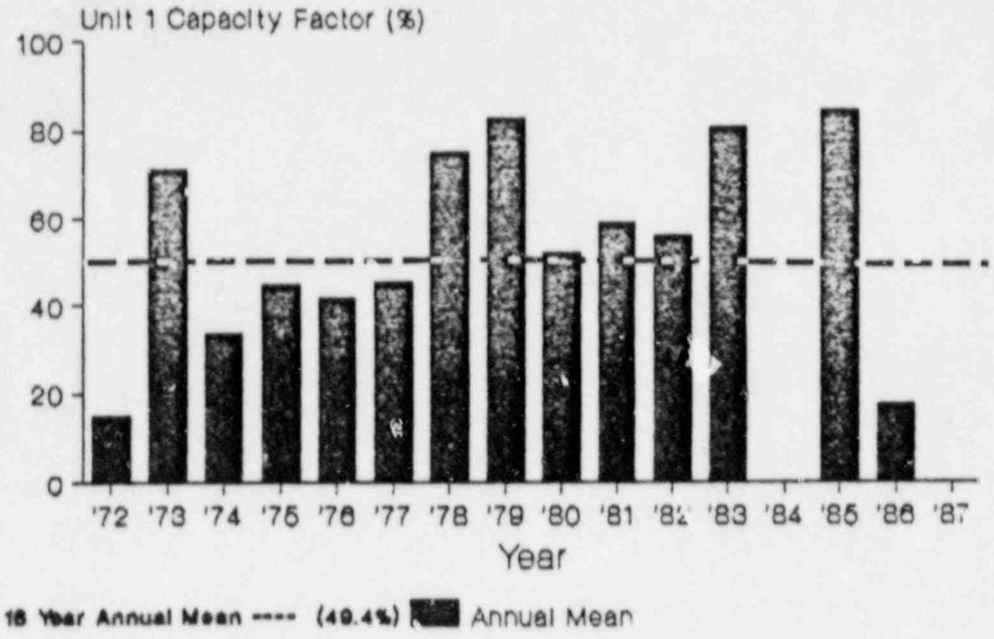
A. PHYSICAL (ABIOTIC) FACTORS

1. POWER OUTPUT AND THERMAL CAPACITY - IMPACT ANALYSIS

To assess power plant impact on marine fisheries' resources in the surrounding waters of Cape Cod Bay, we compared assessment data with the Pilgrim Nuclear Power Station Unit I Maximum Capacity Factor (MDC Net %). The latter is an index of operational output which roughly approximates thermal loading (calefaction) to the marine environment (100% MDC = 15.1 C above ambient water temperature, referred to as ΔT). Since inception of plant operation in July 1972, the annual MDC factor at Pilgrim Station has ranged from 0.0% this year (1987), an outage year, to a high of 84.4% in 1985 (Figure 1). The power level capacity was also extremely low (0.1%) in 1984 (essentially an outage year), while it exceeded 80% during two other years besides 1985, viz. 1979 and 1983. In this report, we stress data comparisons for 1984, 1986 (17.5% annual MDC),and 1987 with the two recent years (1983 and 1985) of high operational output. Pilgrim Station has operated over the years at a cumulative capacity factor of just under 50% ($\simeq$ 7 C Δ T above ambient) or at just about half its possible output. With this operational history, we probably have not fully realized to date potential plant impact on aquatic resources.

2. DISCHARGE CURRENT

At the Pilgrim Station site, localized currents are induced by the plant's circulating water intake and discharge. This once-through cooling system, besides removing waste heat from the plant's condenser tubes, releases a current of water which has



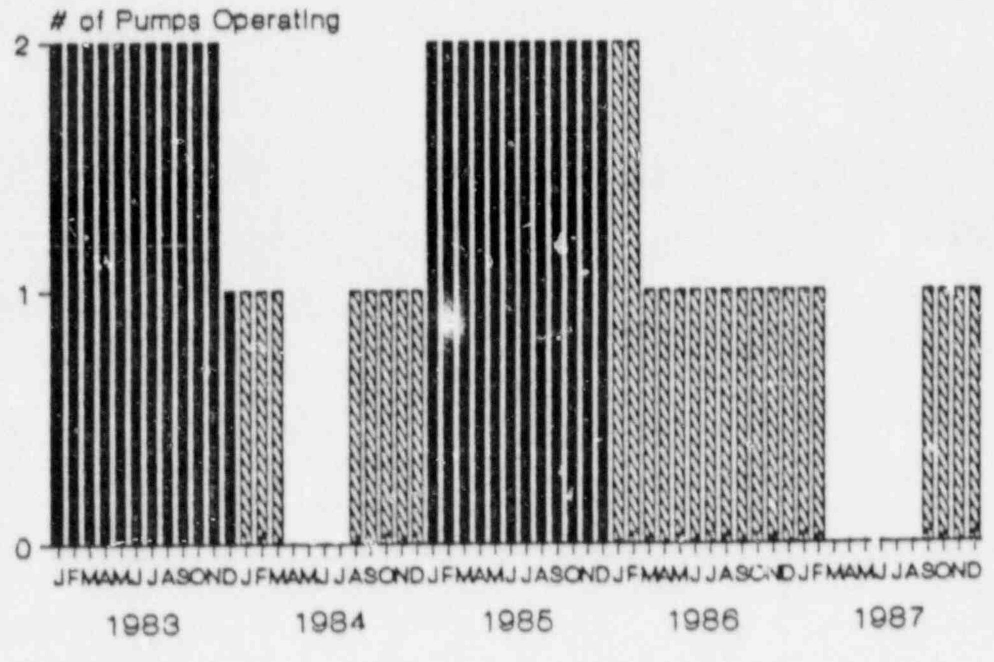


Figure 1 . Annual mean cumulative Pilgrim Station Unit I Capacity Factor (MDC Net %) for 1972-1987, and circulating water pump operation at the plant for 1983-1987.

the physical effect of a scouring or abrasive action on the benthic environment. Furthermore, the interaction of temperature, salinity, and currents is important in influencing the occurrence, distribution, and abundance of marine life.

During the plant outage of 1984, one or both circulating seawater pumps were off (Figure 1), thus minimizing or at least substantially reducing the offshore discharge current. In 1986, both pumps were operated from the beginning of January to early March; thereafter during the outage only one pump was utilized. With the outage continuing in 1987, the plant's two circulating pumps were off from approximately March-August, while one circulating pump was run during the majority of the other six months. During the remainder of the time from 1983-1987 both circulating seawater pumps were operating.

3. WATER TEMPERATURES

Taking a closer look at water temperature in the Pilgrim area for the last five years, we found, as expected, in 1983 and 1985 (>80% power plant capacity) seasonal water temperatures were generally highest in the discharge area because of the addition of waste heat to the waters contiguous to the power plant (Figure 2). Whereas the extent of the near-field region delimited by the discharge flow included a 1,100 m^2 to 1,400 m^2 'denuded' zone (primarily a result of scouring), a peripheral area of 'stunted' algal growth of about 1,900 m^2 to 2,900 m^2 resulted from the thermal component of the discharge (Bridges and Anderson 1984). In summer with the power plant at 100% operating load, we have measured a temperature differential (ΔT) up to about 15 C between discharge and ambient waters. Conversely, in 1984 (outage year), 1986 (plant outage April-December), and 1987 (outage year), water temperatures in the discharge area mirrored ambient levels (Figure 2).

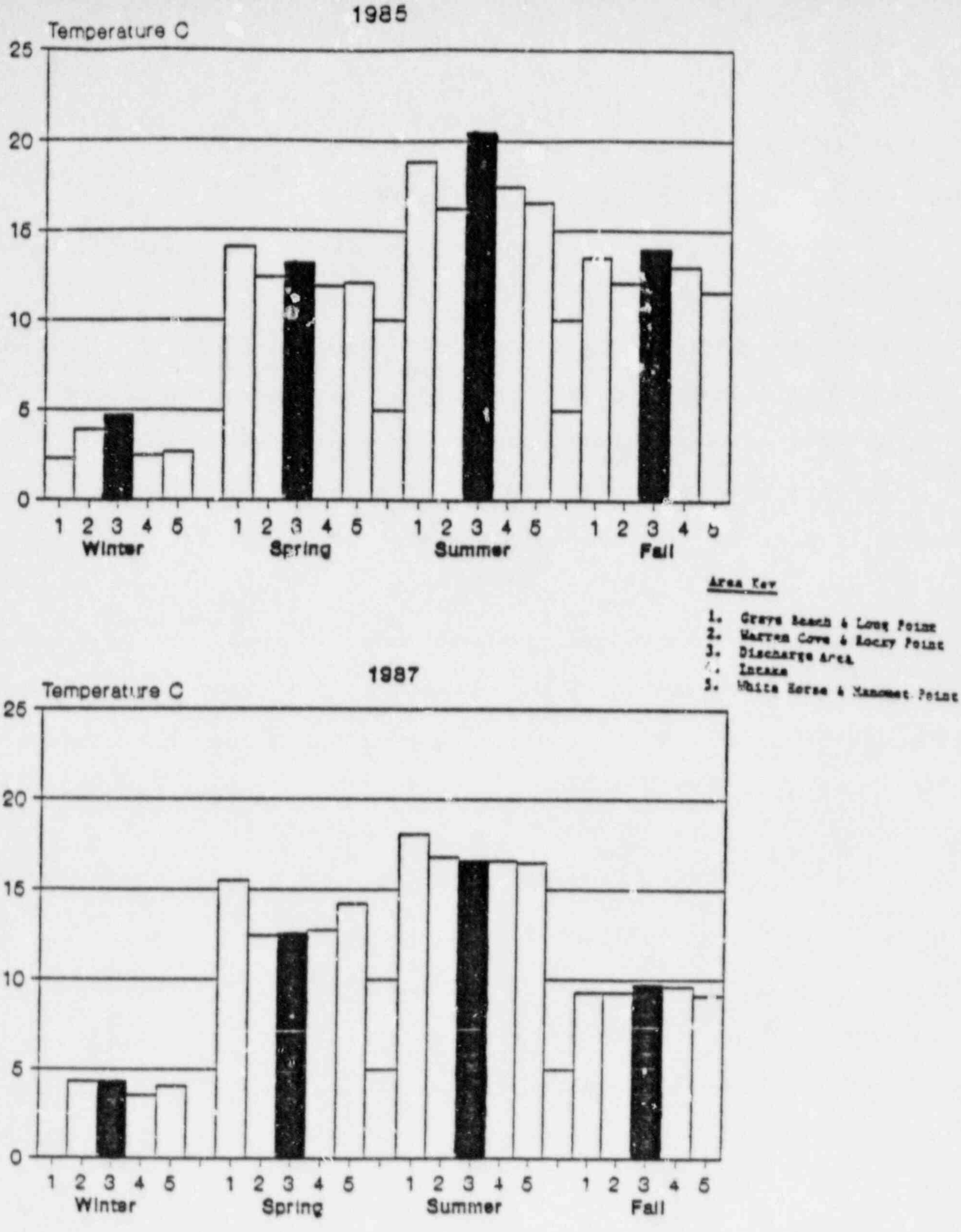


Figure 1. Surface water temperatures in the vicinity of Pilgrim Station averaged by season and area for the year of highest plant operational status (1985) and lowest (1987).

B. IMPACT OF PILGRIM STATION ON FISHERIES RESOURCES

1. COMMERCIAL LOBSTER POT-CATCH FISHERY

Pooled lobster catch statistics from the surveillance (discharge) quadrats (H-11, H-12, I-11, and I-12) were compared with data from the following reference quadrats (E-13, E-14, and F-13) located in Warren Cove (Figure 3) to assess the impact of Pilgrim Station on the local lobster population and fishery. We can compare data collected in 1987 with past years because the same lobsterman has supplied most, if not all, of the impact/control data.

Females outnumbered males in the catch for the entire study area in 1987. Of all the lobster sampled, 54% were females. In the surveillance area, females comprised 53% of the sampled catch; while at the reference quadrats, females comprised 67% of the catch.

As in 1986, the percentage of culls in the surveillance area in 1987 was markedly lower (12.3%) than in the reference area (21.4%). A chi-square test (Sokal and Rohlf 1969) showed this difference to be significant ($P \leq 0.05$) in 1987. Lobster cull rate is enhanced by lobster fishing and bottom trawl activity (Keser et al. 1983; Estrella and McKiernan 1986). In Warren Cove (reference area), commercial trawling is seasonally (November-March) conducted for groundfish; this may account for the higher cull rate there.

The 1987 mean catch rate (catch in number of lobsters per trap haul) for legal-sized lobsters ($\geq$ 81 mm carapace length - CL) in the surveillance area was 0.34 legals/trap-haul, while the reference area's legal catch rate was markedly lower at 0.20.

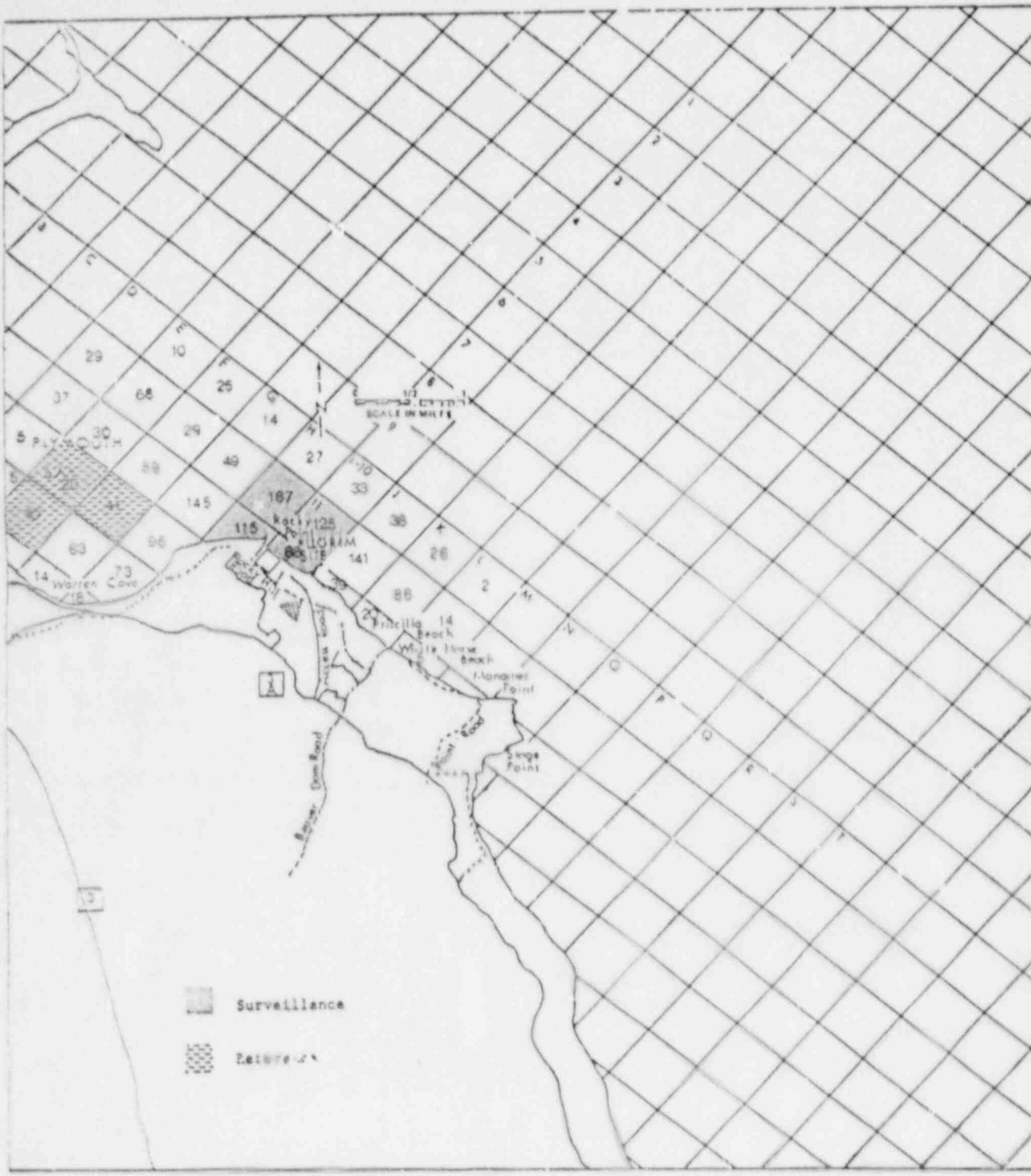


Figure 3. Lobster pot sampling grid for the commercial lobsterman monitored in the Pilgrim Power Plant area (surveillance (H-11, H-12, I-11, and I-12) and reference (E-13, E-14, and F-13) quadrats are shaded) and distribution of his traps sampled in 1987.

The catch rate at the control area dropped over 50% from last year. Mean legal catch rates in the discharge area have declined slightly over the last five years, ranging from 0.47 in 1983 to 0.34 in 1987. The legal catch rate there was 0.40 in 1985 and 1986 and 0.42 in 1984.

This contrasts with the trend for the Pilgrim area and for coastal waters overall. With the cooler ambient temperature regime in 1984 (Estrella 1985), the early season molt apparently was depressed or at least delayed; this, in turn, would have affected recruitment to legal size and impeded lobster activity (Campbell 1983; Estrella 1985). The mean catch rate of legal-sized lobster in western Cape Cod Bay was lower by about 50% or more in 1984 (0.32 legals/trap haul) compared to 1983 (0.61), 1985 (0.66), and 1986 (0.77). The catch rate in 1987 was 0.51. According to Estrella (1985) and Estrella and McKiernan (1986), the coastwide commercial catch rate (catch per trap haul) of marketable lobster in 1984 was lower than in 1983 and 1985 by 19% and 20%, respectively. Record lobster landings were documented for Massachusetts in 1985 and 1986 (Estrella and McKiernan 1986). Cape Cod Bay lobstermen had to contend with colder spring temperatures again in 1987 which delayed the lobster molt, resulting in a 34% reduction in commercial catch rate from 1986.

We tested catch data using several nonparametric statistical tests, which are not dependent on a given distribution but usually work for a wide range of distributions (Sokal and Rohlf 1969). Annual legal catch rates were compared for the discharge and reference areas for block periods of time. The Kruskal-

Wallis test revealed no statistical differences ($P > 0.05$) between areas over the entire survey, for the preoperational/outage years, or for the operational years. With the Wilcoxon's signed-ranks test of legal catch rates by year (operational) arranged as paired observations (surveillance versus reference), we found no significant differences in CPUE ($P > 0.05$) between control and test areas.

Catch sampling data and plant thermal output were examined for a relationship using correlational analysis (Sokal and Rohlf 1969) of Unit I Pilgrim Station Capacity Factor (MDC Net %) versus mean legal catch rates by year for prescribed areas. Sublegals were not examined in this way because of the sampling bias of commercial pots. We found a significant negative correlation ($r = -0.57$; $P \leq 0.05$) between legal lobster catch rate for thermal quadrats pooled (surveillance area) and mean annual Pilgrim Station MDC Net % Capacity Factor for operational years. We then ran a correlation analysis on the mean Unit I thermal output for the period of May-December, which approximates the inshore lobster fishing season, versus legal catch rates for the surveillance area and also obtained a correlation coefficient of -0.57 which is significant at the 95% level. Conversely, when power output and legal lobster catch rates for reference quadrats were tested for association, no correlations were statistically verifiable. When two variables are correlated, cause and effect is not necessarily validated; however, there is the possibility of an inverse relationship between the catch rate of legal-sized lobsters in the impacted area (quadrats H-11, H-12, I-11, and I-12) and the operating level of Pilgrim Station.

As to the effect of current flow on catch rate, Auster (1985) reported that a water current above a critical velocity will retard the foraging behavior of lobster by inhibiting mobility. It is reasonable to conclude this might translate into reduced trap catches in the immediate discharge area where current velocity may reach several feet/second. In fact, our diving observations have revealed few lobster in the immediate area of the discharge canal.

2. RESEARCH LOBSTER TRAP FISHING

An experimental pot-catch sampling program was completed for a second consecutive summer (mid-June through the end of September 1987), with the intent of further determining, in addition to commercial catch monitoring, whether Pilgrim Station operation measurably affects the local lobster population and fishery. Data on lobster size frequencies, sex ratios, culls, berried females, and catch rates were examined.

From 2,282 trap hauls, 5,449 lobster were captured. Catch per unit effort (CPUE) of sublegal lobster (≤81 mm carapace length - CL), as measured by catch per trap haul (CTH), averaged 2.076 overall (Table 1), an increase of 110% from 1986. CTH weighted by immersion time of the pots (CTHSOD), which was the most appropriate measure of CPUE for legals (≥81 mm CL), averaged 0.151 in the study area in 1987, up 72% from last year. Catch rates were up in both reference areas (Rocky Point and White Horse/Priscilla Beach) and in the surveillance area. The reason for the increase is not known at this time.

Table 1. Catch per unit effort from experimental fishing for American lobster in the Pilgrim area for 1987. CTH represents catch per trap haul; CTHSOD indicates catch per trap haul per set-over-day. Catch data are presented in numbers of lobster caught. Mean ±2 standard errors is an estimate of precision.

Area	Legal-sized Lobster (≥ 81 mm CL)		Sublegal Lobster (< 81 mm CL)	
	CTHSOD	Mean ±2 Standard Errors	CTH	Mean ±2 Standard Errors
Entire Study Area	0.151	0.139 - 0.163	2.076	1.997 - 2.155
Surveillance Area	0.146	0.127 - 0.165	1.882	1.758 - 2.006
Entire Reference Area	0.154	0.139 - 0.169	2.204	2.102 - 2.306
Rocky Point (Control)	0.138	0.120 - 0.156	2.244	2.114 - 2.374
White Horse (Control)	0.186	0.157 - 0.215	2.127	1.967 - 2.287

The overall sex ratio of males to females in the study area was 1.1:1 in 1987 and approximately 1:1 last year. Within the respective surveillance and reference zones, males slightly outnumbered females, except in 1986 at White Horse/Priscilla Beach (more females caught). The percentage of females captured that were bearing eggs (ovigerous) was 0.8% in 1987 and 2.9% in 1986. No clear pattern emerged within the sampling zones. Last year, over 80% of the berried females were taken at White Horse/Priscilla Beach; whereas, this year only 10% were captured there. Over half of the egg-carrying females were captured in the surveillance area in 1987.

In 1986 and 1987, the percentage of cull lobster (missing or regenerating claw(s)) captured in the study was about 20%. The density of culls (CTH) was lowest in the discharge area and highest at White Horse/Priscilla Beach each year.

The field research lobster trap study conducted for the last two years has been in effect a trial experiment under essentially control conditions (i.e.,plant outage, with no waste heat discharge and reduced or minimal current flow). The data will be compared with data from future high operational years. This was fortuitous giving us the opportunity to refine the field sampling design. The work became a uniformity trial where we fished standard traps in a standardized manner over the proposed experimental area. The proper pairing of potentially impacted/surveillance sites with non-impacted/reference sites was of prime importance, for it was assumed that lobster at both locations will respond in a similar way to changes in abiotic variables. The invalidity of this assumption would negate the assessment of stress at the surveillance location when the power plant resumes operation.

Based on two sampling seasons of trapping data, two parameters were identified that offer promise for detecting lobster population impact at Pilgrim Station - catch rate (relative abundance) and size composition of lobster. Using the sample mean and estimates of precision, and the approximate test of equality of means of two samples whose variances were unequal (F-max test) (Sokal and Rohlf 1969), catch rates of legals and sublegals were tested between areas. It was found that Rocky Point (reference) and the discharge (surveillance) areas are an approximate station pair to assess power plant effect on catch rate of legal lobster. The Kolmogorov-Smirnov procedure (Sokal and Rohlf 1969) was used to test size distributions of lobster caught in the different areas. As for size composition, it was found that size frequency data of legals at both reference areas could be pooled to increase sample size and then tested against size distribution of legals in the discharge for potential power plant impact.

3. NEARSHORE BENTHIC FINFISH

Pilgrim Station discharged no waste heat and little water current in 1987. For comparative purposes, trawl data from the outage years - 1984, 1986, 1987 - are compared with those recent high operation years when the plant operated greater than 80% of its capacity (1983 and 1985). During the low/off operational years, the amount of current coming from the discharge canal varied, depending on the number of circulating seawater pumps in use. Station 1 (Warren Cove) was considered the primary reference site and was compared with the surveillance site, Station 3 (Discharge), for impact analysis.

Mean annual catch rates for the three dominant groundfish - winter flounder (Pseudopleuronectes americanus), windowpane (Scophthalmus aquosus), and little skate (Raja erinacea) - were examined for differences between reference and surveillance sites (Figure 4). Mean annual CPUE of winter flounder for 1987 at Station 3 exceeded that of Station 1 for the second consecutive year. In 1984 (another outage year), the Station 1 winter flounder catch index was nearly double that of Station 3. Since 1983, however, CPUE of winter flounder at Station 1 has generally declined, while at Station 3, the catch rate has been fairly constant. Thus, the apparent change in relative distribution at these Stations noted in 1986 and 1987 does not appear to be related to reduction in output of heated effluent.

From 1984-1986, the annual catch rate of little skate at Station 1 steadily rose; concurrently, it declined at Station 3. In 1987, these trends were reversed. The annual relative abundance of windowpane increased slightly at both stations in 1986, but declined in 1987 at Station 1.

If differences in relative abundance (indexed by CPUE) resulted from plant operation, one would expect to see differences in 1986 and 1987 data at Stations 1 and 3 relative to previous years, with the exception of the outage year in 1984. This was not apparent, as abundance indices for 1986 and 1987 were independent of each other, indicating no measurable impact of plant operational status on the distribution of the three

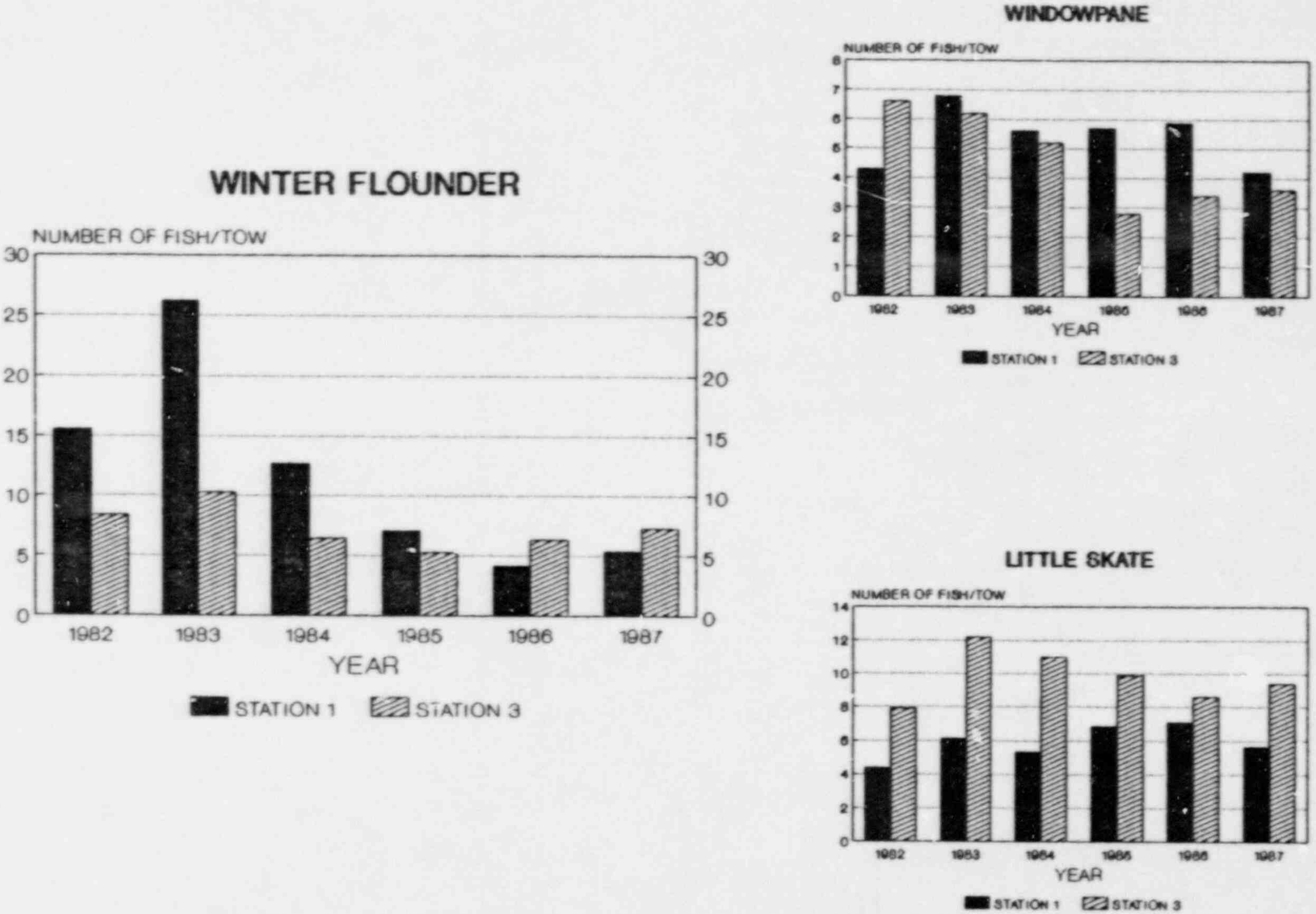


Figure 4. Mean annual catch per standard tow of three dominant groundfish by bottom trawl at reference Station 1, and surveillance Station 3, 1982-1987.

groundfish species evaluated. A similar conclusion was reached from trawl data for the outage year of 1984 (Lawton et al. 1985).

We have used annual mean trawl CPUE of selected finfish species to measure changes in relative abundance over time. Within the annual CPUE for each species are marked seasonal patterns of abundance. The variances of a species' seasonal mean CPUE are less than that of the corresponding annual catch rate; hence, seasonal CPUE's are a more precise statistic to analyze trawl data.

To investigate seasonal variation in trawl catch rates for 1987 at each station, we partitioned catch data for winter flounder, little skate, and windowpane by season: winter (January-March), spring ((April-June), summer (July-September), and fall (October-December). Choice of seasonal demarcations was based on bottom trawl catch rates and sea water temperature data collected at sampling stations in the Pilgrim area over the last decade (Lawton et al. 1983). Comparisons between stations within a season of the overlap of the CPUE standard error bars gives an approximation of any significant differences in catch rates. Trawl data are inherently highly variable; hence the large standard error bars for catch data (Figures 5-7). Winter CPUE's for the species selected were extremely low and will not be considered further.

In summer, little skate (Figure 6) at Station 6 (intake) and at primary reference Station 1 were significantly less abundant than at reference Station 4 and primary surveillance Station 3 (discharge). There is no indication that winter flounder or

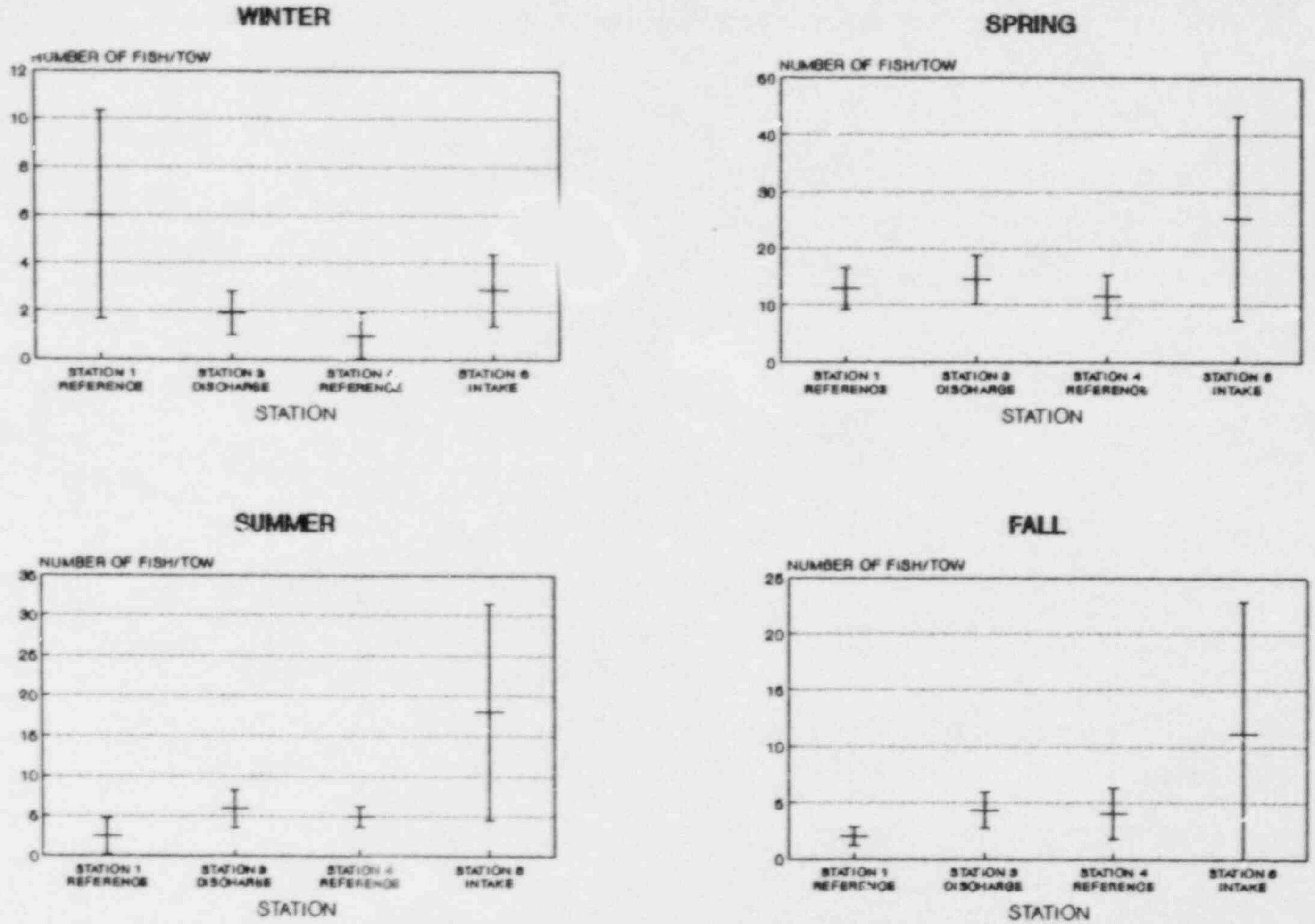


Figure 5. Seasonal mean trawl catch rates with vertical error bars for winter flounder by station in Pilgrim area, 1987. Note changes in Y-axis scale with season.

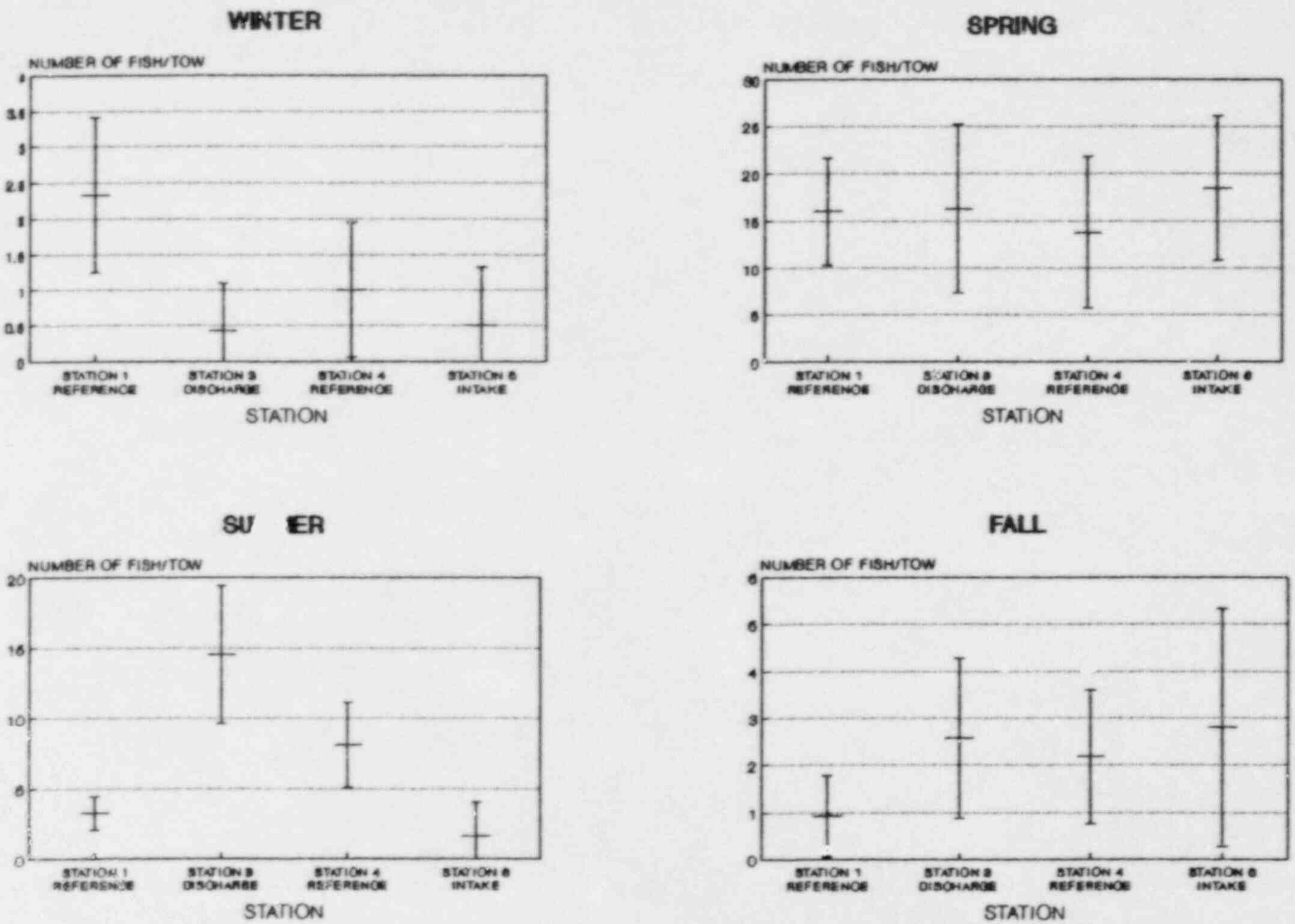


Figure 6. Seasonal mean trawl catch rates with vertical error bars for little skate by station in Pilgrim area, 1987. Note changes in Y-axis scale with season.

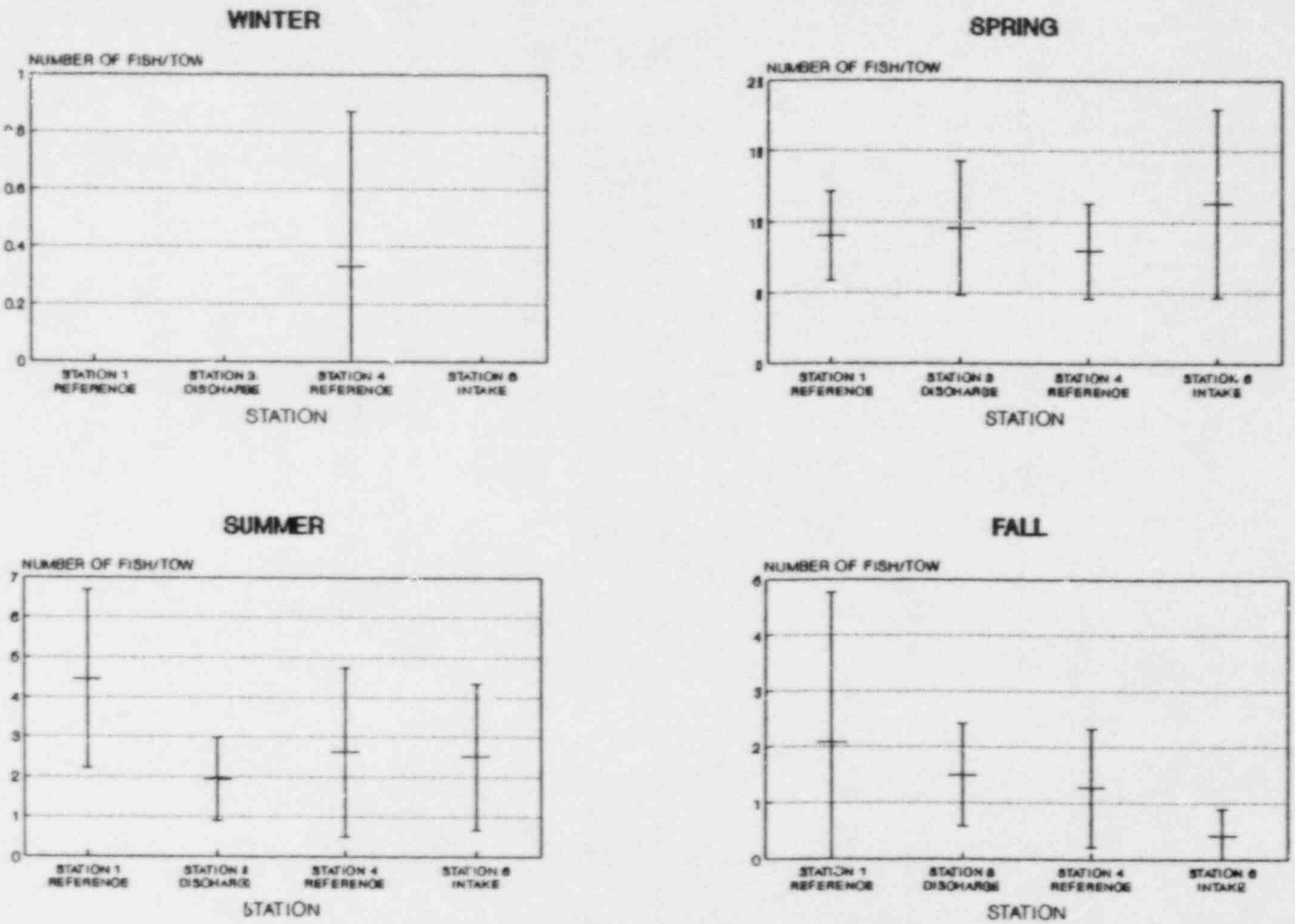


Figure 7. Seasonal mean trawl catch rates with vertical error bars for windowpane by station in Pilgrim area, 1987. Note changes in Y-axis scale with season.

windowpane relative abundance differed significantly amongst any of the stations during the seasons of 1987.

Previous analyses of trawl data indicated the Intake (Station 6) to be a haven for small winter flounder <22 cm total length, presumably due to the algal cover and sheltered environment (Lawton et al. 1985, 1986). To test this seasonally, we subjected this year's spring and summer data for winter flounder to the nonparametric Kolmogorov-Smirnov test for differences in length-frequency distributions between Station 6 and the other stations. In spring, there was a significant difference in the size distribution of winter flounder between Station 6 and reference Station 4 ($P \leq .05$); the comparison between Station 6 and Station 1 generated a probability level of $P = 0.07$. In summer, none of the compared length frequency distributions were significantly different. Plots of the spring and summer percent cumulative frequencies of winter flounder lengths (Figure 8) illustrate that the significant difference in length frequency distributions in spring is due to a pulse of small fish residing in the Intake which exposes them to potential impingement and\or thermal backwash effects.

4. PELAGIC AND BENTHI-PELAGIC FISHES

Our gill net survey abundance index (overnight gill net catch) was influenced by sampling error (variance) and bias (gill nets in general are size selective). Some species were susceptible to a wide range of mesh sizes, and some were entrapped by spines or mouth parts regardless of size. We assumed gear efficiency did not change over time, and fishing effort of the net was uniform for all mesh sizes. Vulnerability

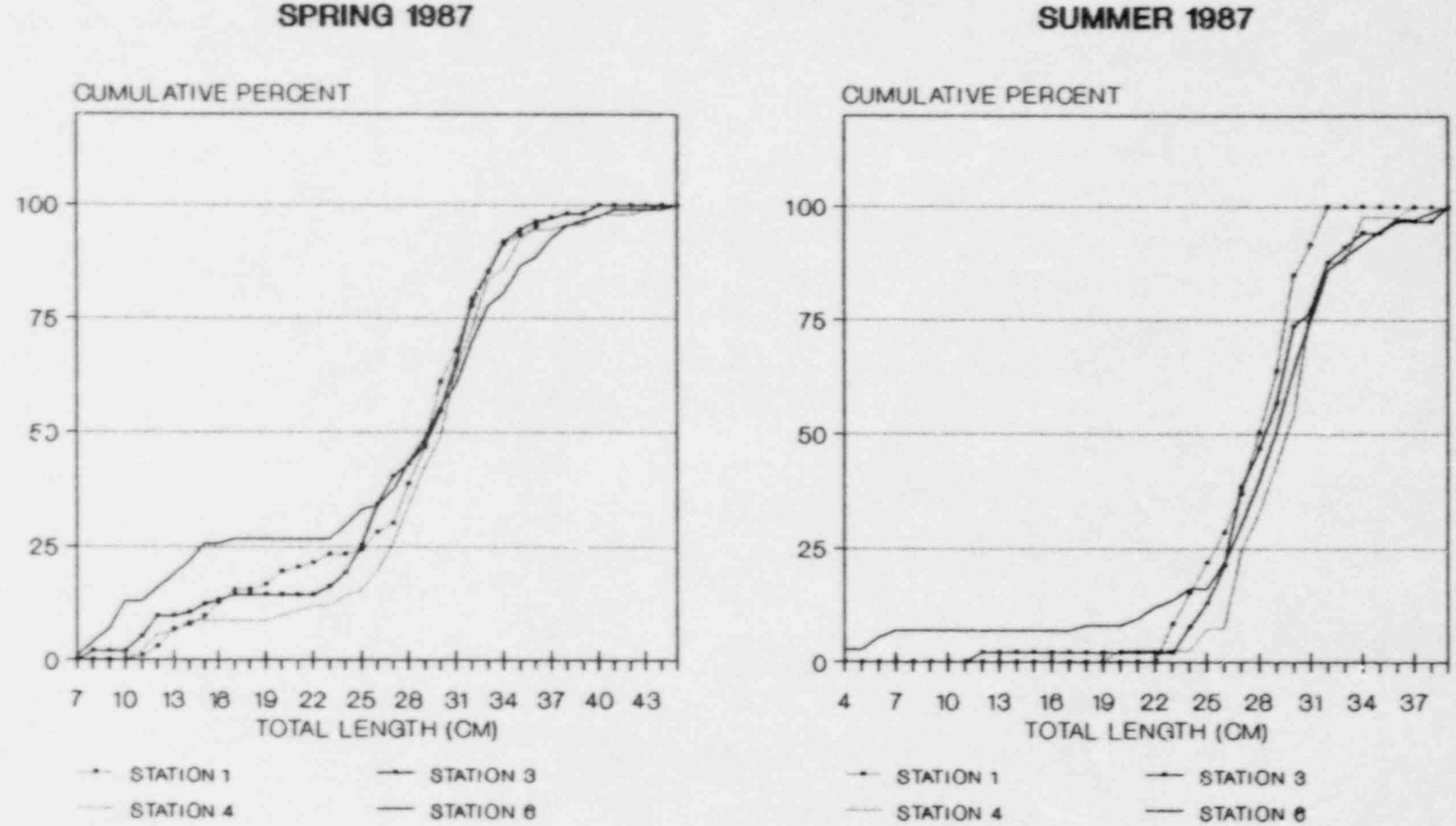


Figure 8. Cumulative length frequency distributions by station for winter flounder trawled in spring and summer 1987, near Pilgrim Station.

of each species was assumed constant, and we assumed that the number of fish already caught did not influence the capture of additional fish.

Pollock

This benthi-pelagic species ranked second, comprising 20% of the 1987 gill-net catch. Relative abundance estimates, generated from catch-per-unit-effort (CPUE) data, reflect local population fluctuations over the survey years (Figure 9). An increase in relative abundance occurred from 1971-1972 (preoperational years), followed by a substantial reduction from 1974-1976. Stock index rebounded in 1977 to exceed past levels and remained relatively high through 1981; CPUE declined in 1982 and has subsequently fluctuated at a reduced level through 1987. Comparing means of CPUE for the preoperational and operational (1973-1983,1985) study years; and between 1983/1985 when Pilgrim Station operational output exceeded 80% and 1984/1986/1987 (outage periods), revealed, respectively, that relative abundance was 13% lower overall during the operational years and 23% lower in 1984/1986/1987 pooled than in 1983/1985 (Table 2).

There is no apparent relationship between the annual index for Pilgrim Station operational output and annual CPUE (relative abundance) data for pollock (Figure 9). When statistically tested, these variables were not significantly correlated ($r = 0.231$; $P > 0.05$). Changes in relative abundance apparently reflect natural variability.

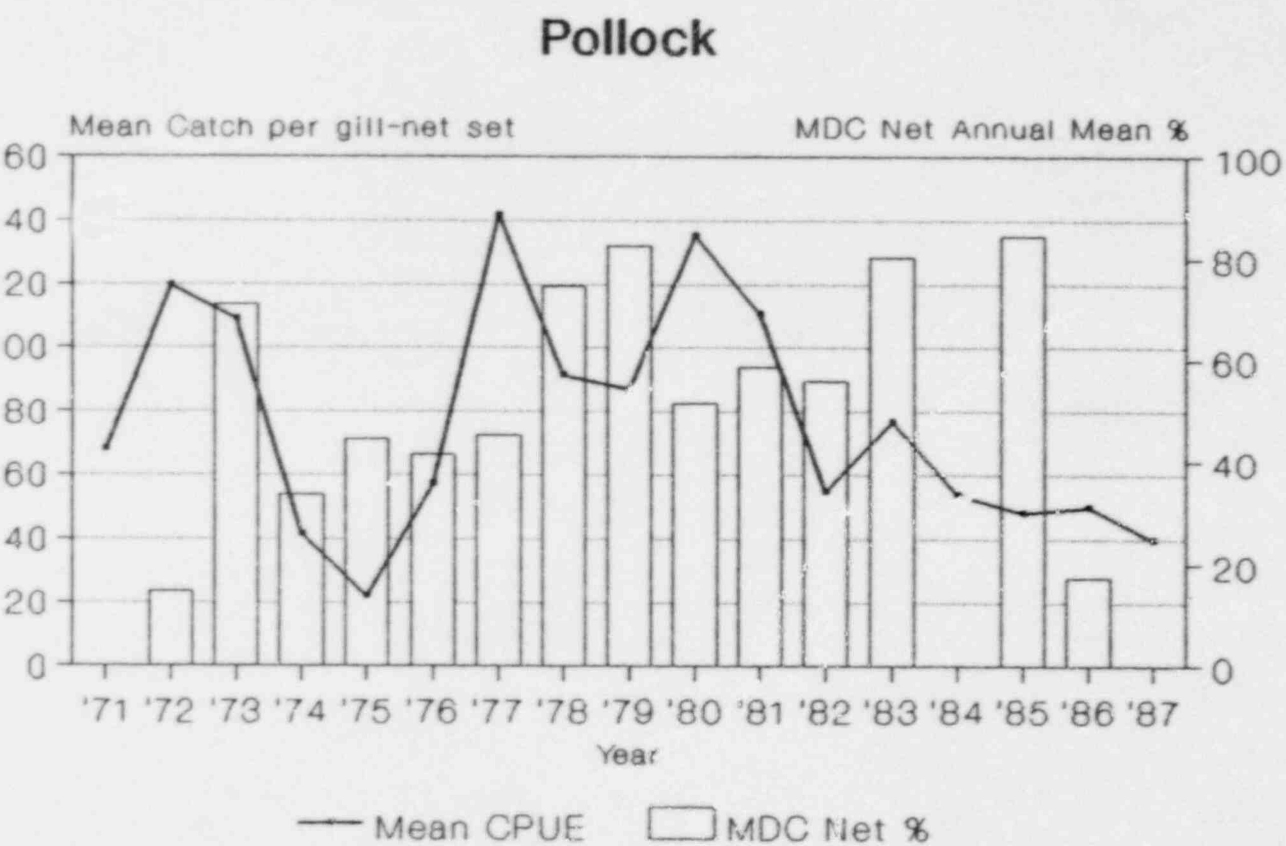


Figure 9. Mean annual gill-net catch per unit effort for pollock in the Pilgrim Station area and annual Unit I Capacity Factor (MDC Net %) at Pilgrim Station, 1971-1987.

Table 2. Mean catch per standard gillnet set (5 panels of 3.8 - 8.9 cm mesh) for various time periods and the percent differences for selected species caught in the vicinity of Pilgrim Station, 1971-1987.

	Species				
Year	Pollock	Cunner	Atlantic herring	Alewife	Tautog
1971-1972	93.8	18.8	7.8	27.6	0.6
1973-1983, 1985	81.3	32.9	32.2	9.2	2.2
Preoperational - operational percent difference	- 13%	+ 75%	+ 313%	- 67%	+ 267%
1983 and 1985 (> 80% capacity)	62.4	25.9	9.1	5.8	5.4
1984, 1986 an 1987 (outage years)	47.8	19.2	19.3	4.1	4.5
1983/1985 - 1984/1986 1987 percent difference	- 23%	- 26%	+ 112%	- 29%	- 17%

Cunner

Cunner ranked fourth in overall gill-net catch (6%). Annual abundance estimates peaked in the operational years of 1978 and 1980 (Figure 10). The benthic cunner exhibited population consistency in the Pilgrim area from 1971-1976, with a grand mean CPUE for these 6 years of 22 fish per gill-net set. From 1977-1983 annual catch rates were about double (grand mean CPUE of 41 cunner per set) that obtained the first six years of the survey, indicating a marked change in distribution and/or abundance of the local population. Subsequently, beginning in 1984, relative abundance has declined with the 4-year catch rate for 1984-1987 averaging 18 fish per set. CPUE in 1987 was the lowest of the survey.

Pooled CPUE for cunner captured during operational study years increased 75% from the average for the pre-operational study years. Catch rates were down again in 1984, an outage year; in 1985, a year of high thermal output; and again in 1986 and 1987 (outage periods).

The plot of plant operational output for spring and summer, when cunner occur in the area, versus CPUE suggests a possible relationship between the two variables (Figure 10). We statistically tested data on CPUE and plant operation power level for survey years through 1987 and found a significant positive correlation ($r = 0.581$; $P \leq 0.05$). Regression analysis of catch rate on the seasonal (spring-summer) plant capacity factor for survey years yielded a significant F ratio ($F_s = 7.13$; $P \leq 0.018$). It is evident from the observed value of F that the variance of CPUE of cunner can be explained partially by the

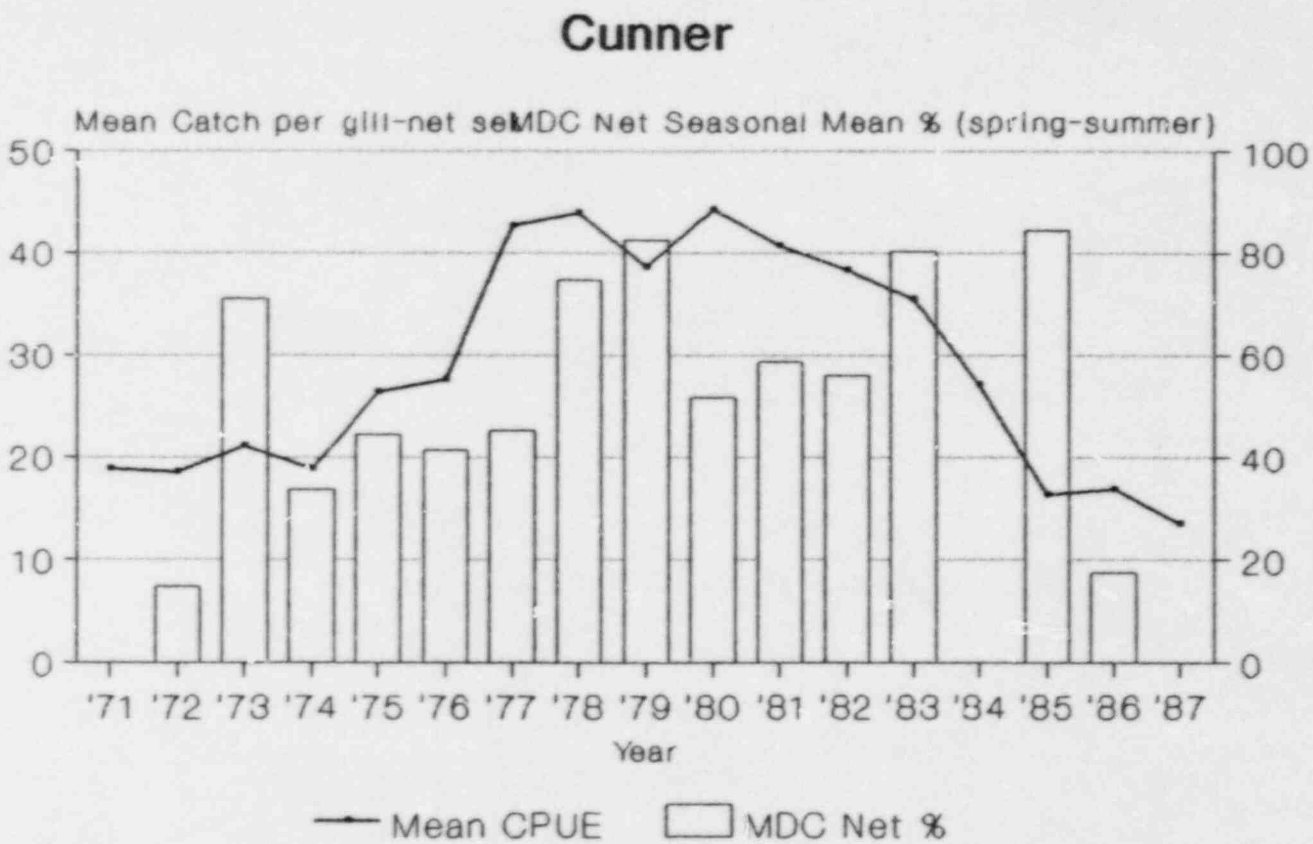


Figure 10. Mean gill-net catch per unit effort for cunner in the Pilgrim Station area and seasonal Unit I Capacity Factor (MDC Net %) at Pilgrim Station, 1971-1987.

regression on plant load. Specifically, almost 34% of the variability in cunner CPUE can be explained by variation in plant operational level (MDC).

Supporting evidence for a positive relationship between relative cunner abundance in the Pilgrim Station discharge area and the power plant thermal outflow into Cape Cod Bay comes from our observational diving program. Substantially more cunner were sighted in the discharge zone than in surrounding areas from 1981-1983, when Pilgrim Station was operating and releasing a warm discharge current. In 1985, cunner were most abundant at Station D_1 in the discharge area. Conversely, in 1984, an outage year, divers sighted relatively more cunner at reference stations than in the surveillance area, which suggests a localized shift in distribution. Waste heat was released from Pilgrim Station on only one day in 1984, and no water current was generated from April-August of that year, when both circulating water pumps were off.

In 1986, no waste heat was released from Pilgrim Station into the discharge area during the cunner's stay inshore; however, one circulating seawater pump was operated, releasing an offshore flowing current. During the diving study in 1986, cunner were sighted in greater numbers in the discharge zone. In 1987 (outage year), with no heat released from the plant and no appreciable current discharged from March-August, cunner were again, as in 1984, less abundant in the discharge than in the control area. In conclusion, it is evident that cunner are attracted to the cooling water discharge at Pilgrim Station. On the negative side, this subjects cunner to potential nearfield plant effects of heat or cold shock. gas bubble disease, and exposure to chemicals (e.g., chlorine).

Atlantic herring

Comprising 18% of the gill-net collection in 1987, Atlantic herring ranked third in catch. Over the survey years, annual relative abundance has fluctuated extensively, with an overall decline indicated subsequent to 1976 (Figure 11). Until 1985, CPUE for sea herring was lowest in 1972 (preoperational study year); by far, the highest annual catch rate was obtained in 1976 (operational study year). Catch statistics for Massachusetts generally corroborated our findings; statewide landings declined in 1973 but increased steadily the next few years, peaking in 1976 (National Marine Fisheries Service 1976). After the decline in the Pilgrim area in 1972, CPUE generally increased during the operational years, but again dropped markedly in 1978. This was followed by a fluctuating CPUE that nevertheless declined overall to an all-time low in 1985; a slight upswing was suggested for 1986 and 1987.

The grand mean catch rate for the operational study years was much greater than the average for the preoperational period (Table 2). Catch rate was 112% higher for the average of 1984/1987 (outage) and 1986 (low plant output) than the average for 1983 and 1985 (> 80% plant capacity). However, no power plant effect has been detected to date. No relationship is discernible in the plot of annual Pilgrim Station operational

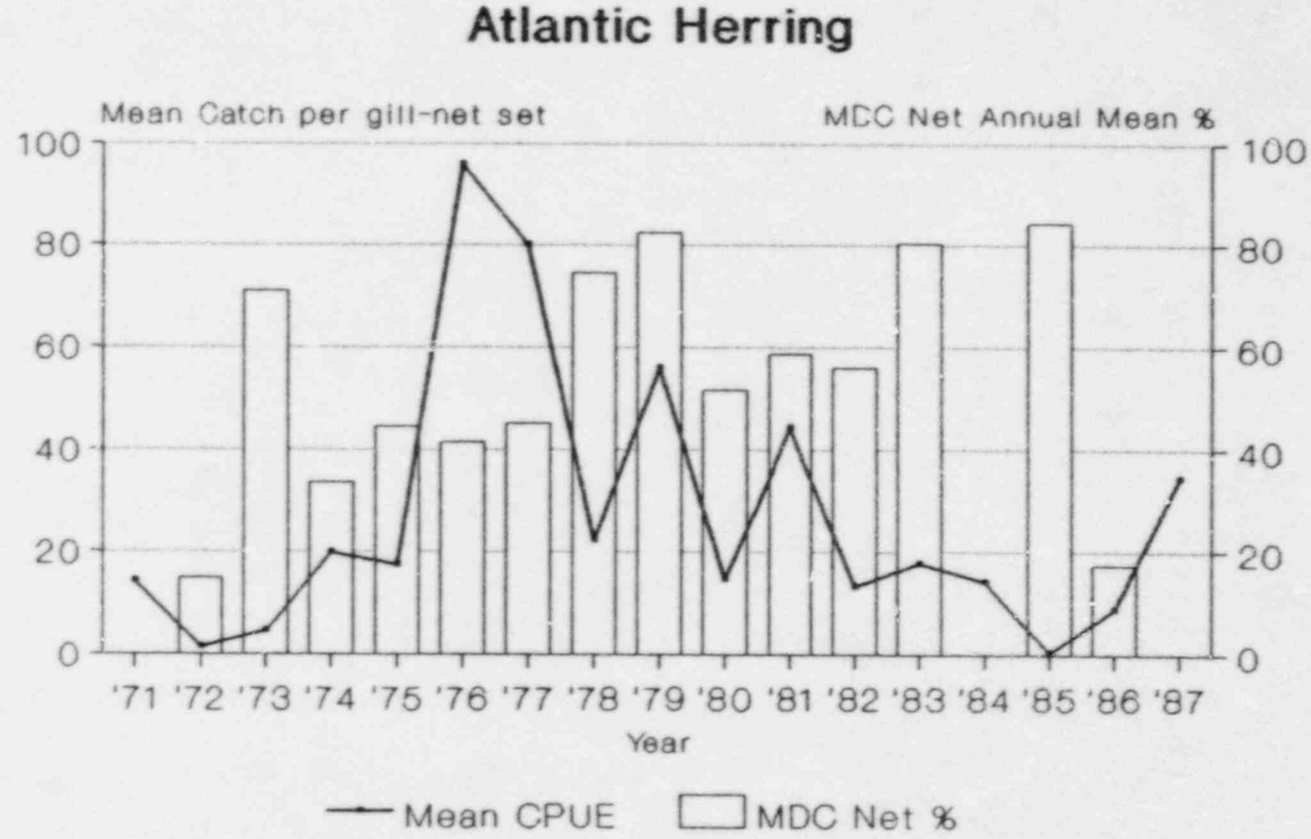


Figure 11. The average gill-net catch/effort for Atlantic herring in the Pilgrim Station area and yearly Unit I Capacity Factor (MDC Net %) at Pilgrim Station, 1971-1987.

output and annual catch data (Figure 11). Catch rate of herring and plant 'load' were not statistically correlated ($r = 0.027$; $P > 0.05$).

Tautog

Tautog comprised 3.1% of the gill-net catch in 1987. Relative abundance fluctuated at low levels from 1971-1981, but from 1982-1986, a high level of abundance was noted (Figure 12). Annual mean catch per set was especially low in 1975 (operational year of low thermal capacity) and high in 1985 (operational year of highest thermal capacity). Creel survey data from Pilgrim Shorefront corroborate this finding; sportfish catches of tautog were relatively low in 1974 and 1975, but peaked in 1985.

A comparison of mean CPUE for preoperational and operational study years revealed an increase in numbers during the latter period (Table 2). The mean of catch rates for 1984, 1987 (outage) and 1986 (low thermal capacity) was 17% lower than the average for 1983 and 1985 (high operational output). For the operational period, excluding the outage years, we found a significant positive correlation ($r = 0.590$; $P \leq 0.05$) between CPUE and Pilgrim Station MDC (Net %) mean Capacity Factor for spring and summer (Figure 12), when tautog are most abundant inshore (Bigelow and Schroeder 1953). The relationship is somewhat questionable, however, for when we included the three outage years in the correlation analysis, no significant relationship was found ($r = -0.012$) at the 95% probability level.

Alewife

The pelagic alewife comprised 3.3% of the annual gill-net total for 1987. Over the survey years, seasonal catch abundance

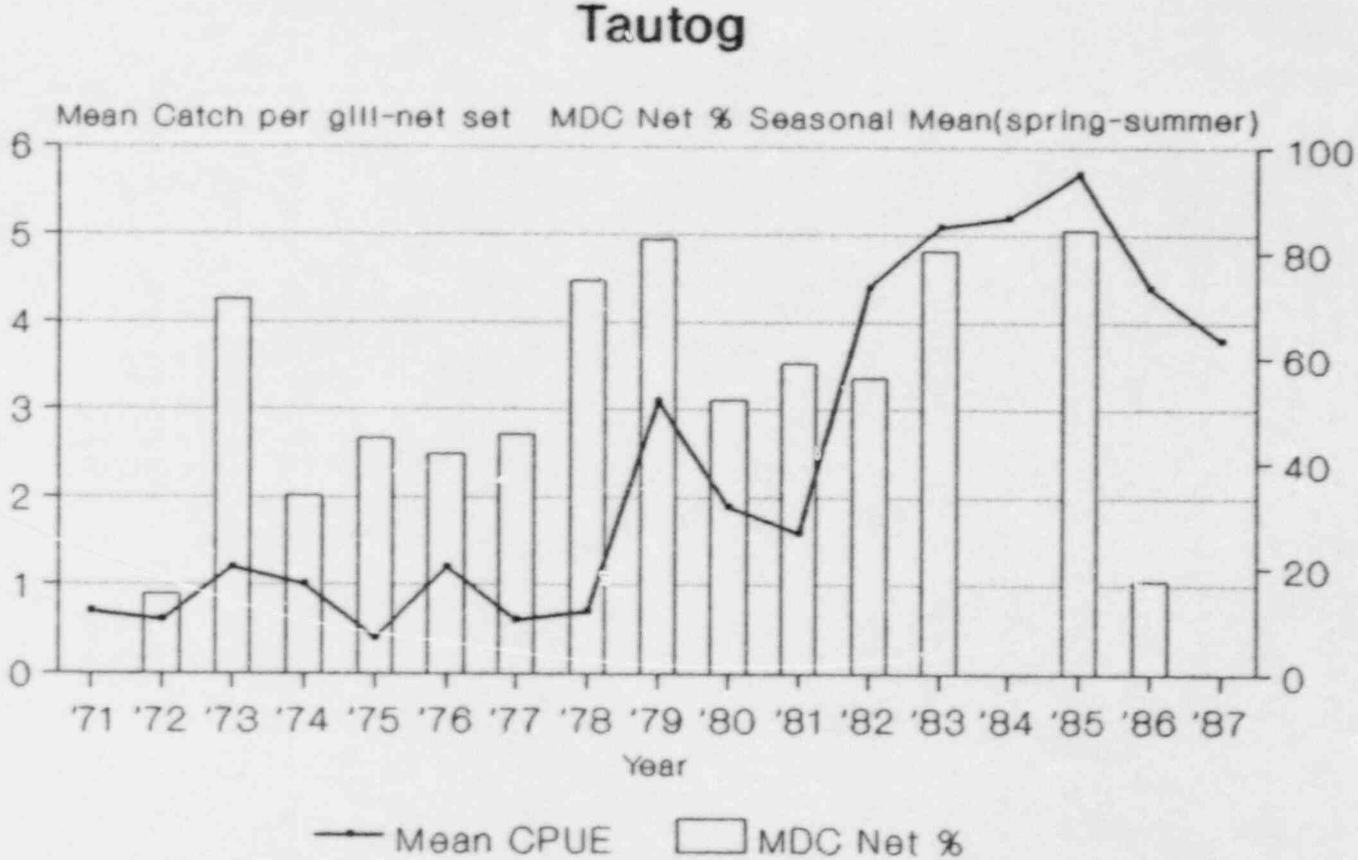


Figure 12. Mean gill-net catch rate of tautog in the Pilgrim Station area and seasonal Unit I Capacity Factor (MDC Net %) at Pilgrim Station, 1971-1987.

has been routinely highest in spring when this anadromous species migrates inshore to spawn in natal rivers. The annual mean CPUE markedly declined in 1972 and then has fluctuated at reduced levels during the operational study period (Figure 13). Catch rates were highest in 1971, followed by 1974. The difference between the overall CPUE for the preoperational and operational study years represents a downward trend of 67% (Table 2). Between 1983 and 1984, catch rate declined 68%, with low catches continuing into 1985 and 1986. There has been a general declining trend in relative abundance during the survey that began prior to operation of Pilgrim Station; the nadir in the catch occurred in 1981, with a slight upswing noted in 1983 and 1987 (Figure 13). It is believed that decreased catches are related to natural variability.

No statistical correlation ($r = -0.071$; $P > 0.05$) was found between catch index and the mean Unit I Capacity Factor (index of power station operational output) for spring and summer, when most alewives were found in the study area. River herring have been subjected to intensive exploitation for years along the Atlantic coast, and the trend for commercial catches has been generally downward in the 70's and 80's (Resource Assessment Division, Northeast Fisheries Center 1983). Thus, the decline indicated in the gill-net records appears to be wide-spread and not limited to the Plymouth area.

5. FISHES OF THE SHORE ZONE

Fishes along the local beaches can potentially be impacted by Pilgrim Station via thermal stress, gas supersaturation,

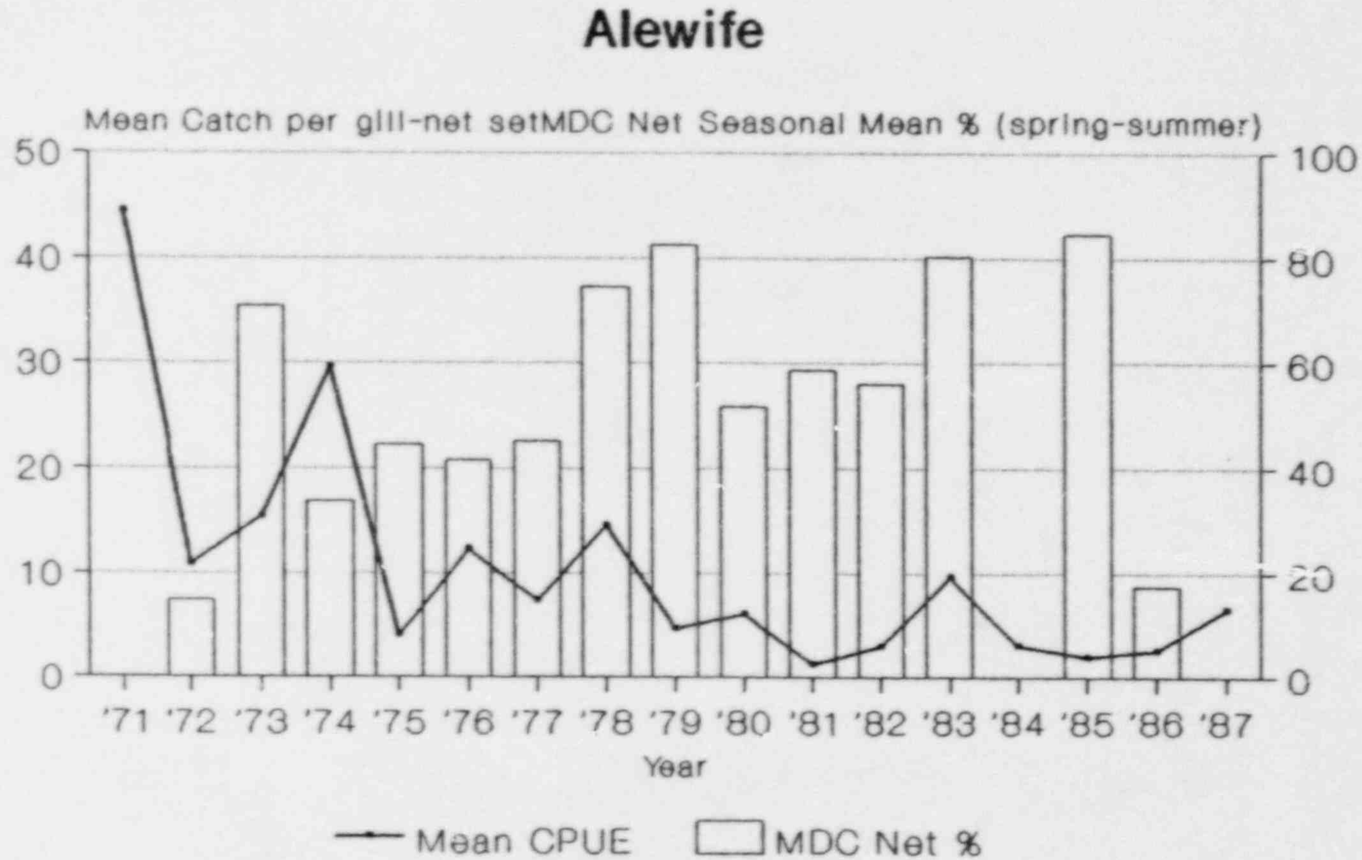


Figure 13. Catch rate of the alewife captured by gill-net in the Pilgrim Station area and seasonal Unit I Capacity Factor (MDC Net %) at Pilgrim Station, 1971-1987.

discharge flow, impingement, entrainment, and heated backwashes. The shore-zone seine program has generated a species list and estimates of the numbers of finfish residing in the intertidal and shallow subtidal zones in the Pilgrim area. As to sampling surveillance sites, the rocky shoreline and breakwater in the area of the discharge precludes seining; however, suitable topography occurs in the Intake (Stations 3 and 6). Reference stations include habitats ranging from open coastal beaches to the mouth of an estuarine embayment. The seine, as a sampling tool, provides information on the occurrence, distribution, relative abundance, and size range of fish in the shore zone.

Abundance data (catch per standard seine haul) of selected species were examined as a means of assessing power plant impact (Table 3). The surveys reveal some rather large natural variations in relative abundance which complicate the measuring of other than large ecosystem level effects of power generation. Using correlation analysis, relationships between monthly mean densities of the study area's dominant species, Atlantic silverside, in the Intake at Pilgrim Station and monthly Pilgrim Station thermal capacity (MDC net %); and between the former and monthly plant pump capacity were tested. No correlations were found (P > 0,05).

Haul seining in the Intake embayment can identify potential sources of impinged fish. Of the 20 finfish species seined form June-November, 1987 in the Intake, 9 were impinged at the power plant during the same time period. Because of the station outage and related decrease in pumping capacity, impingement for the aforementioned six months was extremely low (19 species

Table 3. Mean catch per standard haul seine set for selected species collected along the Plymouth shoreline, western Cape Cod Bay, 1983-1987.

	Stations				
	Warren Cove	Long Point	PNPS Intake	*Manomet Point	Pooled
Year	Mean Catch per Haul Seine Set				
			Atlantic silverside		
1983	103.7	197.7	10.0		119.1
1984	51.2	220.9	41.4		101.7
1985	413.5	165.4	12.9		201.5
1986	21.5	107.0	2.9		46.9
1987	109.6	837.9	70.8	58.8	287.4**
			Winter flounder		
1983	1.0	4.9	0.5		2.4
1984	1.1	2.9	2.0		1.8
1985	1.0	7.4	4.8		4.5
1986	0.4	4.3	9.3		4.3
1987	0.6	1.1	9.0	2.8	3.3**
			Blueback herring		
1983	1.0	13.1	0.0		5.6
1984	0.1	0.2	3.7		1.1
1985	352.0	4.9	184.7		178.2
1986	1.8	14.3	95.9		32.9
1987	1.2	0.1	125.8	0.4	31.1**
			Sand lance spp.		
1983	0.4	0.0	0.6		0.3
1984	0.5	0.2	40.6		10.7
1985	0.0	0.0	449.5		140.5
1986	0.0	2.0	72.3		21.2
1987	0.1	0.0	102.8	0.2	25.2**
			Pooled species		
1983	188.1	253.7	24.7		176.8
1984	54.3	233.8	92.0		120.1
1985	854.5	186.9	688.6		569.0
1986	30.9	150.5	225.9		129.0
1987	130.0	847.5	380.4	63.4	368.1**

*First full season of data collected at this site.

**Includes data from Manomet Point in the calculations.

Shaded column is data from surveillance station.

totaling only 69 fish). Cunner comprised 20% of the collection; lumpfish, 14%; and winter flounder, 10%. Seine catches in the intake consisted predominantly of blueback herring (32%), sand lance (24%), and Atlantic silverside (21%). Highest seine catches were made in August, while the peak impingement month was September.

The Pilgrim Station Intake with its man-made breakwaters and dredged channel is an artificially created embayment that is a haven for shore-zone fish in an otherwise open coastal region. In terms of total fish seined, catch rates, and numbers of species collected, the Intake most resembled the estuarine sampling site off the Long Point barrier beach; catches at the exposed coastal beaches were magnitudes lower. Fish concentrating in the Intake, especially in proximity to the Intake screen wall, are subject to mechanical and backwash thermal effects of the power plant.

Comparing abundance indices over the last five years (two on-line years of high operational output - 1983 and 1985; three nonthermal-stress years - 1984,1986, and 1987), no relationships between catch and plant operation are suggested (Table 3). However, some patterns emerged. Catches in 1987 were generally comparable to those in 1986, with the exception of the large increase in Atlantic silversides at all stations. Catch rates of winter flounder and blueback herring have been highest in the Intake the last two years. Sand lance have consistently been more abundant in the Intake. To date, however, no correlation to plant operation has been detected for these patterns.

6. UNDERWATER FINFISH OBSERVATIONS

With the continuation of the 1986 plant outage through 1987, no waste heat was released and no pumps were in operation from March through August. Through the summer a very dense bed of blue mussels (Mytilus edulis) flourished along the entire length of the discharge canal and extended out beyond the mouth. In some areas of the canal, shell stock and clumps of living mussels were piled as deep as 15 cm, inducing mortality due to over-crowding. With the resumption of pump operation in September 1987, much of the stock and some of the smaller clumps were carried out of the discharge and deposited in the denuded area as far out as the large erratic at Station D_1.

Qualitative evaluation of the standing crop of Irish moss (Chondrus crispus) in the dive area over the course of the summer revealed enhanced growth (distribution and density) even to the point of initial recolonization of the denuded area. By summer's end, the project divers had difficulty in differentiating distinct lines between the denuded, stunted, and control areas. Other flora such as kelp (Laminaria spp.) and the filamentous brown and green algae noted in 1986 (Kelly et al. 1987) were also commonly observed.

Overall finfish distribution (Figure 14) was somewhat similar to 1986 in that the majority of fish (45%) were found in the discharge area. However, relatively more fish were found in the control and stunted areas in 1987 (36% and 19%, respectively) than in 1986 (31% and 4.6%, respectively). Total number of fish in 1987 (536) was the lowest recorded, primarily the result of depressed cunner sightings. Species diversity (7 species) and

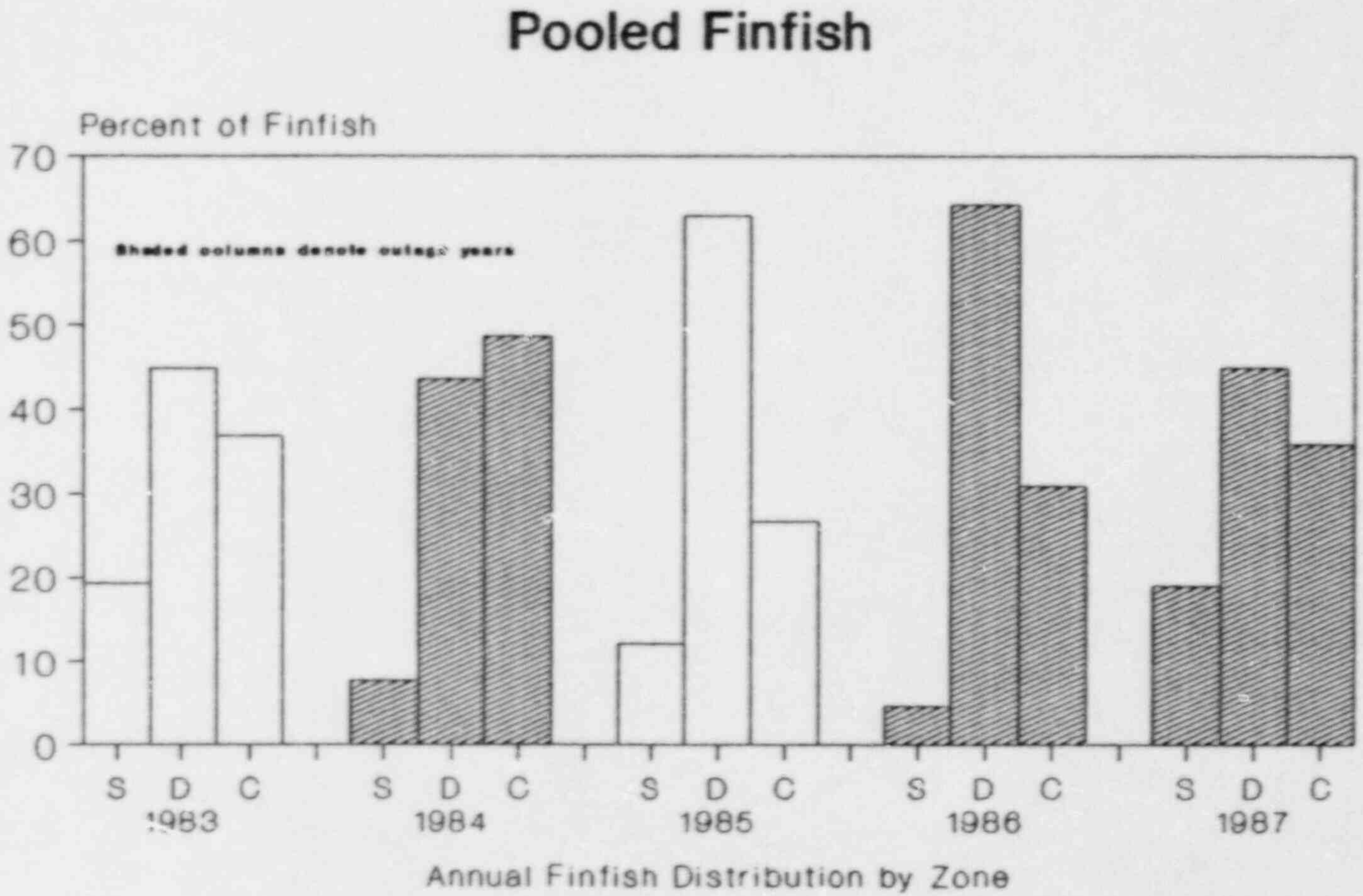


Figure 14. Distribution of finfish observed by divers in each zone (S-Stunted;D-Denuded;C-Control) off the Pilgrim Station discharge canal, 1983-1987.

composition were essentially the same as previous years.

Cunner

Cunner remained the most frequently observed species with 79% of the total sightings. However, a total number of 422 cunner sighted in 1987 represents the lowest relative abundance of the entire study. Comparison of the number of cunner per dive, as an index of relative abundance for the years 1981 (the year the dive stations were located at their present sites) to 1987 (Figure 15), revealed marked variation between years with a strong pulse in 1984 and the sharp decline of 1987. During previous outage periods (1984 and 1986), higher densities of cunner were observed by divers than in the immediately preceeding (1983 and 1985) years of high output (annual mean MDC $\geq$ 80%). A major component of these higher abundance years was large numbers of juveniles, especially in 1984. In 1986 we hypothesized that increased sightings of juveniles during periods of outage were due to the absence of the high velocity thermal effluent. As few juveniles were seen in 1987, however, the large numbers sighted in 1984 and 1986 may have reflected year class strength, rather than a response to the activity of the plant. Decreased occurrence in 1987, particularly that of juveniles, could also result from a shift in distribution. Further, when comparing numbers between years it should be remembered that diving observations are qualitative and can be limited by visibility.

Cunner were found at all stations in 1987, though most often in the control area (Figure 16). Comparison with the outage

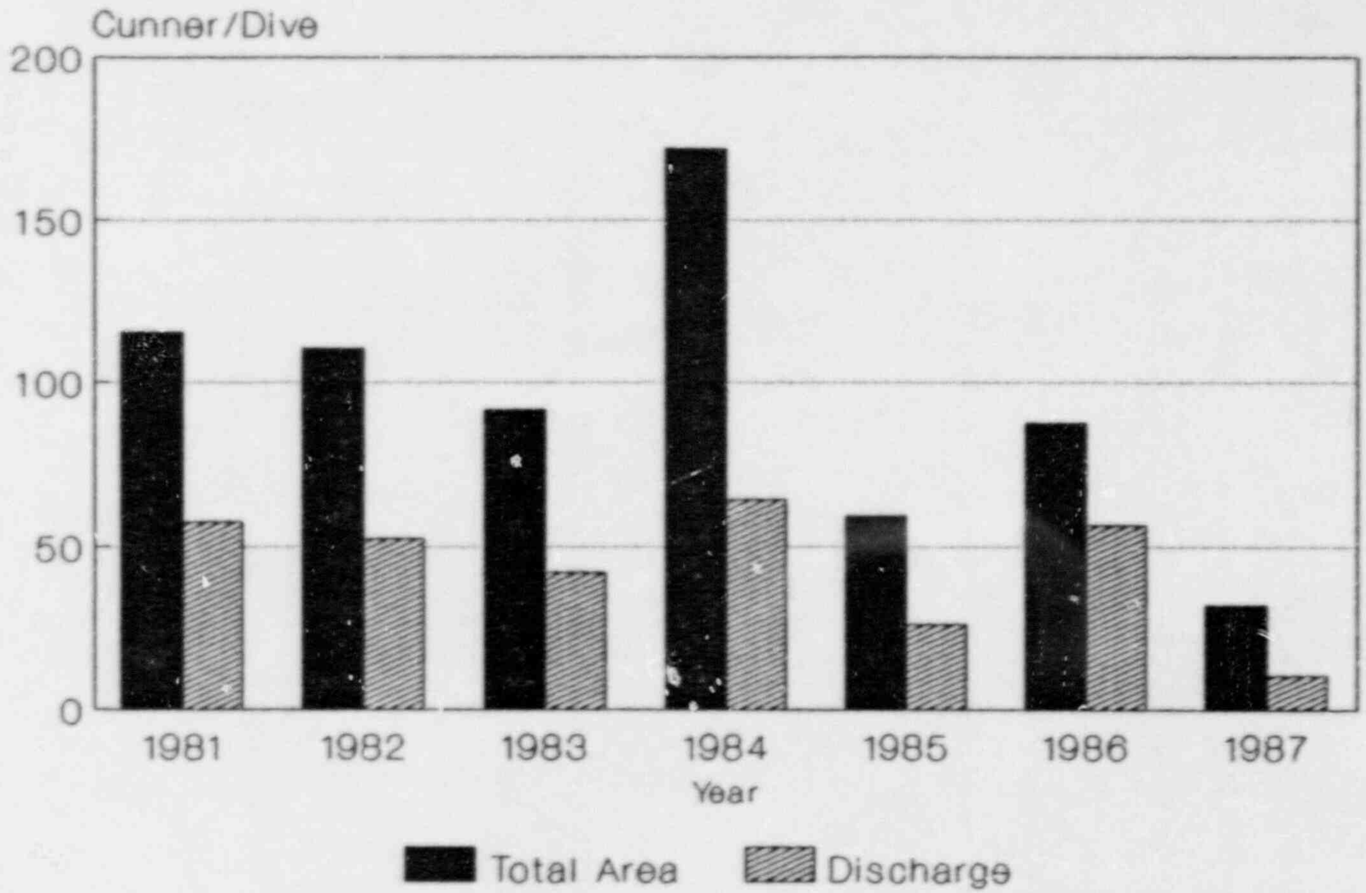


Figure 15. Index of relative abundance (fish/dive) for cunner observed by divers at Pilgrim Station 1981-1987.

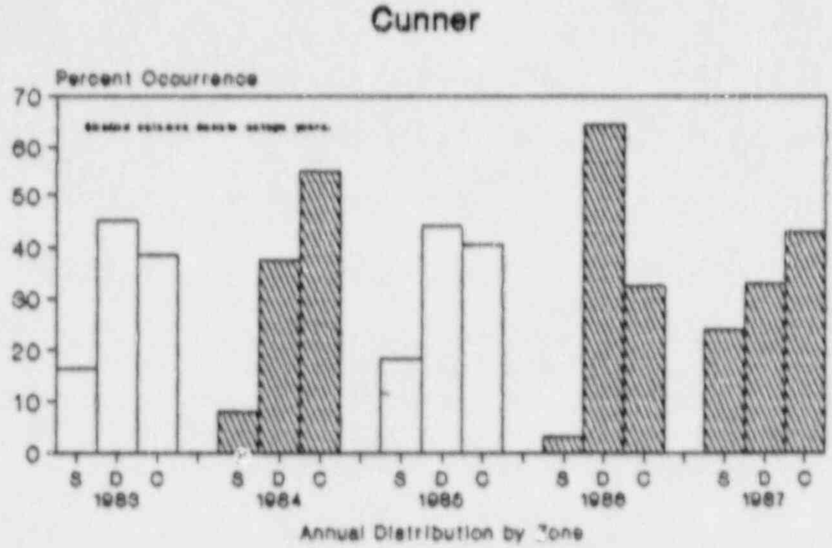


Figure 16. Distribution of cunner observed by divers in each zone (S-Stunted;D-Denuded;C-Control) off the Pilgrim Station discharge canal, 1981-1987.

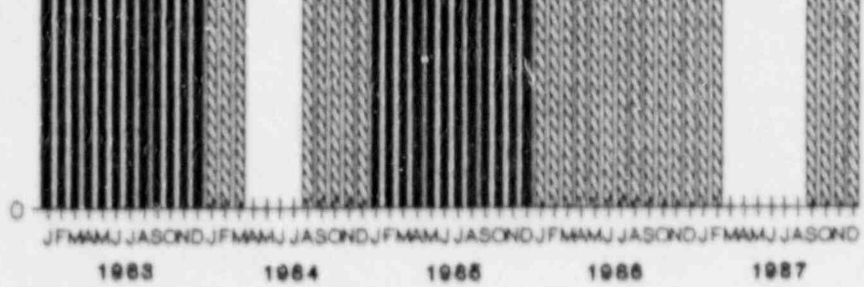


Figure 17. Annual mean circulating water pump operation at Pilgrim Station, 1983-1987.

years of 1984 and 1986, revealed a similar trend in 1984, but greatest abundance in the denuded area in 1986. Although thermal component was essentionally zero (some waste heat was released in early 1986) all three years, there was at least one pump in operation throughout 1986 (Figure 17). In 1984 and 1987, however, there were no pumps in operation during the spring and early summer months. Kelly et al. (1987) theorized a relationship between cunner distribution and pump operation, believing adult cunner to be attracted to the current as a source of food. The absence of current in the early spring and summer, a time when increasing water temperatures cause renewed foraging activity (Creen and Farwell 1971), may have induced a shift toward the more fertile control area and away from the sparse denuded zone. Increased occurrence in the stunted area in 1987, as opposed to previous outage years, may have resulted from an attraction to the abundant flora and fauna growing in the absence of the thermal effluent.

Pollock

Second in observed abundance, pollock was sighted primarily in the denuded area. Relative abundance (93 fish) was down somewhat from 1986 (130), but estimates of pollock abundance based solely on visual observation are generally tenuous because of their active behavior. As always, observation of this species is rather sporadic and local abundance and distribution more dependent on natural variation than any effect of the plant.

Tautog

Tautog sightings were infrequent (10 fish) in 1987 (Figure 18), reflective of an apparent decline in the local population.

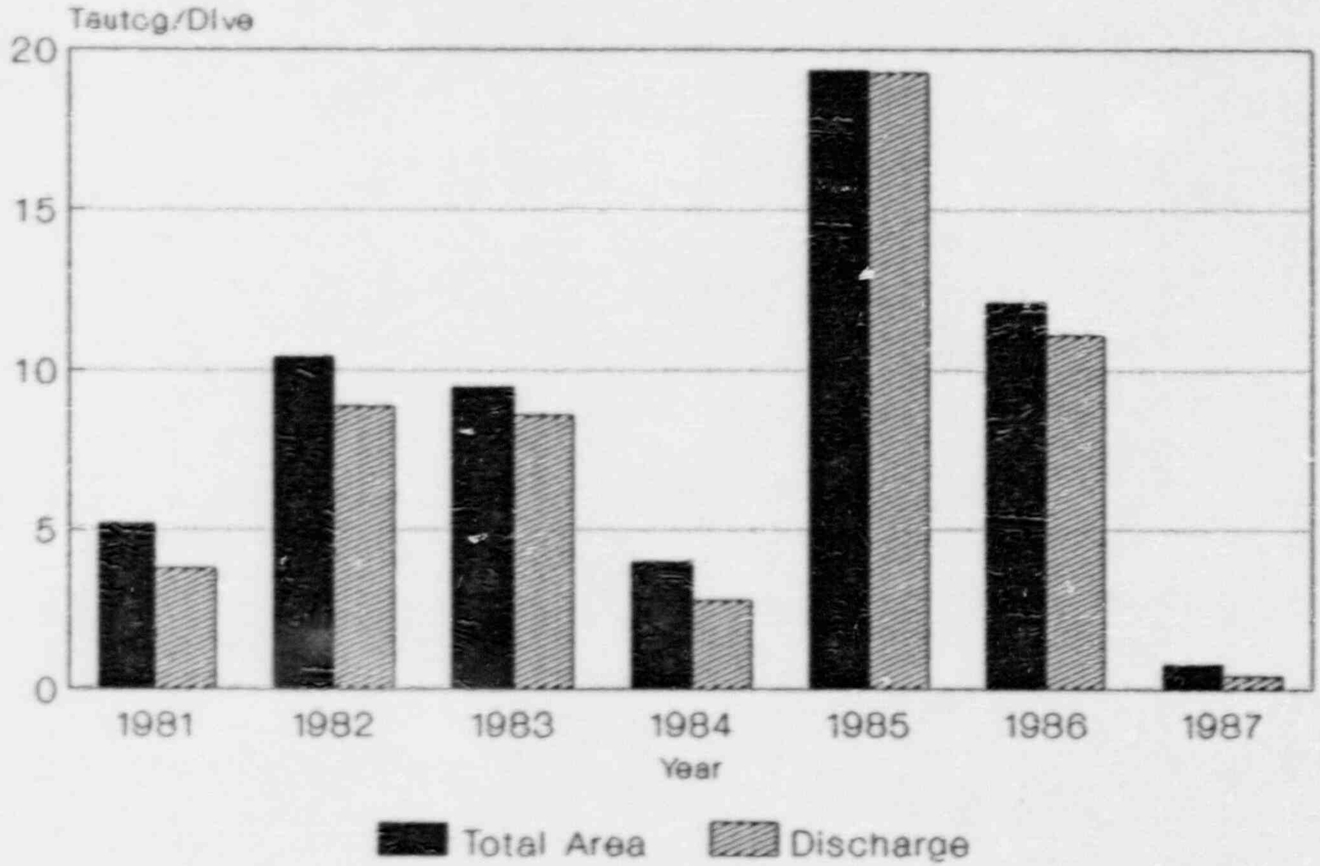


Figure 18. Index of relative abundance (fish/dive) for tautog observed by divers off Pilgrim Station, 1981-1987.

Depressed abundance was also noted in the project gill-net study. Distribution was evenly apportioned between the denuded and control areas (Figure 19), a shift from past years when tautog were found almost exclusively in the denuded area. As no relationship has been found, to date, between tautog occurrence and plant output (mean seasonal MDC), decreased local abundance seems to be the result of natural variation.

7. SPORTFISHING

Overall, angling activity and sportfish catches at Pilgrim Shorefront in 1987 were the lowest recorded at the area since its opening in April, 1973. We attribute this, at least in part, to restricted access at the Shorefront during April and May and to the extended station outage.

Angling activity was curtailed as the footbridge that spans the the discharge channel was closed in April and May because of a storm-induced break in its cement construction. The bridge allows pedestrian passage to the right discharge jetty (facing seaward), the outer intake breakwater, and the beach at the head of the intake embayment. Anglers were limited to fishing from the left discharge jetty, thus effectively removing most of the fishing access. The bridge was repaired, and all fishing locations were accessible again in June.

Throughout all of the fishing season, Pilgrim Station released no waste heat into Cape Cod Bay. From April through August, both circulating water pumps were inoperative, and only a minimal flow of water issued from the discharge canal as a result of the operation of one or more of the five service water pumps.

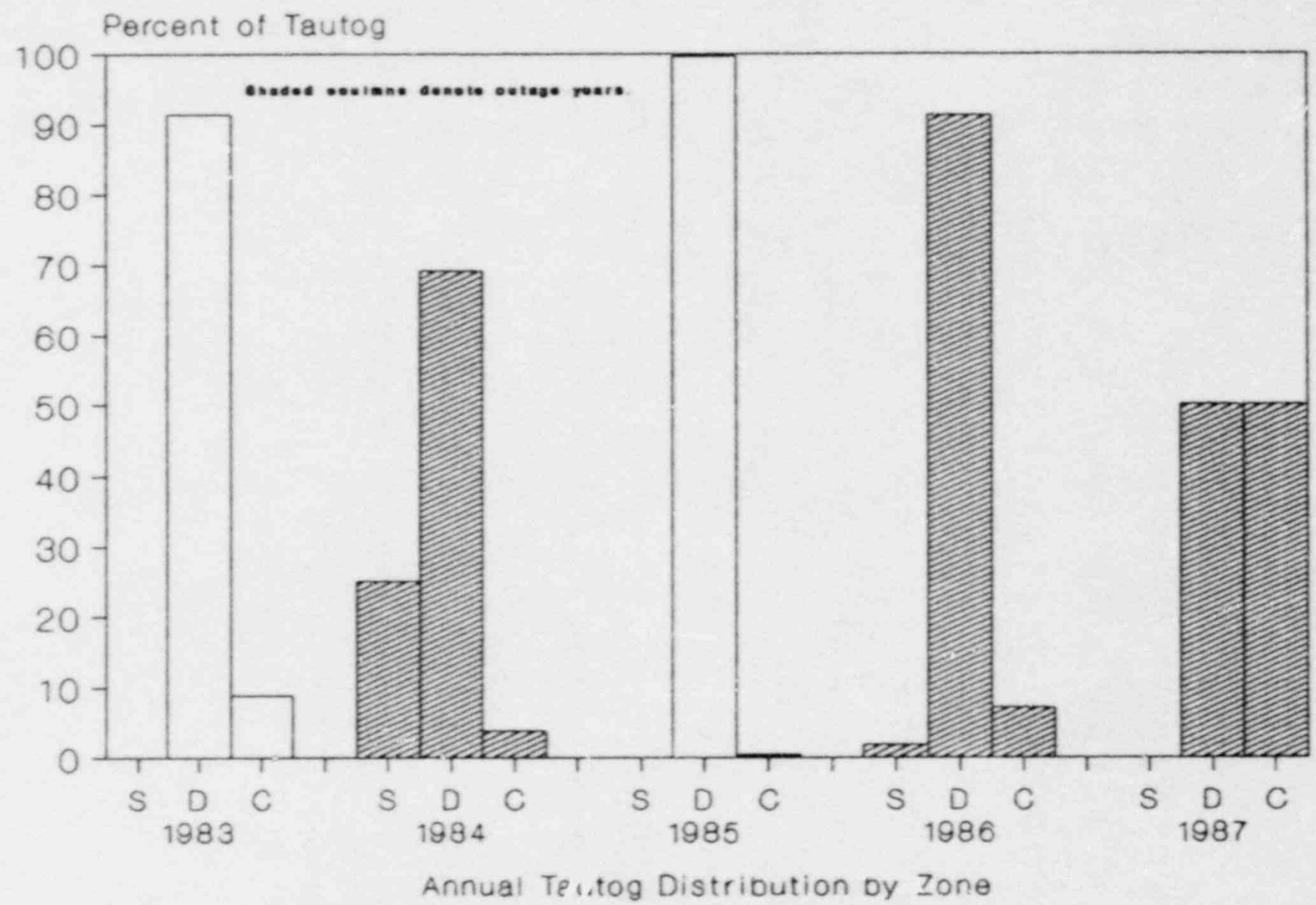


Figure 19. Distribution of tautog observed by divers in each zone (S-Stunted;D-Denuded;C-Control) off the Pilgrim Station discharge canal, 1983-1987.

In early September, one of the circulating pumps resumed operation.

It is conclusive that outages at Pilgrim Station markedly reduce sportfish catches at the Shorefront, especially striped bass and bluefish. Creel data reveal that in 1983 (high plant operational year) an estimated 1,000 bluefish and 150+ striped bass were caught by anglers at the Shorefront. Likewise, in 1985 (high output capacity) an estimated 2,200 bluefish and almost 400 bass were landed there. Conversely, with the absence of a heated discharge current during the three fishing seasons of 1984, 1986, and 1987 (outage periods), the catches of bass and bluefish declined drastically to under 150 fish total for both species and all 3 years combined. Thus, the operation of Pilgrim Station has a positive connotation for sport fishermen off Rocky Point by concentrating popular game fish at a point source within casting distance from shore. However, this attraction to the discharge elevates the potential for fish kills caused by gas supersaturation and thermal stress and can substantially increase the exploitation rate of a species.

IV. IMPACT PERSPECTIVE

The following summary is provided of the major findings of impact on fisheries' resources in the inshore sector of western Cape Cod Bay, centering on the area around the Pilgrim Nuclear Power Station (Table 4). As the summary only highlights salient points, the reader is encouraged to refer to individual sections of this report for more detailed discussion of investigative areas.

Western Cape Cod Bay supports commercially important lobster and groundfish fisheries as well as intensive seasonal recreational lobster and hook-and-line fisheries. The population dynamics of an individual species are influenced by a complex interaction of biotic interrelationships, including intra- and interspecific coactions with abiotic factors (e.g., water temperature and currents). The assessment of ecological impact of Pilgrim Station operation on the area's fisheries' resources involves measuring many of the parameters that influence distribution, abundance, and size composition of target species. Based on monitoring data collected to date off the power station, there have been local biotic changes and environmental disruptions documented; these have been site specific, however.

Although no major perturbations have been detected in the ecology of western Cape Cod Bay as a result of plant operation, the potential for future impact by the plant, either overtly or indirectly by altering community structure, exists. As Pilgrim Station has operated at an average of slightly less than 50% of its operational capacity, we probably have not yet realized the plant's full potential for impacting marine resources. Impact

Table 4. A summary of impact assessment by study of Pilgrim Nuclear Power Station (PNPS) on marine fisheries' resources in western Cape Cod Bay during the operational history of the power plant.

Investigation	Impact of PNPS	1983/1984/1985/1986/1987	Comments
Gill-net study	Cunner evidently attracted to the thermal effluent.	Relative abundance of cunner in the area of the thermal discharge down in 1984 (outage year) and down further in 1985 (high output capacity), suggesting a recent decline in local stock size. CPUE in 1986 was similar to that in 1985. In 1987, CPUE declined further.	The implications of attraction are twofold; to sport fishermen this is beneficial, but conversely this concentrates fish in a high-risk area with the potential for overfishing, thermal stress, gas bubble disease, and exposure to chemicals.
	There is a (?) relationship between CPUE for tautog and PNPS operational output.	Relative abundance of tautog was not appreciably different over these years.	Same as above.
SCUBA observations	Supporting data that cunner are attracted to the plant discharge current.	Increased cunner sightings in the control zone in 1984/1987; in the discharge in 1983, 1985, and 1986 (reduced current).	With no thermal effluent (1984, 1987) there was an apparent shift in distribution of cunner away from the discharge (denuded) zone and toward the control zone.
	Concentrations of striped bass in the vicinity of PNPS linked to the cooling water discharge.	For the first time since 1979, bluefish and bass were not sighted by divers in the environs of PNPS in 1984 but were again sighted in 1985 in small schools frequenting the discharge area. Only a few bass were seen in 1986-87.	As bass exhibit a preference for moving water, such as PNPS effluent, their absence/scarcity in the diving area during outages is apparently related to the lack of discharge flow
Creel survey	With the plant operating, the outfall at PNPS has proven to be an attractive feeding ground concentrating sportfish for an extended period of time in a location close to shore.	Over 1,000 bluefish and > 150 striped bass were caught by anglers at PNPS in 1983; and 2,200 bluefish and almost 400 bass in 1985; no bass and only a small number of bluefish were caught in 1984. Catches were once again low in 1986-87 during the extended outage.	Power Plant has had a positive effect on the sport fishing off Rocky Point; however, the attraction of game fish to the discharge increases the potential for overfishing a local stock and for fish kills via high temperature and gas supersaturation. Bluefishing was prolonged into November 1985 by the presence of the hot-water discharge.
Haul-seine study	Intake embayment with its breakwater and dredged channel appears to be a haven for fishes in an otherwise open coastal region.	Seine catches in the Intake increased in 1984 and 1985, were down in 1986, but back up in 1987.	Shorezone finfish residing in the Intake, especially in the vicinity of the intake screen wall, are subject to plant entrapment, impingement and thermal backwash effects.
Trawl study	Winter flounder may only avoid the immediate area of the discharge canal. Catch abundance of winter flounder, yellowtail flounder, and windowpane was found to be correlated (positive) to PNPS M.D.C. factor (output), when the plant is operating.	A bimodal distribution of flounder relative abundance was found at the surveillance station in 1984 that was not found for 1981-1983, 1985-1987. In 1986-87, CPUE in the discharge area exceeded that at the reference location.	Autumn trends (plots) of relative abundance for winter flounder were different at reference versus surveillance sites from 1981-1983 (operational years) but were similar in 1984 (outage year). In 1985, we found CPUE to be correlated (+) at reference and discharge areas.
	Concentrating in the channel of the intake embayment are winter flounder.	Catch-per-effort for winter flounder dropped markedly in 1984 and 1985 at both the reference and discharge stations. CPUE stabilized, somewhat, in 1986 and 1987.	Seasonal bottom trawl catch rates for winter flounder were consistently higher in the intake embayment in the spring, summer, fall. This is a boon to recreational fishermen at PNPS Shorefront.

Table 4 . Trawl study (cont.).

	The intake at PNPS, an altered environment, has characteristics (relatively sheltered habitat with rock and algal cover) which apparently attract juvenile fish.	A comparison of 1983 to 1984 is not applicable because routine trawling was not conducted in the intake in 1983. However, comparing the catches in the intake with the other sites sampled from 1984-1986, we found that substantially larger numbers of smaller winter flounder were in the intake channel in spring or summer.	This situation has the potential for negative impact for it increases susceptibility to impingement and backwash effects.
Lobster pot-catch study	There may be a connection between PNPS cooling water discharge and legal lobster catch rate in the thermally-affected area.	Catch rate of legal lobsters declined overall in the study area in 1984 from the 1983 level and was the lowest value for the 15-year study; increasing again in 1985 by about 100%. In 1986, CPUE was the highest of the entire survey, but in 1987 dropped to a level identical to 1984.	A significant negative correlation ($P \leq 0.05$) exists for annual thermal capacity and legal lobster catch rate in the impacted area and a correlation (negative) ($P \leq 0.10$) between seasonal thermal capacity and catch.
Dissolved gas analysis and gas bubble disease (GBD) incidents at PNPS.	In August 1985, PNPS was operating at or near 100% capacity; water temperatures in the discharge were as high as 30.5 C and dissolved gases were supersaturated (Nitrogen + argon saturation levels ranged from 112-[illegible]9%). An estimated 600 silversides and 300 juvenile menhaden were afflicted with GBD in the discharge canal; fish were stressed, but mortality, which was likely, was not evidenced.	No GBD incidents observed in 1983. In 1984, PNPS had no thermal component to induce GBD. This was also the case in 1986 and 1987.	Gas supersaturation resulted in several noteworthy incidents of GBD in fish at PNPS. Mortalities of 43,000 and 5,000 adult menhaden occurred in the discharge in 1973 and 1975, respectively. Striped mullet schooling in the discharge were afflicted in late 1975. GBD can severely stress or kill (outright or through increased susceptibility to disease or predation) fish residing in the discharge.

assessment at the past level of plant output may not be valid for a long-term, higher operational status in the future.

V. CONCLUSIONS

Lobster - Commercial Fishery

Sampled commercial lobster trap-catch data from surveillance and reference areas were examined over time. The commercial catch rate of legal lobster (≥81 mm CL) in the discharge area in 1987 was 0.34/trap-haul, while legal catch rate in the control area was 0.20. These figures represent declines of 15% and over 50%, respectively, from 1986. Catch rates in the discharge area, which have declined slightly over the last five years (from 0.47 in 1983 to 0.34 in 1987), have not mirrored commercial catch rates in western Cape Cod Bay which have fluctuated.

Legal catch data from discharge and reference areas were compared statistically and no significant ($P > 0.05$) differences were found over time. However, we found a significant ($P \leq 0.05$) negative correlation between catch rate of legal-sized lobster in the impacted area and the operating level of Pilgrim Station in contrast to no significant correlation for reference areas.

Lobster - Research Study

The field research lobster trap study has been conducted for the last two years under essentially control conditions (no waste heat and reduced or no current during the extended plant outage). This unique situation enabled us to conduct a uniformity trial, where we fished standard traps in a standardized manner in one surveillance and two reference areas. The proper pairing of potentially impacted/treatment sites with non-impacted/reference sites is imperative to assess stress when the plant resumes operation.

We identified two parameters that can be used to assess impact of Pilgrim Station on the local lobster population. Rocky Point (reference) and the discharge area are an appropriate station pair to assess power plant effect on catch rate of legal lobster. As for size composition, size frequency data of legals at the two reference areas can be pooled and tested against size distribution data in the discharge when the plant resumes operation.

Inshore Groundfish

Trawl annual catch/effort data of the three dominant groundfish - winter flounder, little skate, and windowpane - were compared over the years 1983 through 1987, which included three outage years, between Stations 1 (reference location in Warren Cove) and 3 (Discharge area) to assess plant impact. There was no indication of a plant effect on the distribution of these species. Seasonal mean catch rates with estimates of precision were examined spatially. No significant differences are indicated between stations for winter flounder and windowpane. However, in summer, little skate were significantly more abundant in the discharge area (Station 3) and off White Horse Beach (Station 4 - reference) than in the Intake (Station 6) and at the primary reference location (Station 1 - Warren Cove). There is additional confirmation that the Intake is a haven for small winter flounder (< 22 cm), at least seasonally.

Pelagic and Benthi-Pelagic Fish

No relationship was found between plant operation and relative abundance of pollock, Atlantic herring, and alewives off Pilgrim Station. There is a possible attraction impact on tautog abundance in the general discharge area. With cunner, we also found a significant positive correlation between CPUE and plant operational power level ($r=0.581$; $P \leq 0.05$). Almost 34% of the variability in relative abundance of cunner can be explained by variation in plant operational output.

Shore-Zone Fishes

The haul seine provides data on the occurrence, distribution, size composition, and relative abundance of shore-zone fishes in the Pilgrim area. Our surveys have revealed rather large natural variations in relative abundance. The Pilgrim intake embayment most resembled the estuarine sampling site off Long Point in terms of total fish seined, catch rates, and species diversity. Catches at the open coastal beaches, which lack cover, were magnitudes lower. Fish concentrating in the intake channel are subject to impingement and heated backwashes. We tested monthly mean densities of the Atlantic silverside, the dominant fish seined overall, against monthly Pilgrim Station thermal capacity and monthly pump capacity. No significant correlations ($P > 0.05$) were found. To date, plant impact on shore-zone fishes has not been detected from seine data.

Diving Observations

The 1986 plant outage continued through 1987, essentially creating pre-operational conditions for the biota in the discharge area from March-August because both circulating water pumps were not operating during those months. The blue mussel population throughout the entire discharge canal and surrounding the canal mouth rapidly increased in numbers through the summer.

Irish moss in the study area also experienced enhanced growth and began recolonizing the denuded zone; zone demarcations thus became difficult to distinguish. Kelp and filamentous brown and green algae were also commonly observed.

The majority of finfish observed (45%) was found in the discharge area, followed by the control area (36%). The total number of fish observed was the lowest recorded since study inception, primarily due to a decline in cunner sightings. Species diversity and composition were essentially the same as in previous years. Cunner, although at its lowest relative abundance in the study, remained the predominant species observed (79%). The decline in cunner may reflect changes in juvenile abundance and distribution. Cunner numbers increased in the control and stunted areas over previous years, possibly in response to the floral recolonization at these sites. There has been observational evidence of attraction of cunner to the current component of the station discharge.

Pollock ranked second in sightings, observed primarily in the denuded area. Relative abundance of pollock decreased from 1986 (130 fish) to 1987 (93 fish); however, this observed decline may be a sampling artifact related to their mobility. The number of tautog observed was very low in 1987 (10 fish) reflecting a possible decline in the local population. Distribution was evenly apportioned between the denuded and control areas, in contrast to past years when tautog were found almost exclusively in the denuded area. Tautog data support the contention of some attraction for this species to the discharge current.

Sportfishing

Overall angling activity and sportfish catches at the Pilgrim Shorefront were the lowest recorded since the area opened to the public in 1973. Two factors contributing to the low activity and catches were: restricted access to the right discharge jetty, outer intake breakwater, and the beach at the head of the Intake embayment in April and May; and the power outage that lasted throughout the fishing season. Power outages markedly reduce sportfish catches of striped bass and bluefish at the Shorefront as historical data show. The release of a heated discharge concentrates popular gamefish in an area within casting distance from shore. The concentration of fish in the heated effluent, however, increases the potential for fish kills caused by gas supersaturation, thermal stress, and cold shock.

Impact Perspective

Based on monitoring data collected to date off the power station, there have been local biotic changes and environmental disruptions documented; these have been site specific, however.

Although no major perturbations have been detected in the ecology of western Cape Cod Bay as a result of plant operation, the potential for future plant impact, either overtly or indirectly by altering community structure, exists. As Pilgrim Station has operated at an average of slightly less than 50% capacity over its operational history, we probably have not yet realized the plant's full potential for impacting marine resources. Impact assessment at the past level of plant output may not be valid for a long-term higher operational status.

VI. ACKNOWLEDGMENTS

We acknowledge the contributions of numerous staff members of the Division of Marine Fisheries, who assisted in various phases of field sampling and data analysis, especially Karen Bugley, Neil Churchill, Steven Correia, Kevin Creighton, Robert Demanche, Virginia Fay, Dan McKiernan, and Carl Sylvia. We thank Chris Kyranos for allowing us to sample his lobster catches, and W.C. Sibley and Richard Schneider for overseeing the collection of creel data at the Shorefront area. Also greatly appreciated is the work of Carleen Loper and Marie Callahan for typing this report. Finally, we thank Robert D. Anderson, W. Leigh Bridges, and the Pilgrim Administrative-Technical Committee for overseeing the entire study program.

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FINAL

SEMI-ANNUAL REPORT

Number 31

(Volume 1 of 2)

to

BOSTON EDISON COMPANY

on

BENTHIC ALGAL AND FAUNAL MONITORING AT THE PILGRIM NUCLEAR POWER STATION (CHARACTERIZATION OF BENTHIC COMMUNITIES)

January - December 1987

7 April 1988

BATTELLE
Ocean Sciences
397 Washington Street
Duxbury, Massachusetts 02332

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EXECUTIVE SUMMARY

This report presents the results of the most recent benthic monitoring surveys at the Pilgrim Nuclear Power Station (PNPS). The surveys are part of a long-term monitoring effort by Boston Edison Company (BECO) to assess the impact of the thermal effluent on the inshore benthic community. Volume 1 of this report characterizes the benthic environment and its seasonal changes in 1987. Methods and procedures follow guidelines established by the Pilgrim Administrative Technical Committee (PATC) and adopted by BECO as modified in 1981 (Boston Edison Co., 1987a).

The habitats and their algal and faunal communities found at the Manomet Point, Rocky Point, and Effluent subtidal stations are typical of shallow, exposed areas in western Cape Cod Bay (Grocki, 1984; Davis and McGrath, 1984). The rocky substrata characteristic of all three stations are covered with dense macroalgal communities typically dominated by <u>Chondrus crispus</u> and <u>Phyllophora</u> spp. This algal turf has created a habitat suitable for diverse faunal communities. Faunal species at all three sampling stations have numbered from 50 to more than 100 species, and total faunal densities have ranged from 10^4 to 10^6 individuals per square meter. The faunal communities are dominated by arthropods, particularly of the order Amphipoda. The results of this study indicate that faunal species richness, faunal diversity, and total algal biomass in western Cape Cod Bay exhibit seasonal cycles, with low values in spring followed by high values in fall. Faunal densities do not reflect such a cycle and may depend more on the topography of the stations than on seasonality.

INTRODUCTION

This report presents, in a condensed format, the results of the most recent series of benthic monitoring surveys performed at the Pilgrim Nuclear Power Station (PNPS). Detailed technical information is available from Battelle Ocean Sciences upon request. The report is presented in two volumes. Volume 1 contains a characterization of the benthic environment and its seasonal changes in 1987; Volume 2 discusses the impact of the PNPS operations on the benthic communities based on the observations described in Volume 1 and in comparison to earlier observations (1983 to 1986). It is hoped that this format will make the results more accessible to readers who are not necessarily interested in technical details.

PNPS is located on the northwest shore of Cape Cod Bay, 8 km (5 miles) southeast of Plymouth Harbor, Massachusetts. The quantitative algal and faunal data presented and analyzed in this report were derived from field collections conducted in March and September 1987. Qualitative transect data were collected on March 25, June 9, September 29, and December 22, 1987.

METHODS

The specifications for methods and procedures follow guidelines established by the Pilgrim Administrative Technical Committee (PATC) and adopted by BECO as modified in 1981 (Boston Edison Co., 1987a). A detailed description of the field, laboratory, and analytical processes that pertain to the current report can be found in Semi-Annual Report No. 29, Volume 1 (Boston Edison Co., 1987a). As in previous samplings, five replicate 0.1089-m^2 benthic samples were collected with SCUBA at the Effluent station and the two reference stations at Manomet Point and Rocky Point (Figure 1, Plate 1, Plate 2). Quantitative samples were preserved in the field and returned to the laboratory, where faunal and algal fractions were separated and analyzed. Qualitative transect data were collected using a fixed line stretched offshore along the discharge canal centerline and a movable line placed perpendicular to the fixed line. The transect was traversed by divers who noted the boundaries of the stunted and denuded Chondrus (Irish moss) zones that extend offshore from the effluent canal. Quantitative data were analyzed on the Battelle VAX system using software that had previously been used to analyze PNPS benthic data.

The continuing outage at PNPS that began in April 1986 was of particular interest during this reporting period. No thermal loading took place during 1987. One circulating pump was operating for most of January, February, and September through December (during six days in December, two pumps were operating); from March through August, there was no or very little current generated.

Battelle's Project Manager for the PNPS algal and faunal investigations was Ms. Tracy Stenner. Algal taxonomy was performed by Ms. Brenda Cavicchi and Ms. Maureen Nolan. Faunal taxonomy was conducted by Ms. Nancy Padell and Mr. Russell Winchell. Field logistics and collections were

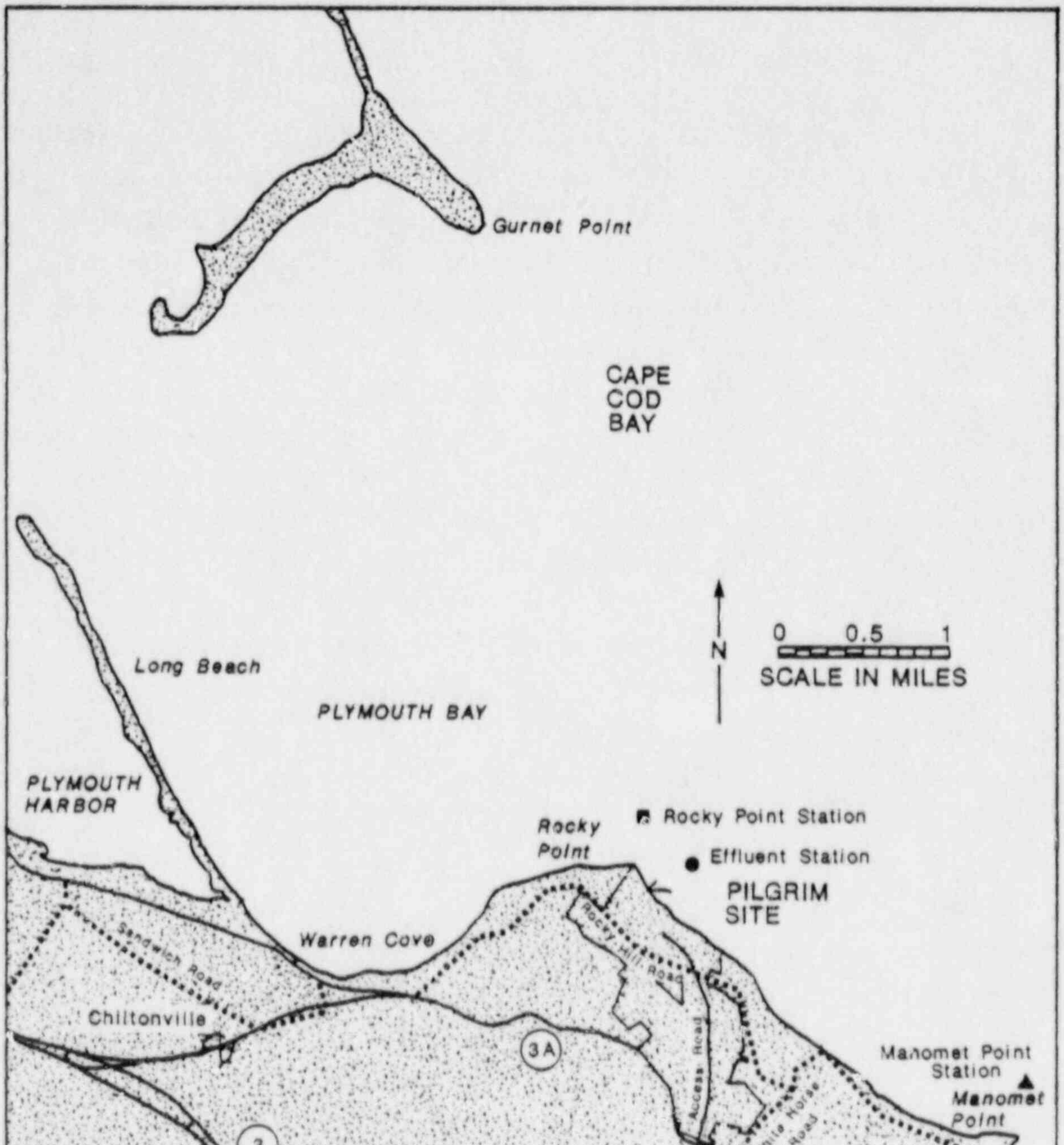

FIGURE 1. LOCATION OF THE ROCKY POINT, EFFLUENT AND MANOMET POINT SUBTIDAL (3 m MLW) STATIONS.

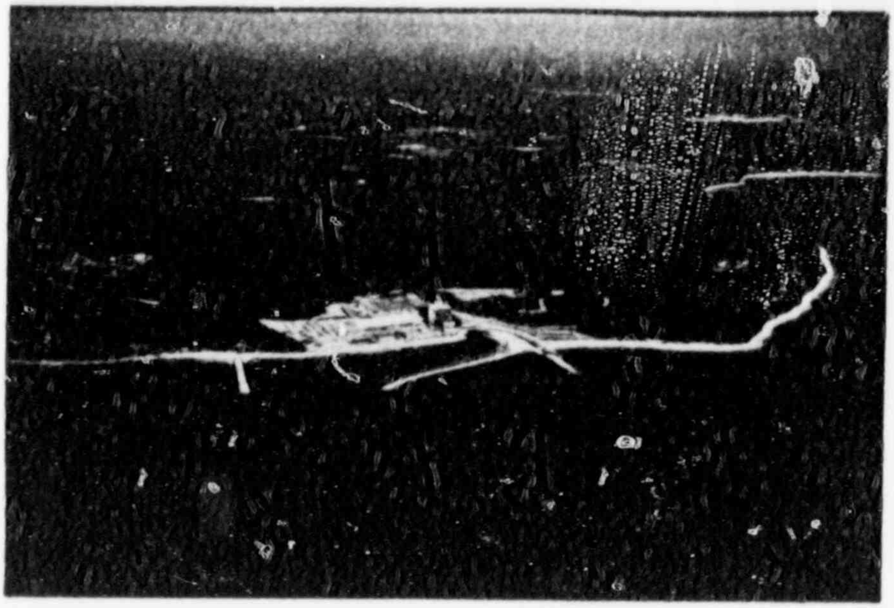

Plate 1. Aerial view of the Rocky Point and Effluent quantitative sampling stations. The Rocky Point station is located approximately 0.25 nautical miles northwest of the Effluent station and serves as a reference station.

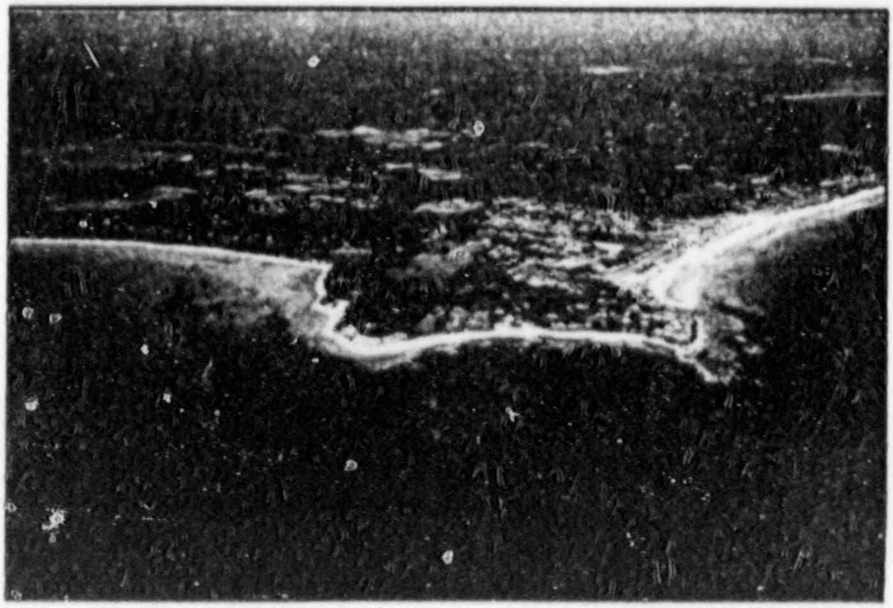

Plate 2. Aerial view of the Manomet Point quantitative sampling station. The Manomet Point station is located approximately 2 nautical miles southeast of the Effluent station and serves as a reference station.

supervised by Mr. John Williams. Additional personnel participating in this project included Dr. Brigitte Hilbig, Dr. James A. Blake, Mr. Phillip Nimeskern, Mr. Robert Williams, Mr. Steven Mellenthien, Mr. Carlos Fragata, Mr. Mark Curran, Mr. Tom Angell, Mr. Brian Dwyer, Mr. Eugene Ruff, Ms. Ellen Baptiste, Ms. Barbara Greene, and Ms. Elisabeth Haase.

RESULTS

FAUNAL STUDIES

Systematics

During 1987, a new species was added to the taxonomic list of benthic invertebrate fauna at PNPS. This species is the bivalve Hiatella striata, which was collected at all three station. This species co-occurs with its congener H. arctica and is distinguishable from the latter only as a juvenile when the characteristic spines on the shell are still visible. H. striata has been found to be quite common in Massachusetts Bay (Blake et al., 1987; Sebens et al., 1987). The taxonomic list now consists of 466 invertebrate species that have been observed at the three monitoring stations sampled during this program.

Species Richness

Species richness values (number of species) for all three stations in March and September 1987 are presented in Table 1. The values for spring 1987 were recalculated excluding the indeterminate and juvenile individuals that were not identified to species. Both in spring and fall, the lowest number of species (S) was found at the Effluent station (36 and 41 species, respectively). The numbers of species at the two reference stations were quite similar. At the Manomet Point station, 48 species were found in March, and 62 species in September. At the Rocky Point station, 42 species were found in March, and 60 species were found in September.

TABLE 1. FAUNAL SPECIES RICHNESS FOR THE MONTHS OF MARCH AND SEPTEMBER 1987.

Station/Month	Number of Species (S)	Species Richness ($\hat{S}$)($\pm$95% CI)	Variance ($\hat{S}$)
<u>Effluent</u>			
March	36	43.2 ± 7.37	7.04
September	41	48.2 ± 6.47	5.44
<u>Manomet Point</u>			
March	48	57.6 ± 7.53	7.36
September	62	72.4 ± 7.53	7.36
<u>Rocky Point</u>			
March	42	49.2 ± 4.15	2.24
September	60	67.2 ± 12.36	19.84

CI = confidence interval.

In order to assess rare species that might be present but not found in the samples because of the relatively small area sampled (five replicates equals 0.5445 m^2), a jackknifed estimate was calculated following procedures of Heltshe and Forrester (1983). The estimated species richness ($\hat{S}$) was lowest at the Effluent station both in March and September, followed by the Rocky Point station and the Manomet Point station. The variance of the estimated species richness (var $\hat{S}$) is a measure of the spatial distribution of species that occurred only in one replicate sample from a station ("unique" species). High values for var ($\hat{S}$) indicate that all unique species at the station are concentrated in a small space; low values for var ($\hat{S}$) indicate that the unique species are randomly distributed over the area a community inhabits. High var ($\hat{S}$) was found only in September at Rocky Point; for all other samples, var ($\hat{S}$) was low.

At all three stations, species richness increased from spring to fall. Species richness was not significantly different among stations in spring, as indicated by overlapping 95 percent confidence intervals. In the fall, the Effluent station had significantly lower species richness than the reference stations, indicated by a lower 95 percent confidence interval that does not overlap with those of the reference stations.

Species richness calculated from samples of previous years and a comparison of these earlier values with ones from 1987 will be discussed in relation to PNPS operations in Volume 2 of this report.

Faunal Density

Benthic macrofaunal densities per replicate sample and per square meter were calculated for both March and September 1987 (Table 2). In March, mean densities at the Effluent

TABLE 2. FAUNAL DENSITIES AT THE EFFLUENT, MANOMET POINT, AND ROCKY POINT STATIONS IN MARCH AND SEPTEMBER 1987.

	Mean Number of Individuals per Replicate		Number of Individuals per m^2	
	Mar	Sep	Mar	Sep
Effluent	3346	3106	30,725	28,518
Manomet Point	6086	5744	55,873	52,746
Rocky Point	3282	4133	30,125	38,009

station were intermediate between densities at the Manomet Point and Rocky Point stations. In September, mean densities at the Effluent were lower than those at the reference stations. The highest mean densities per replicate among the fall samples were again found at Manomet Point. Densities increased from spring to fall at Rocky Point by 26 percent, but decreased at the other stations by 6 to 7 percent.

Species Dominance

The 15 numerically dominant species present in replicate samples from each station in March and September 1987 are presented in Table 3 as mean number of individuals per replicate. The species composition of the March samples is detailed in Semi-Annual Report No. 30 (Boston Edison Co., 1987b) and can be summarized as follows: the Effluent station shared all of the top 5 and 10 of the top 15 species with the Manomet Point station; with the Rocky Point station, the Effluent station shared 3 of the top 5 and 12 of the top 15 species. The two reference stations shared 3 of the top 5 and 11 of the top 15 species. The top 15 species contributed 97.24 percent of the total fauna at the Effluent, followed by 95.09 percent at Manomet Point and 93.02 percent at Rocky Point.

In September, the Effluent station and the Manomet Point station shared 2 of the top 5 species and 9 of the top 15 species. The shared two species of the top five dominants, the arthropods *Calliopus laevisculus* and *Ischyrocerus anguipes*, ranked first and third, respectively, at the Effluent and third and fifth, respectively, at Manomet Point. The remaining top five species at the Effluent ranked much lower at Manomet Point; the top two species at Manomet Point (*Margarites helicinus* and *Pleusymtes glaber*) did not occur among the dominants of the Effluent station.

TABLE 3. RANK ORDER OF ABUNDANCE FOR THE 15 DOMINANT TAXA IN SAMPLES COLLECTED IN MARCH AND SEPTEMBER 1987.

March 1987		September 1987	
Station/Species	Mean Number per Replicate	Station/Species	Mean Number per Replicate
Effluent		**Effluent**	
Jassa falcata	1642.4	Calliopius laeviusculus	789.6
Ischyrocerus anguipes	443.2	Jassa falcata	566.4
Acarina	378.4	Ischyrocerus anguipes	312.8
Dexamine thea	191.2	Pontogeneia inermis	296.8
Mytilus edulis	106.4	Lacuna vincta	212.8
Corophium acutum	96.8	Acarina	198.4
Idotea phosphorea	92.0	Caprella penantis	185.6
Calliopius laeviusculus	76.0	Dexamine thea	102.4
Lacuna vincta	61.6	Idotea phosphorea	65.6
Pontogeneia inermis	52.8	Corophium acutum	43.2
Caprella penantis	39.2	Haliclystus salpinx	36.8
Corophium insidiosum	37.6	Corophium insidiosum	28.0
Corophium bonelli	13.6	Caprella linearis	28.0
Corophium spp.	12.0	Metopella angusta	21.6
Pagurus acadianus	11.2	Mytilus edulis	20.8
Total of 15 Species	3254.4	Total of 15 Species	2908.8
Remaining Fauna—27 spp.	92.0	Remaining Fauna—46 spp.	196.8
Total Fauna—42 spp.	3346.4	Total Fauna—61 spp.	3105.6
Manomet Point		**Manomet Point**	
Jassa falcata	2479.2	Margarites helicinus	635.2
Ischyrocerus anguipes	1081.6	Pleusymtes glaber	615.2
Corophium acutum	449.6	Acarina	460.0
Acarina	387.2	Calliopius laeviusculus	313.6
Mytilus edulis	276.0	Onoba aculea	284.8
Dexamine thea	215.2	Ischyrocerus anguipes	284.8
Caprella penantis	210.4	Mytilus edulis	257.6
Lingula aculeus	176.8	Dexamine thea	252.0
Lacuna vincta	172.8	Corophium insidiosum	250.4
Margarites helicinus	81.6	Pontogeneia inermis	248.8
Idotea phosphorea	72.0	Jassa falcata	225.6
Proboloides holmesi	72.0	Lacuna vincta	165.6
Pleusymtes glaber	41.6	Caprella linearis	145.6
Pontogeneia inermis	40.0	Corophium bonelli	142.4
Corophium bonelli	32.0	Mitrella lunata	121.6
Total of 15 Species	5788.0	Total of 15 Species	4403.2
Remaining Fauna—40 spp.	298.4	Remaining Fauna—76 spp.	1340.8
Total Fauna—55 spp.	6086.4	Total Fauna—91 spp.	5744.0
Rocky Point		**Rocky Point**	
Ischyrocerus anguipes	659.2	Jassa falcata	404.8
Jassa falcata	500.0	Acarina	349.6
Dexamine thea	426.4	Ischyrocerus anguipes	307.2
Acarina	281.6	Pleusymtes glaber	287.2
Lacuna vincta	265.6	Pontogeneia inermis	238.4
Pontogeneia inermis	258.4	Dexamine thea	219.2
Cingula aculeus	131.2	Alvania spp.	204.8
Calliopius laeviusculus	117.6	Caprella penantis	161.6
Corophium acutum	108.0	Margarites helicinus	154.4
Caprella penantis	95.2	Corophium bonelli	136.0
Mytilus edulis	56.8	Onoba aculea	134.4
Corophium bonelli	53.6	Nicolea zostericola	126.4
Idotea phosphorea	37.6	Corophium insidiosum	124.8
Phoxocephalus holbolli	31.2	Calliopius laeviusculus	114.4
Corophium insidiosum	30.4	Caprella linearis	95.2
Total of 15 Species	3052.8	Total of 15 Species	3058.4
Remaining Fauna—33 spp.	228.8	Remaining Fauna—70 spp.	1080.8
Total Fauna—48 spp.	3281.6	Total Fauna—85 spp.	4139.2

The Effluent and Rocky Point stations shared 3 of the top 5 and 8 of the top 15 species. The shared top five species included the two species also shared by the Effluent and Manomet Point stations and in addition the amphipod Pontogeneia inermis. Calliopus laevisculus, which ranked first at the Effluent, occurred at a much lower rank at Rocky Point; Lacuna vincta, ranking fifth at the Effluent, was not among the dominants at Rocky Point.

The two reference stations shared 2 of the top 5 and 11 of the top 15 species in September 1987; three of these species, Margarites helicinus, Pleusymtes glaber, and Onoba aculea, were not among the top 15 species at the Effluent station. Margarites helicinus, which ranked first at Manomet Point, ranked much lower at Rocky Point; similarly, Jassa falcata, which ranked first at Rocky Point, ranked much lower at Manomet Point. Seven of the top 15 species were present at all three stations. Mytilus edulis ranked 15th at the Effluent, sixth at Manomet Point, and was not among the top 15 species at Rocky Point.

The comparison of the dominant species in spring and fall samples revealed that seasonal changes were the least noticeable at the Effluent station. Two of the top five dominants in spring (Jassa falcata and Ischyrocerus anguipes) were also among the top five dominants in fall, outranked by Calliopus laevisculus that increased about 10-fold in number between spring and fall and moved into first rank. In addition, 11 of the 15 top spring dominants were present among the 15 top fall dominants. Slight changes took place in the species rankings; changes in species composition were minor and occurred among relatively rare species.

At Manomet Point, changes were evident both in ranking of the dominants and species composition. Only one of the top five spring dominants was also among the top five fall dominants, and only 8 of the spring top 15 dominants were also among the fall top 15 dominants. The two species ranking first and second in the fall samples (Margarites helicinus and Pleusymtes glaber) increased about 10-fold in number between March and September and therefore outranked the top two species of the spring samples. Onoba aculea was among the top five species in the fall but was not among the dominant species at any station in the spring. Corophium acutum, which ranked third in the spring samples, was not among the dominants in the fall at Manomet Point.

Seasonal changes at Rocky Point were somewhat intermediate. Four of the five top spring dominants were also among the fall top five dominants, and 8 of the top 15 spring dominants were also among the top 15 fall dominants. Many of the rankings changed slightly; changes in species composition were noted mostly among the relatively rare species. Lacuna vincta, ranking fourth in the spring samples, was not among the top 15 dominants in the fall samples. Mytilus edulis, which was present in low numbers in the spring samples from Rocky Point, was no longer among the dominants in fall.

Species Diversity

Species diversity is a measure of the number of species present (species richness) in combination with the distribution of population size of the respective species (evenness). In general, low evenness values indicate that a community is dominated by one or a few species (Levinton, 1982). Communities with high diversity are normally not stressed. Shannon-Wiener diversity (H') and evenness (J') values (Levinton, 1982) were calculated for samples collected in March and September 1987 (Table 4). The data were calculated excluding juvenile and indeterminate individuals that were not identified to species. The practice of calculating diversity with and without Mytilus has been continued for consistency with past reports.

TABLE 4. DIVERSITY VALUES (SHANNON-WIENER) FOR EACH STATION SAMPLED IN MARCH AND SEPTEMBER 1987.

	March 1987				September 1987			
	With *Mytilus*		Without *Mytilus*		With *Mytilus*		Without *Mytilus*	
Station	H′	J′	H′	J′	H′	J′	H′	J′
Effluent	2.47	0.48	2.33	0.46	3.33	0.62	3.29	0.62
Manomet Point	2.88	0.52	2.74	0.49	4.50	0.76	4.43	0.75
Rocky Point	3.60	0.67	3.53	0.66	4.48	0.76	4.42	0.75

H′ = Shannon-Wiener diversity.
J′ = evenness.

Both in spring and fall, the lowest diversity (H′) was found at the Effluent. The highest diversity was found at Rocky Point in March and at Manomet Point in September. Excluding *Mytilus* from the data decreased the diversity index slightly at all stations during both seasons, reflecting the essentially small contribution of *Mytilus* to the total fauna. Species diversity increased from March to September at all stations.

The evenness values (J′) show the same general pattern as the diversity index. In spring, evenness was highest at Rocky Point, followed by Manomet Point and the Effluent. In fall, evenness was equally high at both reference stations and lowest again at the Effluent station. Elimination of *Mytilus* from the Effluent station data decreased evenness in March and had no effect in September; at the reference stations, the elimination of *Mytilus* decreased evenness. At all stations, evenness was highest in the fall.

Measures of Similarity

Similarity analysis followed by cluster analysis (Boesch, 1977) was used to answer the following questions concerning the structure of the benthic communities present at the three stations sampled in 1987:

- Does the benthic community at the Effluent station differ from the community at the reference stations?
- Do seasonal changes of the benthic community at the Effluent station differ from those at the reference stations?
- If there are differences in species composition and/or seasonality: which species cause these differences?

To answer these questions, similarity analyses were performed for replicates (normal analysis) and species (inverse analysis). By the normal cluster analysis, all 30 replicates sampled in 1987 were compared for the species present in each replicate; by the inverse cluster analysis, the co-occurrence of the top 50 numerically dominant species identified in the 1987 samples was compared.

Normal Analysis

Normal cluster analyses were performed using the Bray-Curtis similarity measure followed by group average sorting (Boesch, 1977). A second similarity measure, the Normalized Expected Species Shared (NESS) (Grassle and Smith, 1976), was also used, but the results are omitted from this report because both Bray-Curtis and NESS showed the same pattern.

The results of the similarity analysis for the spring samples are shown in Figure 2. The dendrogram shows that the Effluent station is almost as similar to the reference stations as the reference stations are to each other; this is indicated by the levels of similarity marked on the horizontal lines connecting the Effluent station with both reference stations (0.69) and the reference stations to each other (0.72). The difference between these two values is minor.

The cluster analysis of the fall samples resulted in a dendrogram with two main groups, one comprising all replicates of the Effluent station and the other including both reference stations (Figure 3). The most dissimilar group within the reference station cluster contains two replicates of the Rocky Point station (outer right edge of the dendrogram). In comparison to spring, the reference stations were more similar to each other in fall, whereas the Effluent station was less similar to the reference stations.

A normal cluster analysis of the combined spring and fall data was performed to show seasonal patterns. Figure 4

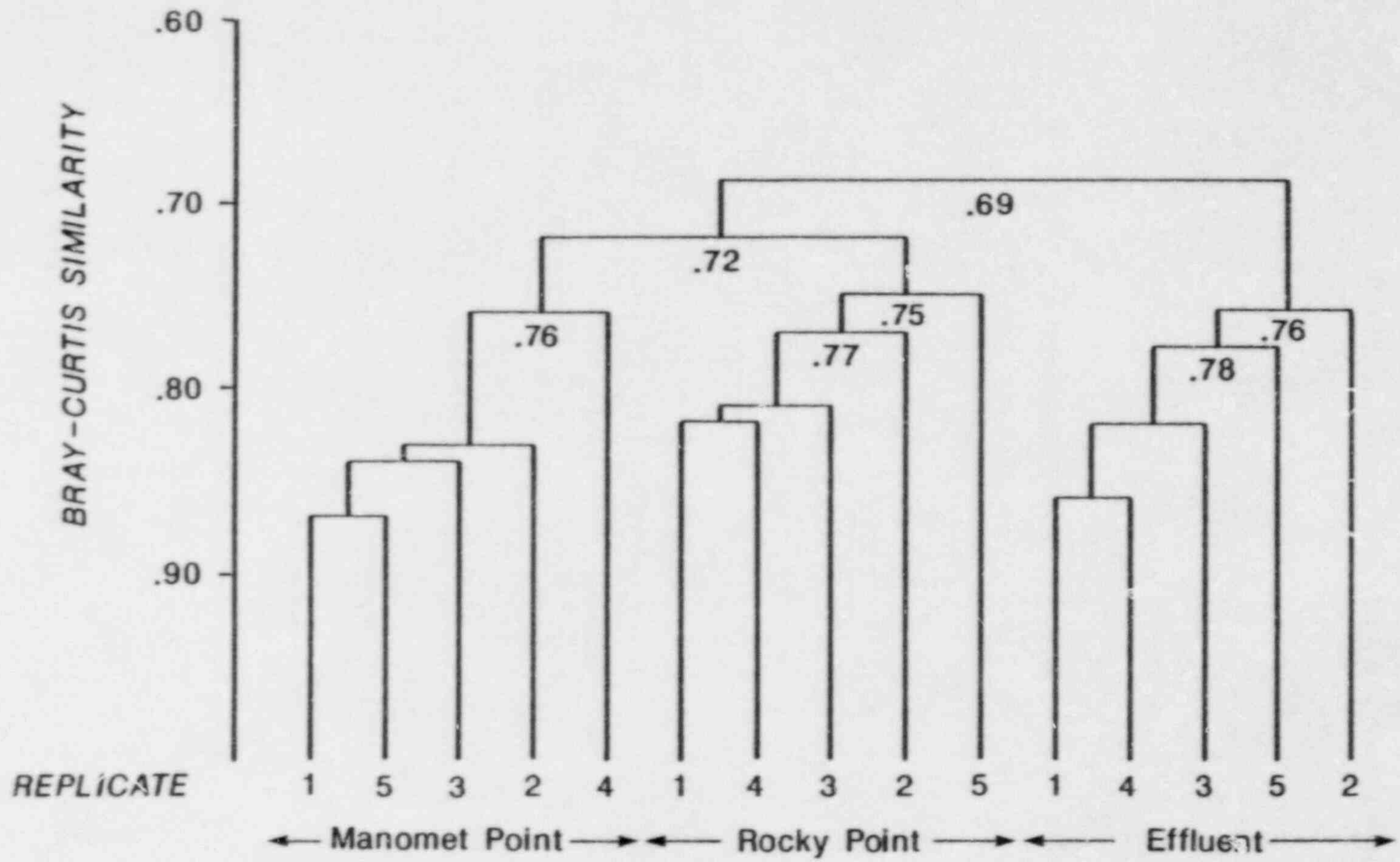

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FIGURE 2. DENDROGRAM SHOWING RESULTS OF CLUSTER ANALYSIS OF MARCH 1987 DATA USING BRAY-CURTIS AND GROUP AVERAGE SORTING.

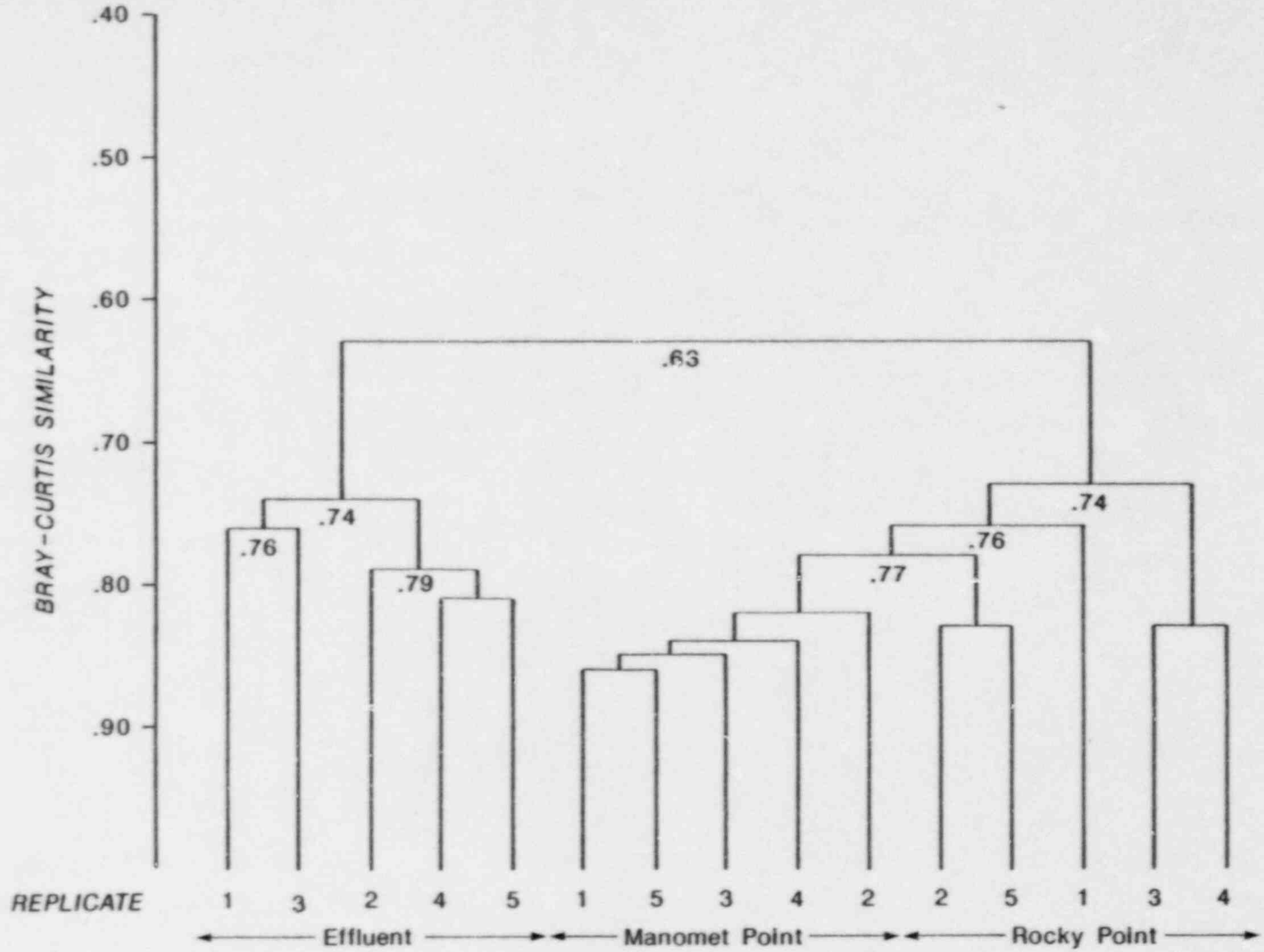

FIGURE 3. DENDROGRAM SHOWING RESULTS OF CLUSTER ANALYSIS OF SEPTEMBER 1987 DATA USING BRAY-CURTIS AND GROUP AVERAGE SORTING.

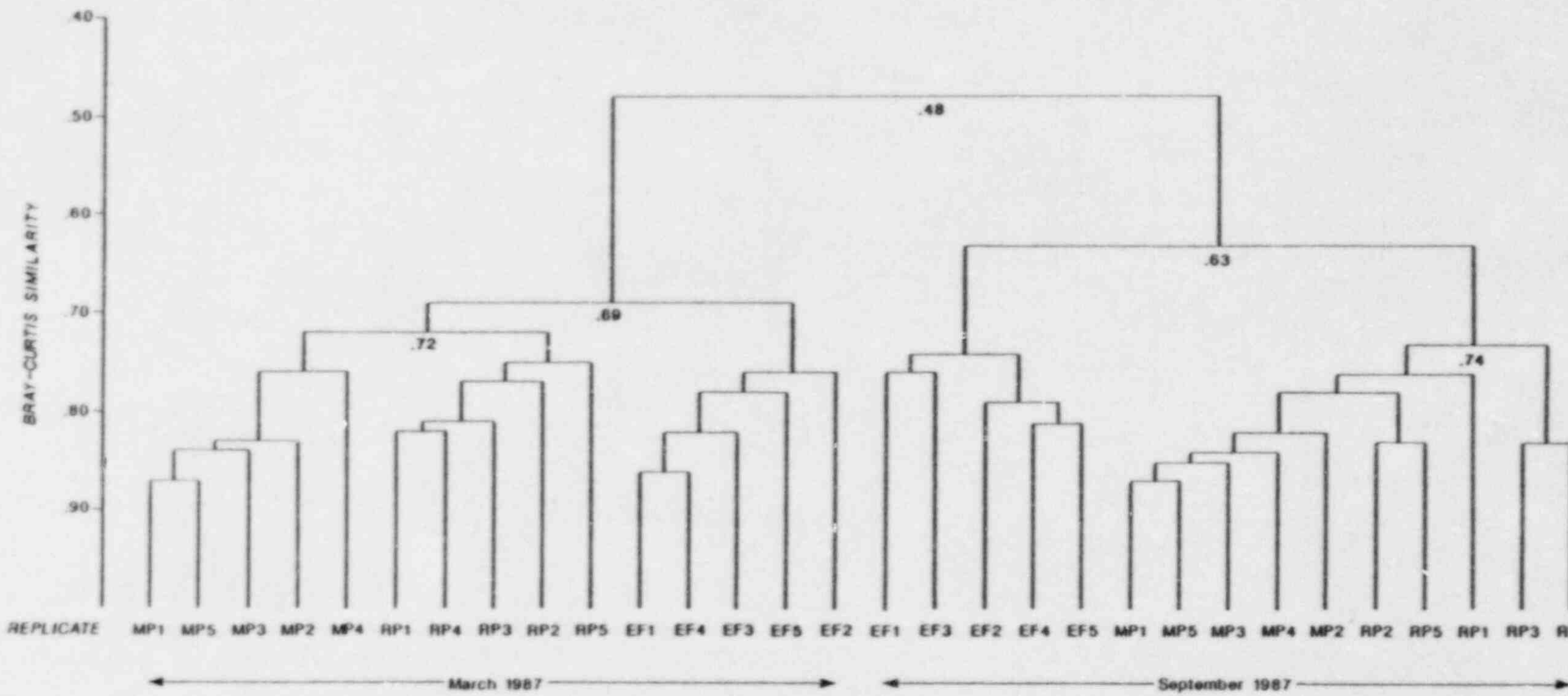

FIGURE 4. DENDROGRAM SHOWING RESULTS OF CLUSTER ANALYSIS OF MARCH AND SEPTEMBER 1987 DATA USING BRAY-CURTIS AND GROUP AVERAGE SORTING.

shows the Bray-Curtis similarity measure for all 30 samples collected in 1987. The two main clusters of replicates seen in this dendrogram are the spring samples on the left side and the fall samples on the right side, clearly indicating seasonal differences in species composition at all three stations. All clusters were identical to those produced when spring and fall data were analyzed separately; i.e., the March cluster in Figure 4 is the same as the dendrogram shown in Figure 2, and the September cluster in Figure 4 is the same as the dendrogram shown in Figure 3. The absence of seasonal differences would have resulted in clusters that contained a mixture of spring and fall replicates.

Inverse Analysis

The top 50 numerically dominant species were used in an inverse analysis of the spring and fall 1987 data. This analysis indicated the fauna responsible for the seasonal pattern shown in Figure 4. The dendrogram resulting from this analysis is presented in Figure 5.

Eight species groups were identified in this analysis. Group 1 contains 16 species, including 11 arthropods, four molluscs, and one polychaete. Except for the latter, all species of Group 1 were among the top 15 dominants of at least one station in 1987. Group 2 contains 13 species that include arthropods (four species), molluscs (four species), echinoderms (two species), polychaetes (two species), and coelenterates (one species). Some of these species occurred among the top 15 dominants of at least one station in 1987. Group 3 is formed by nine species that are mostly polychaetes (five species); the remaining species are two molluscs, one echinoderm, and one arthropod. Group 4 includes two arthropod species; one of them, the hermit crab Pagurus acadianus, was among the top 15 dominants at the Effluent station in spring. Group 5 is composed of two arthropods and two polychaetes; only the amphipod Phoxocephalus holbolli was

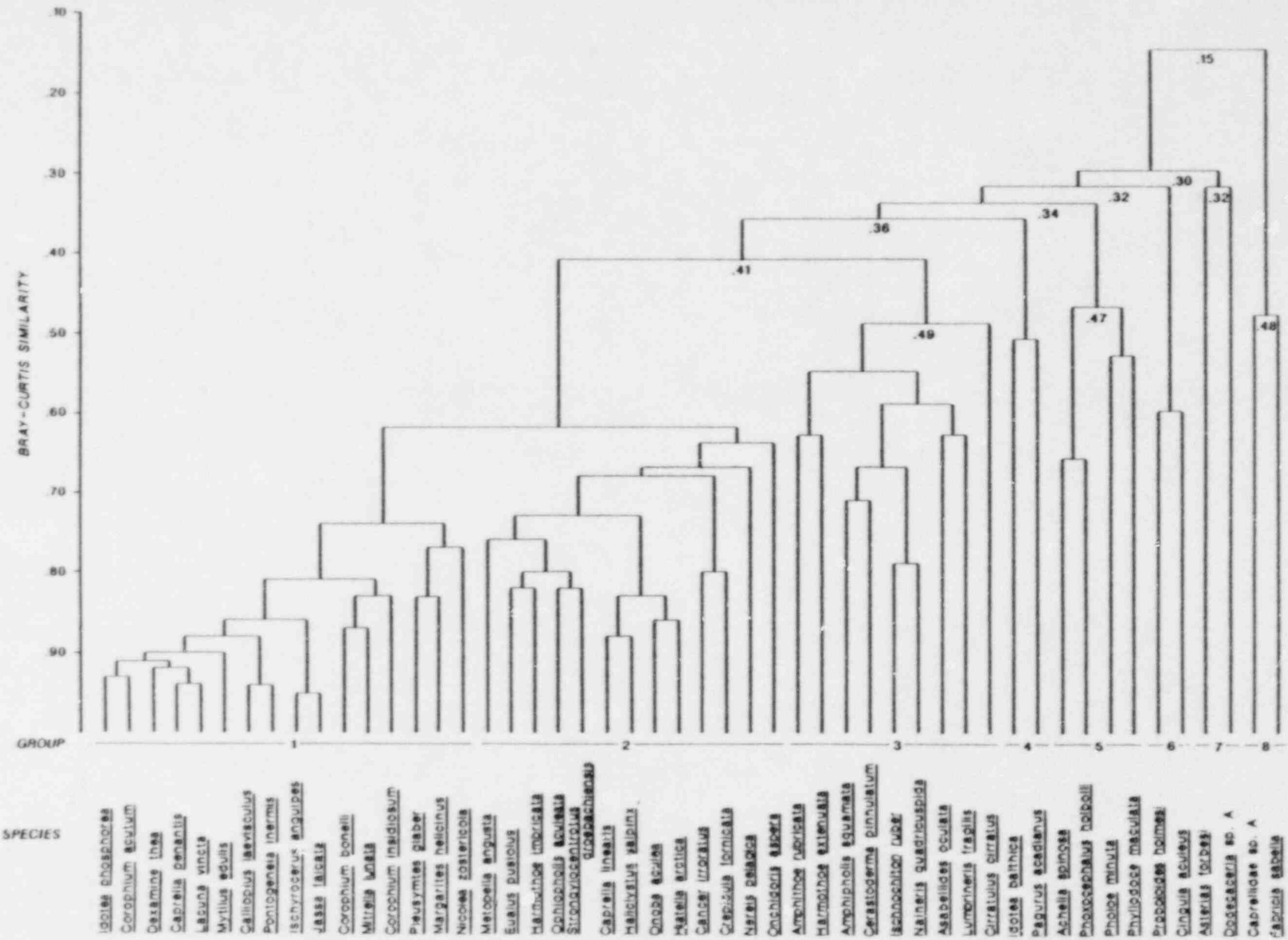

FIGURE 5. DENDROGRAM SHOWING RESULTS OF INVERSE CLUSTER ANALYSIS OF MARCH AND SEPTEMBER 1987 DATA USING BRAY-CURTIS AND GROUP AVERAGE SORTING.

found among the top 15 dominants in 1987. Group 6 contains two molluscs; one of them, Cingula aculeus, occurred among the top 15 dominants. Group 7 comprises the sea star Asterias forbesi and the polychaete Dodecaceria sp. A. Group 8 is composed of an amphipod, Caprellidae sp. A, and a polychaete Fabricia sabella. The members of each of these eight groups were found to co-occur and rank similarly; the higher the level of similarity, the more often this co-occurrence was observed.

Nodal Analysis

Nodal analysis is a method to relate the groupings resulting from the normal cluster analysis (by replicate) and inverse analysis (by species)and allows interpretation of the patterns observed in the similarity analyses of stations (Boesch, 1977). Two different measures are used: constancy and fidelity. Constancy is a measure of the frequency of a species group in one replicate group (in this instance, a station) compared to its frequency in all replicates combined; fidelity is the degree of restriction of a species group to a replicate group. The highest possible constancy value is 1.0, indicating that all species of a species group occurred in all replicates of a replicate group. The lowest possible constancy value is 0, indicating that no species of a species group occurred in any of the replicates comprising a replicate group. Fidelity values are between 0 (all species of a species group are evenly distributed over all replicates) and >3 (all species of a species group occurred in only one replicate).

Results of the nodal analysis are presented in Figures 6 and 7. Both figures show an abbreviated version of the dendrograms used for this analysis and a matrix. The top dendrogram in Figures 6 and 7 is the same as shown in Figure 5 (species groups 1 through 8); the dendrogram on the left side is the one shown in Figure 4 (replicate groups 1 through

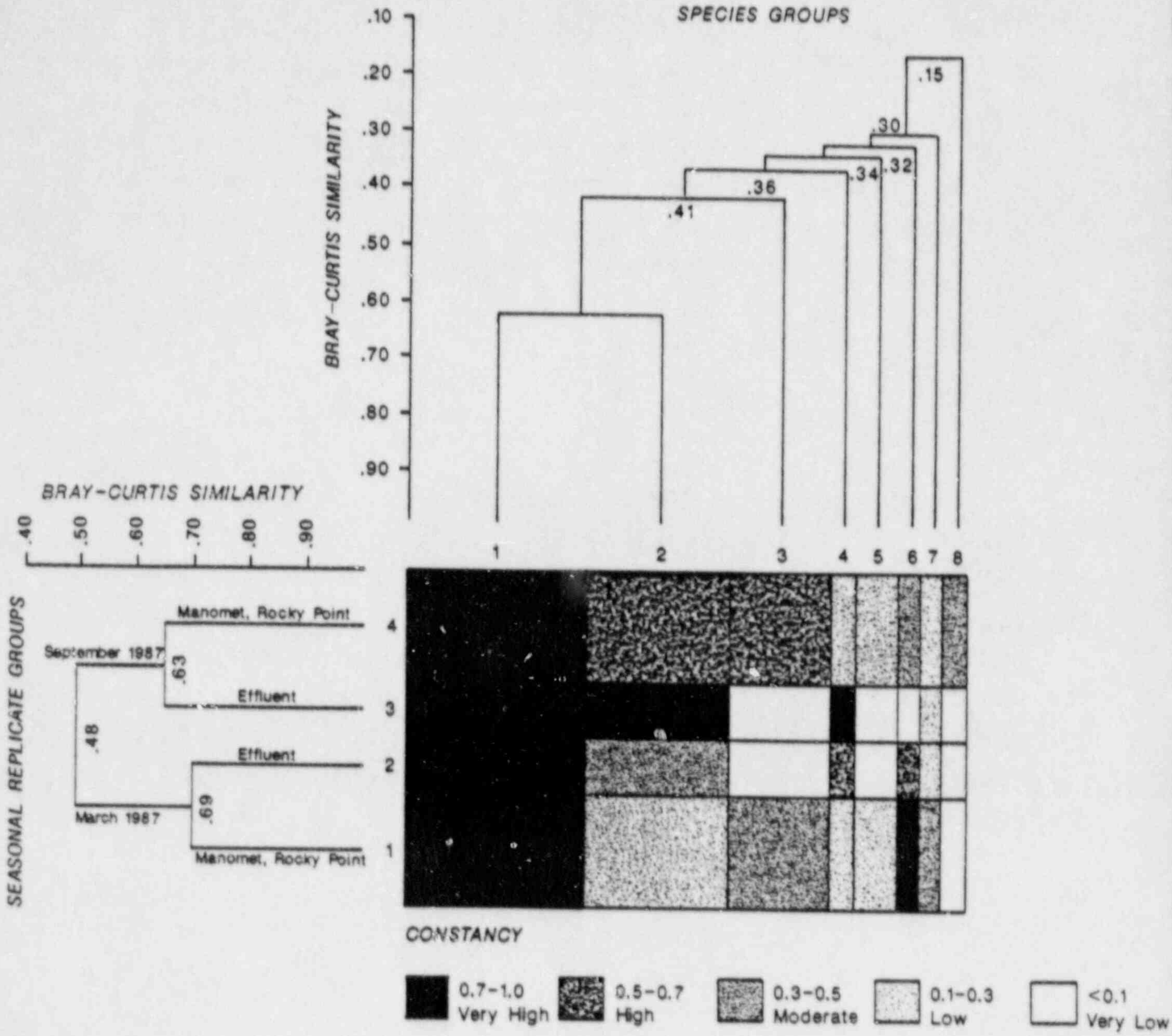

FIGURE 6. CONSTANCY DIAGRAM FOR SPECIES GROUPS AND REPLICATE GROUPS IN 1987. CLUSTERING IS WITH BRAY-CURTIS SIMILARITY AND GROUP AVERAGE SORTING.

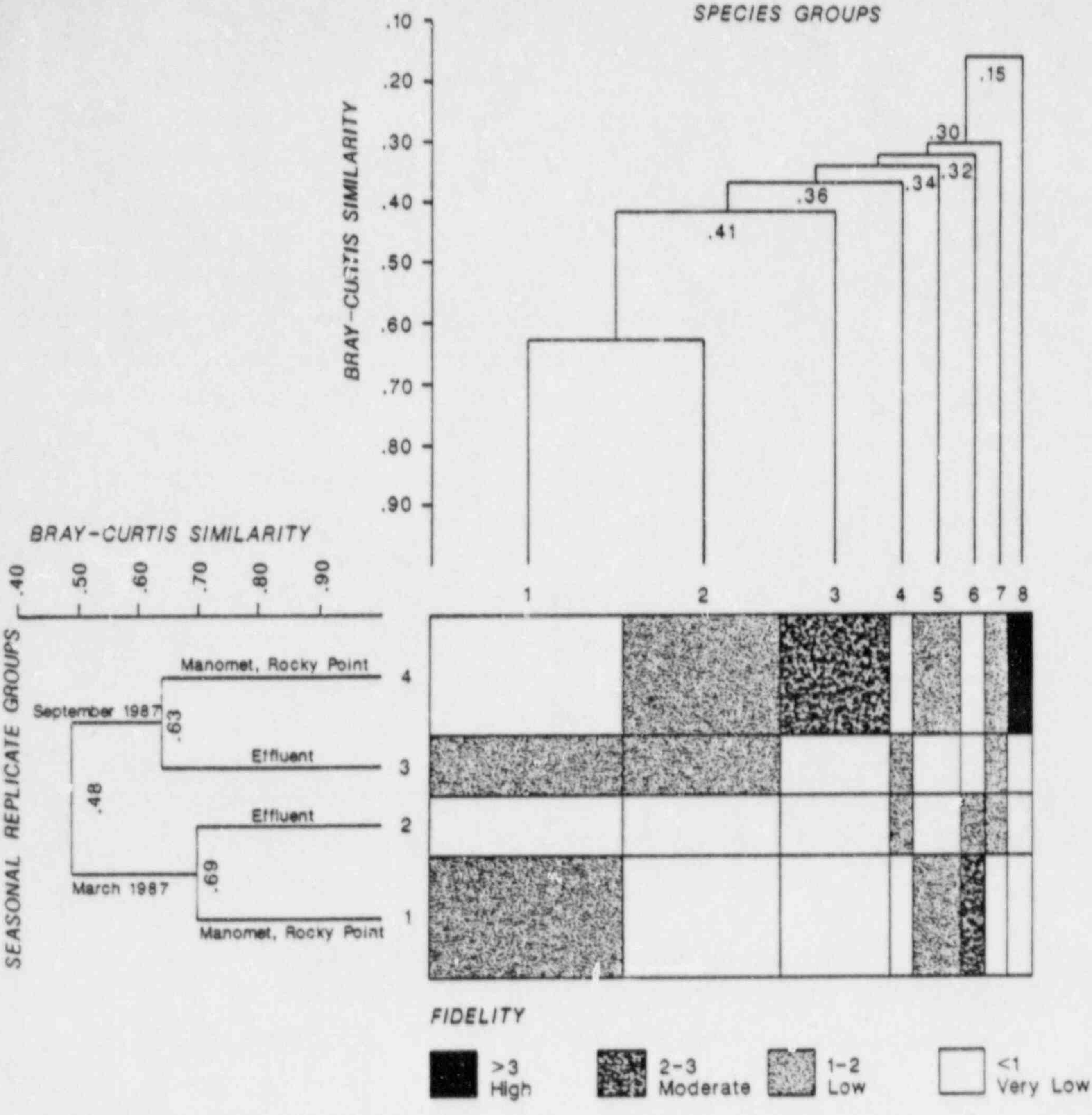

FIGURE 7. FIDELITY DIAGRAM FOR SPECIES GROUPS AND REPLICATE GROUPS IN 1987. CLUSTERING IS WITH BRAY-CURTIS SIMILARITY AND GROUP AVERAGE SORTING.

4). The central part of Figures 6 and 7 is the matrix showing the intersections of each species group with each replicate group. The width of each field of the matrix depends on the number of species that form each species group. For example, the fields in column 1 are widest because species group 1 contains 16 species; columns 4 and 6 through 8 are narrowest because the species groups 4, 6, 7, and 8 each contain only two species. The length of each field depends on the number of replicates that form each replicate group. That is, the fields in the upper and lower rows of the matrix are twice as wide as the ones inbetween, because replicate group 1 contains 10 replicates, whereas replicate group 2 contains only five replicates.

Species group 1 showed very high constancy at all stations during both spring and fall (Figure 6); this was to be expected because species group 1 includes species that were among the top 15 dominants of all three stations during both seasons. The fidelity of species group 1 was low to very low (Figure 7), i.e., none or only very few species of this group were restricted to a particular station.

Seasonal differences as shown in Figure 4 were mainly a result of changes in the species groups 2, 3, and 6. For example, species group 2 showed a seasonal pattern both in constancy (Figure 6) and fidelity (Figure 7). In spring, constancy was low at the reference stations and moderate at the Effluent station; i.e., members of species group 2 were found in some of the spring replicates of each station. Fidelity was very low at all stations; i.e., the species occurred scattered in replicates of all stations. In fall, constancy was high at the reference stations and very high at the Effluent station; i.e., most or all species of this group occurred regularly in all replicates of each station. Fidelity in the fall was low.

Species group 3 showed seasonal patterns at the reference stations. Constancy was moderate in March and high in September (Figure 6); fidelity was very low in March and moderate in September (Figure 7).

Species group 6 exhibited a clear seasonal pattern at all stations. Constancy was high (Effluent station) to very high (reference stations) in spring but very low (Effluent station) to moderate (reference stations) in fall (Figure 6). Fidelity was low (Effluent station) to moderate (reference stations) in spring but very low in fall at all stations (Figure 7).

In summary, the nodal analysis revealed that species groups 2 and 3 were characteristic for fall samples, whereas species group 6 was characteristic for spring samples.

Spatial differences (among stations) were mostly caused by species groups 3, 4, 6, and 8. For example, species group 3 showed very low constancy (Figure 6) and fidelity (Figure 7) at the Effluent station in both seasons, whereas constancy at the reference stations was moderate (spring) to high (fall) and fidelity was very low (spring) to moderate (fall).

Species group 4 showed a pattern opposite to that of group 3: constancy was low and fidelity was very low at the reference stations during both seasons, whereas constancy at the Effluent station was high (spring) to very high (fall) and fidelity was low (both spring and fall).

Species group 6 showed a spatial pattern in the constancy values. Constancy was very low (September) to high (March) at the Effluent station, whereas constancy at the reference stations ranged from moderate (September) to very high (March).

Species group 8 showed a strong restriction to the reference stations, indicated by moderate constancy and very high fidelity in September. At the Effluent station, both constancy and fidelity were very low during both seasons. The very low constancy and fidelity values at the reference stations in March indicate that this species group also exhibits a seasonal pattern.

In summary, the nodal analysis showed that species groups 3, 6, and 8 had their strongest affinities with the reference stations, whereas group 4 had its strongest affinity with the Effluent station.

ALGAL STUDIES

Systematics

The list of species identified in the 1987 samples was identical to the cumulative algal species list presented in Semi-Annual Report No. 16 (Boston Edison Co., 1980). No additional species have been found.

Algal Community Description

The rock and cobble substrata found at the Manomet Point, Rocky Point, and Effluent stations were heavily colonized by red macroalgae (Rhodophyta) during 1987. Biomass of *Chondrus crispus* was highest at the Effluent station; biomass of *Phyllophora* spp. was highest at the Effluent in fall, whereas in spring the highest values were found at Manomet Point. The highest biomass of benthic flora other than *Chondrus* and *Phyllophora* occurred at Rocky Point; the highest biomass of epiphytic algae was found at Manomet Point, whereas the lowest values were from the Effluent station. The primary hosts for epiphytes were *Chondrus* and *Phyllophora*, but other benthic species, such as *Polyides rotundus* and *Ahnfeltia plicata*, also served as host plants. Red algae), including *Spermothamnion repens*, *Polysiphonia elongata*, *Phycodrys rubens*, and *Ceramium rubrum* were the most commonly observed epiphytes. The warm-water indicator Gracilaria foliifera was neither seen in the replicate samples of March and September, nor observed within the stunted and denuded zones during the transect surveys of 1987.

Algal Community Overlap

Community overlap was calculated for the March and September 1987 data; Jaccard's coefficient of community (Grieg-Smith, 1964) was used to measure the similarity in algal species composition between stations. This coefficient provides a mathematical evaluation of the similarity between two replicates or stations using only species occurrence, without referring to any differences in the abundance of the species observed. Species occurrence records of the 37 indicator species listed in Table 5 were used for all community overlap calculations.

Results of community overlap comparisons between replicate samples for each station for the March and September 1987 collecting periods are presented in matrix form in Figures 8 and 9. The community overlap was generally higher between the two reference stations (77.2 percent in March, 80.0 percent in September) than between either of the reference stations and the Effluent station (66.7 to 70.8 percent in March, 70.8 to 76.0 percent in September), indicating more of a difference between the Effluent station and the reference stations. This difference was less distinct in September. The overlap values for September were identical at 80.0 percent between the two reference stations and between the Effluent and Manomet Point stations. Overall, the similarity of all three stations was high (>65 percent in March, >75 percent in September). All replicate overlap ranges were narrower in September than in March;

TABLE 5. THE 37 ALGAL INDICATOR SPECIES USED IN THE QUANTITATIVE COMMUNITY ANALYSES.

CHLOROPHYTA (green algae)	
Bryopsis plumosa	*Enteromorpha flexuosa*
Chaetomorpha linum	*Rhizoclonium tortuosum*
C. melagonium	*Ulva lactuca*
PHAEOPHYTA (brown algae)	
Chordaria flagelliformis	*Laminaria digitata*
Desmarestia aculeata	*L. saccharina*
D. viridis	*Sphacelaria cirrosa*
RHODOPHYTA (red algae)	
Ahnfeltia plicata	*Phyllophora truncata*
Antithamnion americanum	*P. pseudoceranoides*
Bonnemaisonia hamifera	*P. traillii*
Calophyllis cristata	*Plumaria elegans*
Ceramium rubrum	*Polyides rotundus*
Chondrus crispus	*Polysiphonia elongata*
Corallina officinalis	*P. fibrillosa*
Cystoclonium purpureum	*P. harveyi*
Gracilaria foliifera	*P. nigrescens*
Gymnogongrus crenulatus	*P. urceolata*
Membranoptera alata	*Rhodomela confervoides*
Palmaria palmata	*Spermothamnion repens*
Phycodrys rubens	

A. MANOMET POINT STATION

Upper triangle: Number of Species Shared; lower triangle: Percent Overlap

	1	2	3	4	5
1		11	10	10	10
2	73.3		11	10	11
3	77.0	68.8		10	11
4	66.7	52.6	62.5		10
5	77.0	68.8	84.6	62.5	

B. ROCKY POINT STATION

Upper triangle: Number of Species Shared; lower triangle: Percent Overlap

	1	2	3	4	5
1		13	13	12	12
2	76.5		13	12	13
3	81.3	72.2		13	13
4	75.0	66.7	81.3		13
5	75.0	76.5	81.3	86.7	

C. EFFLUENT STATION

Upper triangle: Number of Species Shared; lower triangle: Percent Overlap

	1	2	3	4	5
1		7	12	9	12
2	50.0		8	7	8
3	80.0	50.0		11	14
4	56.3	46.7	64.7		11
5	66.7	42.1	73.7	55.0	

OVERLAP BETWEEN STATIONS

Station Pair	Number of Shared Species	Community Overlap
Manomet Point-Rocky Pt.	17	77.2
Manomet Point-Effluent	16	66.7
Rocky Point-Effluent	17	70.8

FIGURE 8. ALGAL COMMUNITY OVERLAP (JACCARD'S COEFFICIENT OF COMMUNITY) AND NUMBER OF SPECIES SHARED BETWEEN REPLICATE PAIRS AT THE MANOMET POINT, ROCKY POINT, AND EFFLUENT SUBTIDAL STATIONS (3 m MLW), MARCH 1987.

	1	2	3	4	5
1		16	16	17	14
2	69.6		16	18	16
3	80.0	76.2		15	14
4	77.3	81.8	68.2		16
5	66.7	80.0	73.7	80.0	

Upper right: Number of Species Shared

Percent Overlap
A. MANOMET POINT STATION

	1	2	3	4	5
1		14	14	13	14
2	70.0		17	14	15
3	66.7	85.0		15	16
4	68.4	70.0	75.0		14
5	70.0	71.4	76.2	70.0	

Upper right: Number of Species Shared

Percent Overlap
B. ROCKY POINT STATION

	1	2	3	4	5
1		13	15	[illegible]	13
2	65.0		14	11	11
3	68.2	70.0		14	13
4	78.9	55.0	66.7		14
5	68.4	61.1	65.0	87.5	

Upper right: Number of Species Shared

Percent Overlap
C. EFFLUENT STATION

OVERLAP BETWEEN STATIONS

Station Pair	Number of Shared Species	Community Overlap
Manomet Point-Rocky Pt.	20	80.0
Manomet Point-Effluent	20	80.0
Rocky Point-Effluent	19	76.0

FIGURE 9. ALGAL COMMUNITY OVERLAP (JACCARD'S COEFFICIENT OF COMMUNITY) AND NUMBER OF SPECIES SHARED BETWEEN REPLICATE PAIRS AT THE MANOMET POINT, ROCKY POINT, AND EFFLUENT SUBTIDAL STATIONS (3 m MLW), SEPTEMBER 1987.

i.e., the similarity among the September replicates was greater than among the March replicates.

Algal Biomass

Algal biomass usually shows a very regular seasonal pattern at all three stations, with biomass values being low in spring and high in fall (Boston Edison Co., 1987). This typical pattern, however, has been reversed in the previous year to high biomass values in spring and considerably lower values in fall. In 1987, this atypical pattern was somewhat evident, but the more typical pattern seemed to dominate.

Chondrus crispus Biomass

Chondrus crispus biomass values by station for March and September 1987 are presented in Table 6. In March, the mean replicate value for *Chondrus* biomass was highest at the Effluent (ca. 172 g/m^2) and lowest at the Rocky Point station (ca. 33 g/m^2). The mean at the Effluent was 38 percent higher than at Manomet Point and more than 5 times higher than at Rocky Point. The range of replicate biomass was greatest at the Effluent (ca. 10 to 315 g/m^2) and smallest at Rocky Point (ca. 1 to 110 g/m^2). *Chondrus* comprised 52 percent of the algal biomass at the Effluent station, followed by 34 and 22 percent at the reference stations at Manomet Point and Rocky Point, respectively.

In September, the highest mean *Chondrus* biomass values per replicate were again observed at the Effluent (ca. 180 g/m^2), but were lowest at Manomet Point (ca. 95 g/m^2). The mean *Chondrus* biomass at the Effluent was 3 percent higher than at Rocky Point and 90 percent higher than at Manomet Point. The greatest range of replicate biomass was again found at the Effluent station (ca. 1 to 454 g/m^2), and the

TABLE 6. AVERAGE DRY WEIGHT BIOMASS PER REPLICATE (g/m^2) OF MACROALGAE AT EFFLUENT, MANOMET POINT, AND ROCKY POINT SUBTIDAL (3 m MLW) STATIONS IN MARCH AND SEPTEMBER 1987. NUMBERS IN PARENTHESES REPRESENT CONTRIBUTION TO TOTAL ALGAL BIOMASS.

	Effluent		Manomet Point		Rocky Point	
	March	September	March	September	March	September
Chondrus crispus	172.35 (52%)	180.09 (36%)	124.79 (34%)	94.81 (27%)	32.92 (22%)	174.02 (32%)
Phyllophora spp.	132.78 (40%)	245.70 (49%)	218.89 (59%)	167.76 (47%)	76.10 (51%)	157.77 (29%)
Remaining						
Benthic Species	17.04 (5%)	24.04 (5%)	3.23 (1%)	20.14 (6%)	23.83 (16%)	156.23 (28%)
Epiphytic Species	9.79 (3%)	47.16 (9%)	25.58 (7%)	73.35 (21%)	17.50 (12%)	63.48 (12%)
Total	331.95	496.99	372.49	356.05	150.35	551.49

lowest at Manomet Point (ca. 24 to 127 g/m^2). Chondrus made up 36 percent of the total algal biomass at the Effluent station, followed by 32 and 27 percent at the reference stations at Rocky Point and Manomet Point, respectively.

Overall, Chondrus biomass increased from March to September at the Effluent and at Rocky Point, but decreased at Manomet Point. This atypical pattern was observed at this station in 1986. The fact that the decline from spring to fall was more drastic in 1986 than in 1987 may indicate a return to the more typical seasonal pattern (increase from March to September) of the algal biomass.

Phyllophora spp. Biomass

Mean values of Phyllophora biomass measured in March and September 1987 are shown in Table 6. In March, the mean Phyllophora biomass per replicate was highest at Manomet Point (ca. 219 g/m^2) and lowest at Rocky Point (ca. 76 g/m^2). Mean biomass at the Effluent station was intermediate (ca. 133 g/m^2); this value is 39 percent lower than that at Manomet Point and 74 percent higher than that at Rocky Point. The range of replicate biomass was greatest at Manomet Point (ca. 107 to 372 g/m^2) and smallest at the Effluent (ca. 80 to 204 g/m^2). Phyllophora spp. comprised 40 percent of the total algal biomass at the Effluent, 51 percent at Rocky Point, and 59 percent at Manomet Point.

In September, the highest mean Phyllophora biomass per replicate was found at the Effluent (ca. 246 g/m^2) and the lowest at Rocky Point (ca. 158 g/m^2). Biomass at the Effluent was 46 percent higher than at Manomet Point and 56 percent higher than at Rocky Point. The greatest range of replicate biomass was observed at the Effluent (ca. 62 to 372 g/m^2), and the smallest at Rocky Point (ca. 111 to 209 g/m^2). Phyllophora spp. comprised 49 percent of the total algal biomass at the Effluent station, followed by 47 and 29 percent at Manomet Point and Rocky Point, respectively.

A typical seasonal increase of *Phyllophora* biomass from spring to fall occurred at the Effluent and Rocky Point, whereas a decline was noted at Manomet Point. The seasonal variations of *Phyllophora* were similar to those observed for *Chondrus*.

Biomass of Remaining Benthic Species (RBS)

The algal biomass category designated remaining benthic species (RBS) is composed of all benthic algae excluding *Chondrus crispus*, *Phyllophora* spp., *Laminaria* spp., and algal epiphytes. Abundant species were *Chaetomorpha* spp. at all stations, *Phycodrys rubens* at the reference stations, and *Polyides rotundus* at the Effluent.

Mean replicate biomass values for the RBS are presented in Table 6. In both March and September 1987, the highest mean RBS biomass was found at Rocky Point (ca. 24 and 156 g/m^2, respectively). The lowest mean RBS biomass was noted in both months at Manomet Point (ca. 3 g/m^2 in March and 20 g/m^2 in September). The mean RBS biomass at the Effluent was intermediate (ca. 17 g/m^2 in March and 24 g/m^2 in September). The range of replicate biomass was greatest at the Effluent in March (ca. 1 to 70 g/m^2) and at Rocky Point in September (ca. 1 to 749 g/m^2); the smallest range of replicate biomass was observed at Manomet Point in March (ca. 1 to 8 g/m^2) and at the Effluent in September (less than 1 to ca. 18 g/m^2). The RBS comprised 5 percent of the total algal biomass both in March and September at the Effluent, 0.9 percent in March and 6 percent in September at Manomet Point, and 16 percent in March and 28 percent in September at Rocky Point.

Epiphytic Algal Species

Mean replicate biomass values of epiphytic algae are presented in Table 6. As during most of the previous studies, *Phyllophora* spp. exhibited a higher degree of epiphytic colonization than Chondrus crispus. It has been hypothesized that the higher biomass of epiphytes associated with Phyllophora spp. was due to the sturdier morphology of this species (Boston Edison Co., 1986a). In both March and September 1987, mean biomass was highest at Manomet Point (ca. 26 and 73 g/m^2, respectively) and lowest at the Effluent (ca. 10 and 47 g/m^2, respectively). In March, epiphytic algal biomass at the Effluent was 62 percent lower than at Manomet Point and 44 percent lower than at Rocky Point; in September, epiphytic algal biomass at the Effluent station was 36 percent lower than at Manomet Point and 26 percent lower than at Rocky Point. Epiphytic algae at the Effluent station made up 3 percent of the total algal biomass in March and 9 percent in September; at the Manomet Point and Rocky Point stations, the contribution of epiphytic algae to the total algal biomass was 7 and 12 percent, respectively, in March, and 21 and 12 percent, respectively, in September. At all three stations, the biomass of epiphytes increased from spring to fall.

Total Algal Biomass

Mean values for total algal biomass in March and September 1987 are shown in Table 6. In both months, the values at the Effluent were intermediate between the values measured at the reference stations, but the average biomass for the entire year was greatest at the Effluent. In March, total algal biomass at the Effluent station was 11 percent lower than at Manomet Point and more than twice as high as at Rocky Point; in September, total algal biomass at the Effluent was 10 percent lower than at Rocky Point and 40 percent higher than at Manomet Point. Biomass increased from spring to fall at the Effluent and at Rocky Point, whereas it decreased at Manomet Point. In comparison to 1986, the atypical seasonal decline of biomass reversed to the normal pattern at the former two stations and was still present only at the latter station.

Chondrus/Phyllophora Colonization Index Study

Colonization and colonization index values for Chondrus crispus and Phyllophora spp. are presented in Table 7 for March and September 1987. Colonization values are determined for the primary host species (Chondrus and Phyllophora) and are a qualitative measure of the degree of algal epiphytes and invertebrate species present on the host species. Colonization index values are the summations of colonization values for algal and faunal colonizers. Details of the procedure are the same as presented in the Semi-Annual report No. 30 (Boston Edison Co., 1987b).

Data from 1987 continue to indicate that Phyllophora spp. was more heavily colonized by epiphytes than was Chondrus. This observation has been typical during most of the past samplings and, as was noted earlier, is probably due to the denser frond development of Phyllophora spp. compared with Chondrus. Generally, colonization was lowest at the Effluent and highest at Manomet Point; it increased from spring to fall.

QUALITATIVE TRANSECT SURVEY

Qualitative transect surveys of nearfield impact zones were initiated in January 1980 and have been conducted quarterly since 1982. Four surveys of the area were performed during 1987 (March 25, June 9, September 29, and December 22), bringing the total number of surveys conducted to 28. Results of surveys conducted from 1980 through 1983

TABLE 7. COLONIZATION INDEX VALUES FOR *CHONDRUS CRISPUS* AND *PHYLLOPHORA* SPP. AT THE MANOMET POINT, ROCKY POINT, AND EFFLUENT SUBTIDAL (3 m MLW) STATIONS IN MARCH AND SEPTEMBER 1987.

	Manomet Point		Rocky Point		Effluent	
	Mar	Sep	Mar	Sep	Mar	Sep
Chondrus crispus						
Algal Colonization	5	12	6	11	5	8
Faunal Colonization	5	13	5	12	5	14
Total	10	25	11	23	10	22
Phyllophora spp.						
Algal Colonization	12	20	12	20	7	17
Faunal Colonization	12	20	8	16	9	17
Total	24	40	20	36	16	34

were summarized in Semi-Annual Report No. 22 to Boston Edison Company (Boston Edison Co., 1983). A detailed discussion of the March and June 1987 surveys can be found in Semi-Annual Report No. 30 (Boston Edison Co., 1987b). These results will be summarized here, along with new data from the September and December 1987 surveys.

The denuded zone has been defined as being essentially devoid of Chondrus crispus, whereas the stunted zone was defined as having Chondrus of decreased size and density compared with conditions considered normal for this species. However, because of the increasing recolonization of the denuded and stunted zones caused by the continuing outage of PNPS, it became difficult in 1987 to define these zones. The border between the stunted and denuded zones was no longer clearly defined; the denuded zone had areas of patchy or scattered Chondrus growth and other areas that were either partly denuded or partly overgrown by new Chondrus plants. These zones were thus ill-defined, but nevertheless still visible, because recolonization had not advanced far enough to give the area a completely normal appearance. The zones were, therefore, still marked in the drawings (Figures 10-13), but the size (m^2) of the stunted and denuded zones was not calculated after June 1987.

March 1987 Transect Survey

The extent of the denuded and stunted areas immediately offshore from PNPS, as measured on March 25, 1987, is shown in Figure 10. The denuded zone extended approximately 78 m offshore along the centerline of the effluent discharge canal. As in previous years, the denuded zone was wider on the northwest (left) side of the centerline than on the southeast (right) side, ranging in lateral extent from 5 to 18 m on the northwest side. One prominent peak at 30 m was

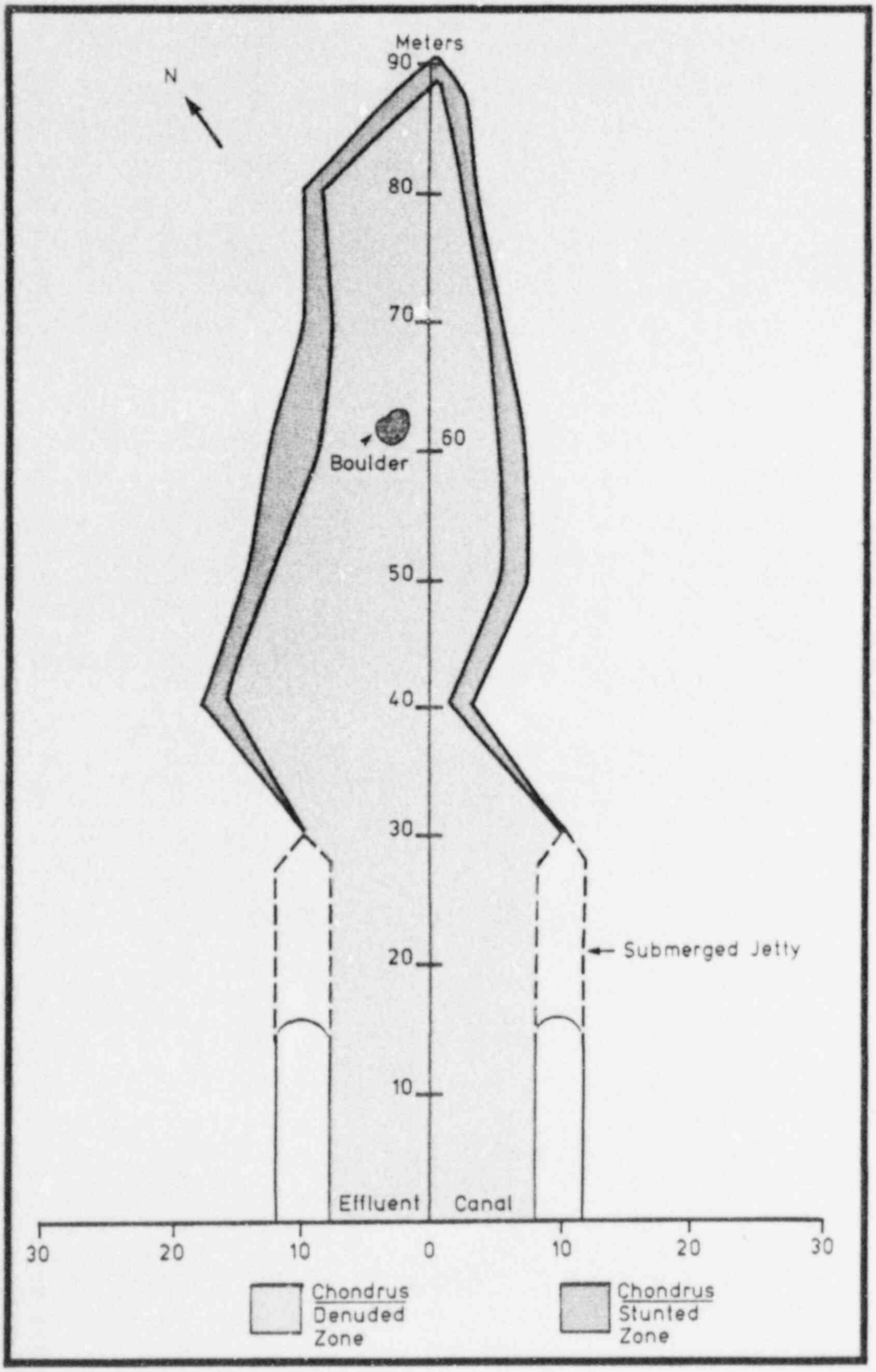

FIGURE 10. CONFIGURATION OF DENUDED AND STUNTED ZONES AT PILGRIM NUCLEAR POWER STATION FOR 25 MARCH 1987.

observed on the northwest side. The southeast portion, to the right of the centerline, was of relatively uniform width (except for a reduced area at 30 m), averaging about 5 m out from the transect line. Ulva lactuca and Polysiphonia spp. were present in the denuded zone during the quantitative survey. The boulder plotted in Figures 10-13 serves as a visual fix for the proper placement of the transect line; it is used as a landmark by the Battelle and Division of Marine Fisheries dive teams.

The stunted zone in March extended 80 m offshore along the centerline and like the denuded zone was much broader on the northwest side of the transect line, ranging from 10 to 18 m. The southeast portion of the stunted zone was narrow, averaging about 6 m out from the transect line.

The area encompassed by the denuded zone was 676 m^2, representing a 10 percent reduction since December 1986 (753 m^2). The stunted zone equaled 176 m^2, representing a 58 percent reduction since December (421 m^2). The total nearfield impact area in March equaled 852 m^2, which was 27 percent less than in December.

June 1987 Transect Survey

The transect map for June 9, 1987, is presented in Figure 11. The denuded zone extended approximately 60 m along the transect line. The southeast extent of this zone ranged from 0 to 10 m, and the northwest extent from 0 to 9 m. The prominent peak noted on the northwest portion of the denuded zone in March was not present in June. The stunted zone observed in June 1987 extended approximately 70 m offshore along the discharge centerline. The stunted zone ranged in width from 1 m on the southeast side to 5 m on the northwest side. As mentioned earlier, the zonal boundaries were less distinct, as the zones themselves were being

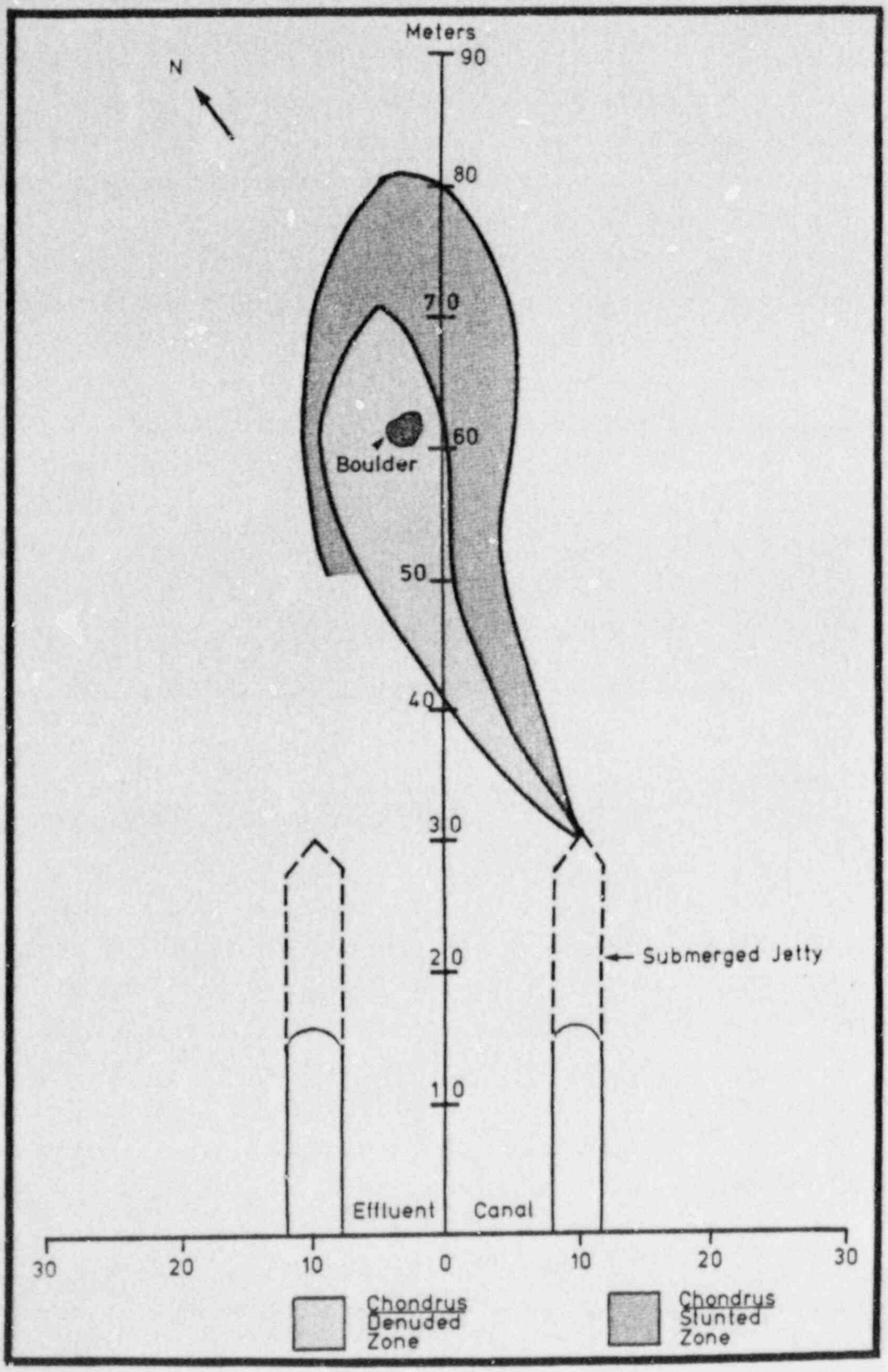

FIGURE 11. CONFIGURATION OF DENUDED AND STUNTED ZONES AT PILGRIM NUCLEAR POWER STATION FOR 9 JUNE 1987.

recolonized. As in March 1987, the warm-water indicator--Gracilaria spp.--was absent, whereas the cold-water Laminaria spp. was observed within the acute impact zone. This change in species composition is directly caused by the absence of thermal effluent.

The area contained within the denuded or partially denuded zone was 179 m^2, a 74 percent decrease from March 1987. The stunted zone equaled 284 m^2, a 61 percent increase since March 1987. This increase is directly related to the decrease of the denuded zone. The total nearfield impact area equaled 463 m^2, representing a 46 percent reduction since March 1987.

September 1987 Transect Survey

The extent of the denuded and stunted zones as measured on September 29, 1987, is shown in Figure 12. The stunted and denuded zones observed in September extended offshore approximately 82 m along the transect line. Up to 50 m offshore, it was impossible to define a denuded zone; the zonal boundaries were indistinct, but a stunted zone could be seen starting at the ends of the submerged jetties. The denuded zone was again wider northwest of the transect line (5 to 8 m) than on the southeast side (3 to 5 m). A prominent peak of the stunted zone was noted 50 m offshore on the northwest side. Except for this peak, the stunted zone extended about 4 to 10 m out on the northwest side and 6 to 8 m out from the transect line on the southeast side. Fucus spp. and Laminaria spp. were present, the latter being a cold-water indicator; the warm-water species Codium spp. was also seen. This species seems to be more temperature resistant than Gracilaria, a typical warm-water organism that was completely absent from the denuded zone in 1987.

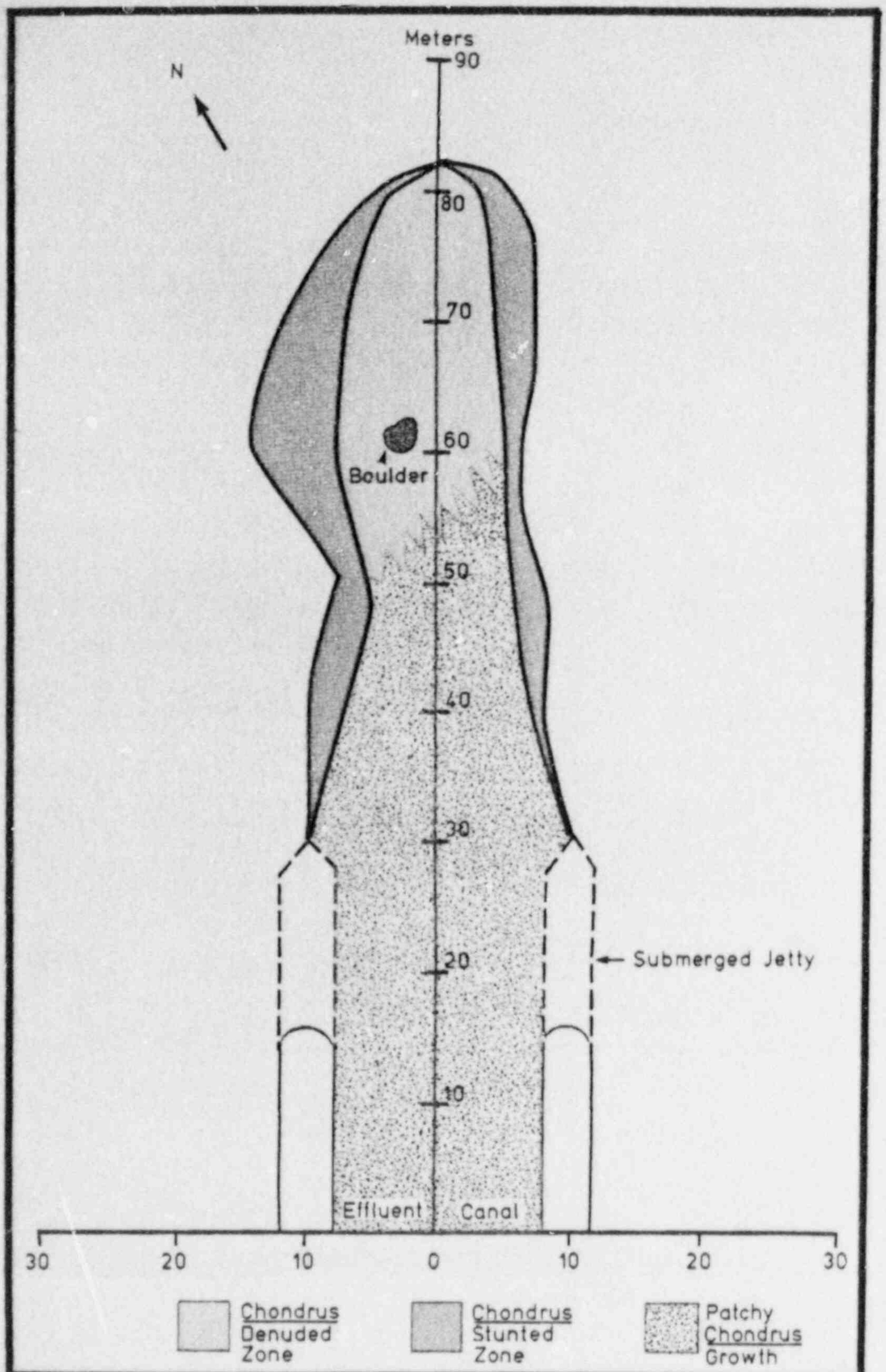

FIGURE 12. CONFIGURATION OF DENUDED AND STUNTED ZONES AT PILGRIM NUCLEAR POWER STATION FOR 29 SEPTEMBER 1987.

December 1987 Transect Survey

The extent of the denuded and stunted zones as measured on December 22, 1987, is presented in Figure 13. It was again extremely difficult to define zones. The denuded zone was relatively well-defined only between about 60 and 80 m offshore; it extended about 8 m out from the transect line on the northwest side and 2 to 3 m out from the transect line on the southeast side. The stunted zone was identifiable between 60 and 80 m offshore on the northwest side and at 70 m offshore on the southeast side. The remaining former denuded zone was partially denuded on the northeast side; i.e., some of the rocks were denuded, whereas others were colonized by Chondrus and Laminaria. This partially denuded zone extended 5 to 11 m out from the centerline. The remaining former stunted zone on the northeast side of the transect line showed patchy Chondrus growth; it extended 10 to 15 m out from the centerline. The entire acute impact zone on the southwest side of the centerline (except for the small areas with defined denuded and stunted zones) showed patchy Chondrus extending 2 to 8 m out from the centerline. Laminaria and Fucus were frequently observed in the acute impact area; no typical warm-water algae were seen.

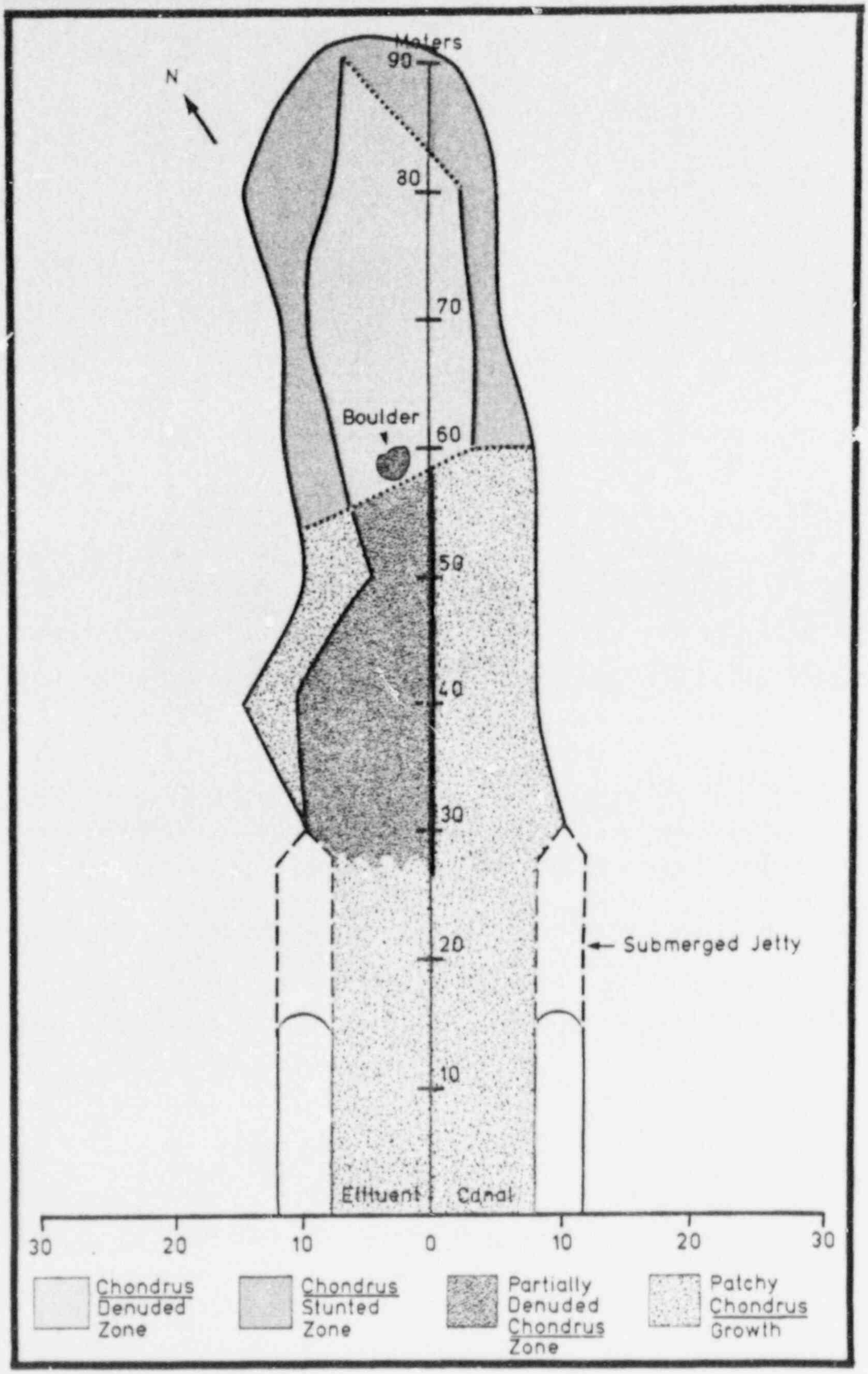

FIGURE 13. CONFIGURATION OF DENUDED AND STUNTED ZONES AT PILGRIM NUCLEAR POWER STATION FOR 22 DECEMBER 1987.

CONCLUSIONS

FAUNAL STUDIES

- Species richness was lowest at the Effluent station both in March and September. At all three stations, species richness increased from March to September.

- Faunal densities were intermediate at the Effluent in March and lowest in September. At Rocky Point, densities increased by 26 percent from March to September. At the other stations, densities decreased by six to seven percent.

- Dominant species were similar among stations both in March and September. Seasonal changes were least noticeable at the Effluent.

- Species diversity was lowest at the Effluent both in March and September. *Mytilus edulis* contributed only very little to the total fauna. Diversity increased from March to September at all stations.

- Similarity among all stations was high both in March and September. The Effluent station was as similar to the reference stations as the reference stations were to each other. Seasonality was evident at all stations.

ALGAL STUDIES

- Algal communities were dominated by *Chondrus crispus* and *Phyllophora* spp. The warm-water indicator *Gracilaria foliifera* was not found.

• Algal community overlap among stations was generally greatest in September. The values for the two reference stations were somewhat higher than for the Effluent and reference stations.

• Chondrus biomass was highest at the Effluent both in March and September. Phyllophora biomass was intermediate at the Effluent in March and highest in September. Total algal biomass was intermediate at the Effluent during both months; however, the average biomass for both months combined was highest at the Effluent.

• Colonization was lowest at the Effluent and highest at Manomet Point during both months. Phyllophora was most heavily colonized.

QUALITATIVE TRANSECT SURVEY

• The acute impact zone decreased considerably between March and June because of shutdown of the circulating water pumps. By September recolonization advanced so far that zonal boundaries were obscured. The impact area increased again between June and September because of current scouring caused by circulating water pumps.

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FINAL

SEMI-ANNUAL REPORT

Number 31

(Volume 2 of 2)

to

BOSTON EDISON COMPANY

on

BENTHIC ALGAL AND FAUNAL MONITORING AT THE PILGRIM NUCLEAR POWER STATION (IMPACT ON BENTHIC COMMUNITIES)

January - December 1987

7 April 1988

BATTELLE
Ocean Sciences
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EXECUTIVE SUMMARY

This volume of Semi-Annual Report No. 31 summarizes impact findings for the benthic monitoring program from 1983 through 1987. Methods and procedures follow guidelines established by the Pilgrim Administrative Technical Committee (PATC) and adopted by Boston Edison Company (BECO) as modified in 1981 (Boston Edison Co., 1987b).

The cooling system at Pilgrim Nuclear Power Station (PNPS) could potentially affect the benthic communities at the mouth of the discharge canal by warming ambient waters and by increasing current velocities enough to cause benthic scouring. In 1987 the benthic communities near the effluent canal of PNPS went through a stage of recovery because of the continuing power outage at PNPS. The response of the algal community was directly related to the outage. The former acute impact zone was almost completely obscured, and warm-water species were replaced by typical cold-water species. The response of the faunal community at the Effluent was not as evident, because the fauna depends on the algal cover for habitat. Even subtle differences in density or height of the algal cover may result in insufficient conditions for the settlement of many invertebrates. Such conditions were present in 1987, resulting in lower species richness, diversity, and density of the faunal communities at the Effluent. However, some recovery of the faunal community was reflected by the increased levels of similarity between the Effluent and reference stations. If the outage is prolonged in 1988, fauna at the Effluent station will probably closely approach normal.

INTRODUCTION

The benthic monitoring program being conducted near the Pilgrim Nuclear Power Station (PNPS) began in 1972 and has continued at varying levels to the present time. The objectives of this program are to identify and assess the significance of impacts associated with operations of PNPS on the nearshore benthic communities. Introduction of an environmental perturbation has the potential to affect members of these communities because their ability to migrate away from disturbances is limited. Significant changes in benthic community parameters may, therefore, be correlated with the source of the perturbation.

PNPS is a base-loaded, nuclear-powered electrical generating unit designed to produce 655 megawatts of energy under full operational conditions. The station is cooled by water withdrawn from Cape Cod Bay; the water is used to remove heat from the station condensers. The cooling water is then returned to the Bay via a discharge canal designed to dissipate heat from the water through rapid mixing and dilution. The two circulating water pumps produce a combined flow of approximately 20 m^3 per second at full operational capacity. Plate 1 shows the plume created as the effluent leaves the discharge canal. The cooling system at PNPS presents two sources of potential impact on the benthic communities at the mouth of the discharge canal: warming of ambient waters and increased current velocities resulting in benthic scouring.

Operational conditions at PNPS over recent years have provided an opportunity to assess the degree of impact experienced by the benthic communities and the time frame over which these communities could be expected to recover if the effect of PNPS were removed. Figure 1 presents the annual maximum dependable capacity factor (MDC) and circulating water pump operation for PNPS from 1983 to 1987.

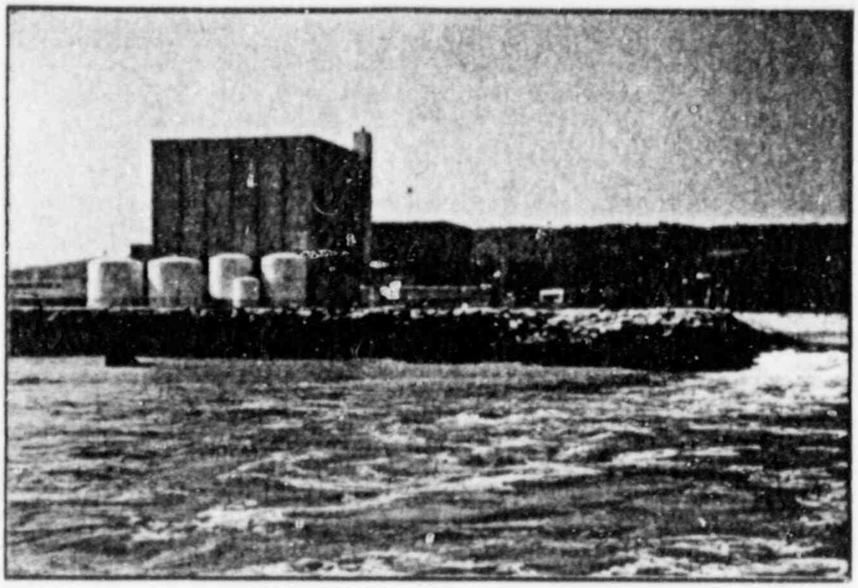

Plate 1. Effluent plume exiting the PNPS cooling water discharge canal. The effluent plume presents two sources of potential impact on benthic communities: increased ambient temperatures and increased current velocities resulting in benthic scouring.

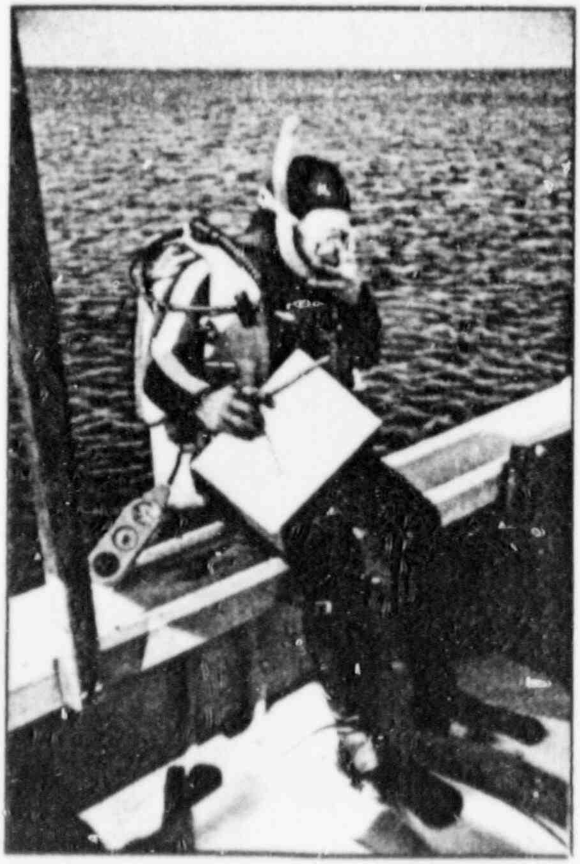

Plate 2. Diver with underwater writing tablet preparing to enter water. Diver transect surveys are conducted quarterly to map the extent of the acute impact zone associated with the PNPS effluent canal.

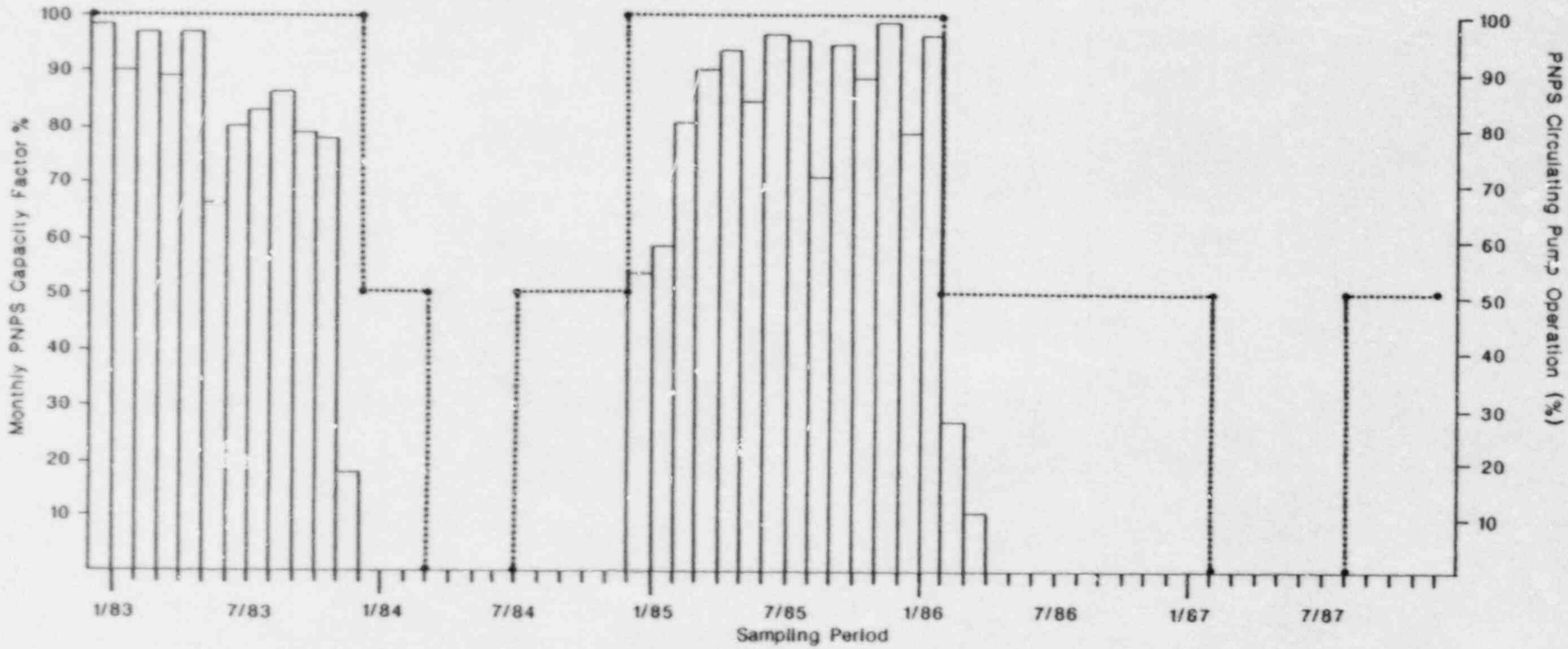

FIGURE 1. MONTHLY PNPS CAPACITY FACTOR (BARS) AND CIRCULATING PUMP ACTIVITY (DOTTED LINE) PLOTTED FOR THE PERIOD 1983 THROUGH 1987.

The MDC is a measure of reactor output that roughly approximates thermal loading to the marine environment. A maximum value of 100 percent for the MDC represents the highest allowable change in ambient temperature (32°F ΔT).

The cumulative capacity factor from 1983 to 1987 has been approximately 36 percent. During this time, there have been dramatic swings in power output. In 1983, PNPS experienced a productive year, with an annual MDC of 80.3 percent. The following year (1984), PNPS was off-line for a full 12 months, resulting in an annual MDC of only 0.1 percent. The outage in 1984 also resulted in reduced scouring off the effluent discharge canal, with partial circulating water flow during most of the year and no flow from April to mid-August 1984. The extremely low MDC in 1984 was followed by a record high in 1985 (84.4 percent). The recent up and down trend in PNPS output was continued in 1986, with an annual MDC of 17.5 percent. Outages of some duration began on March 7, 1986, and since mid-April 1986, the station has been completely off-line until the publication of this report. Two circulating water pumps operated through February 1986; only one pump was on line from March 1986 through February 1987. Except for a few days, no pumps were operating from April through August 1987. From September through December 1987 one pump was again on line; during six days in December, both pumps were operating. The situation at PNPS from 1983 through 1987 has, therefore, presented a valuable opportunity to compare the results from two peak operational years (1983, 1985) with results from three years of high potential environmental recovery (1984, 1986/87).

Because the outage that began in April 1986 lasted throughout 1987, it was expected that responses of the benthic communities to the lack of thermal effluent and reduced current from PNPS would be more pronounced in 1987 than in 1986, and that these responses would be similar to those noted during 1984 when PNPS experienced a negligable power output. These 1984 responses were summarized in Semi-Annual Report No. 27 (Boston Edison Co., 1986) and included the following:

- A change in the relative rankings of the Effluent and reference stations in terms of species richness; the Effluent station typically ranked third prior to the 1984 outage, but ranked second in March 1985.
- Species diversity values at the Effluent station were more similar to diversity at the reference stations than would be typical if PNPS were operating.
- A lagged recovery at the effluent acute impact zone resulting in macroalgal growth within the previously denuded Chondrus zones.
- Presence and absence of several species of algae (most notably Gracilaria foliifera and Laminaria spp.), considered indicators of warm-water (G. foliifera) and cold-water (Laminaria spp.) habitats, in response to the presence and absence of thermal effluent from PNPS.

This volume of the Semi-Annual Report summarizes impact findings in relation to the benthic monitoring program. It discusses overall trends in the data presented in Volume 1 and in previous reports in an effort to summarize the effects associated with PNPS operations on benthic communities. Volume 2 places particular emphasis on the period from 1983 to 1987 for reasons discussed above.

METHODS

The present design of the benthic monitoring program includes quantitative and qualitative approaches for determining the presence and extent of impacts associated with PNPS. Specifications for methods and procedures follow guidelines established by the Pilgrim Administrative Technical Committee (PATC) and adopted by BECO as modified in 1981 (Boston Edison Co., 1987b). The quantitative studies measure and compare benthic community parameters at three stations (Figure 2): a surveillance station located approximately 120 m offshore from the mouth of the discharge canal (Effluent station), and two reference stations located 0.25 nautical miles northwest (Rocky Point station) and 2 nautical miles southeast (Manomet Point station) of the Effluent station. Algal and faunal community analyses performed on data collected from these stations are compared for spatial (reference vs. surveillance) and temporal (differences in seasonal trends) variability. Differences between the Effluent and reference stations are then examined for indications of an impact from PNPS at the Effluent station.

Because of its distance from the source of perturbation, the quantitative Effluent station was chosen as a site likely to experience a less severe effect from PNPS than that experienced by communities located closer to the effluent discharge canal. The acutely impacted areas immediately offshore of the canal (0 to 90 m from the submerged ends of the canal) are monitored through qualitative methods. The techniques for these areas include diver surveys (Plate 2) to measure the offshore and lateral extent of algal stunting and denudation caused by the effluent discharge. The focus of these observations is the red macroalga Chondrus crispus, a species prevalent throughout western Cape Cod Bay. Divers swim along a measured transect line, noting the boundaries of

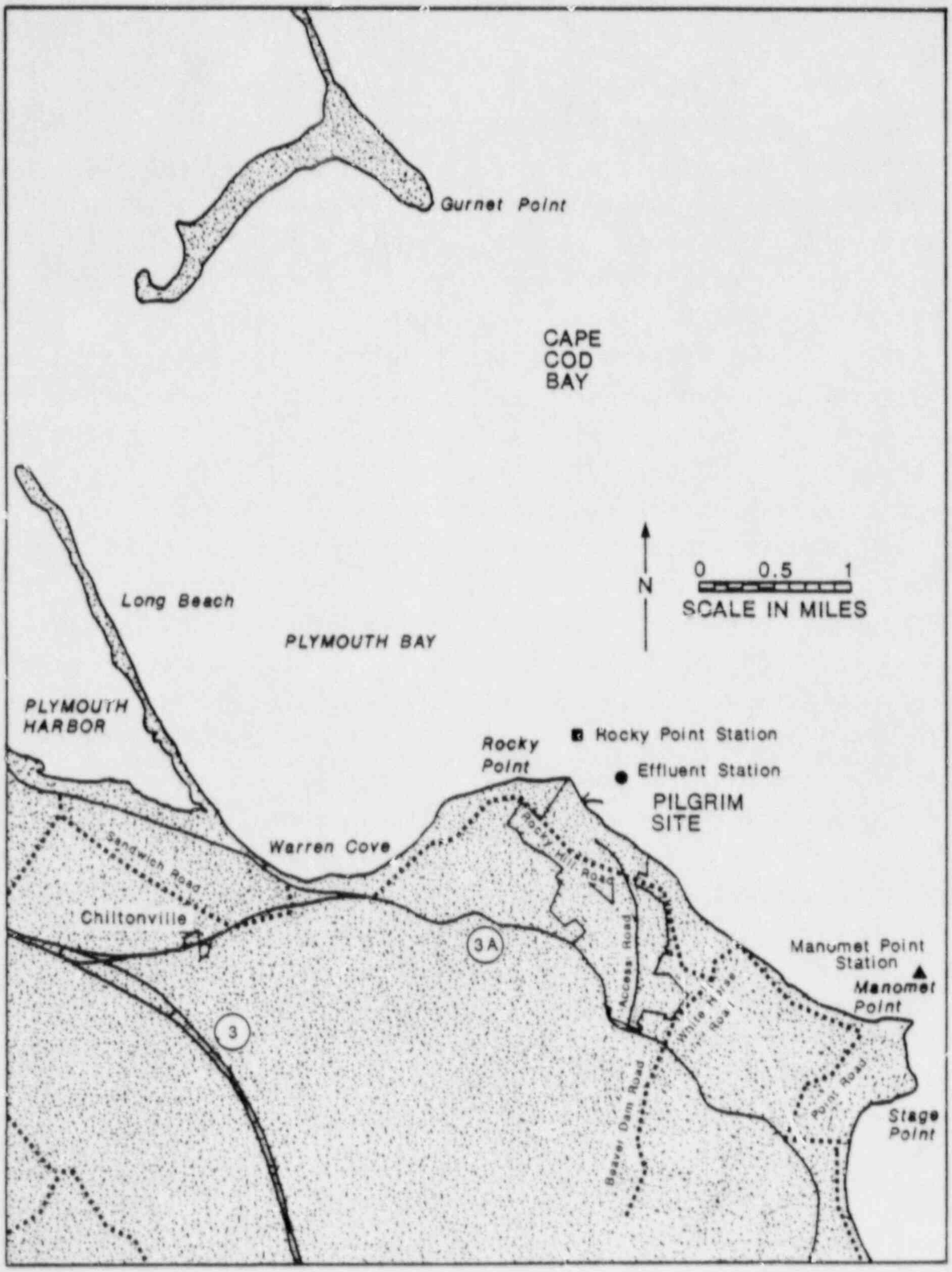

FIGURE 2. LOCATION OF ROCKY POINT, EFFLUENT, AND MANOMET POINT SUBTIDAL (3 m MLW) STATIONS.

the denuded, stunted, and normal Chondrus zones typical of the acute impact area associated with the PNPS discharge effluent. Variations in the size of these zones over time are recorded as a means of determining the area most severely affected by PNPS operations. Detailed descriptions of all sampling and analysis techniques can be found in Semi-Annual Report No. 29, Volume 1 (Boston Edison Co., 1987a).

QUANTITATIVE FAUNAL COMMUNITY STUDIES

SPECIES RICHNESS

Until 1985, species richness values at all three stations sampled during this study had varied according to a seasonal pattern of low species richness in spring followed by high species richness in fall (Figure 3). Additionally, the Effluent station had exhibited depressed species richness in comparison with the reference stations. The consistent pattern of reduced species richness at the Effluent station was assumed to be directly related to an effect associated with PNPS operations.

As discussed in Semi-Annual Report No. 27 (Boston Edison Co., 1986), data from 1985 indicated a lagged response at the Effluent station to the refueling outage of 1984. In 1986, species richness values at the Effluent station were again affected by the lack of heated effluent being discharged from PNPS. The response to the outage of 1986 was similar to that in 1984-1985, in that a high output year (1985) followed by a low output year (1986) appears to have disrupted the typical, PNPS-induced pattern of species recruitment at the Effluent station. In March 1986 (immediately after the first brief outages in 1986), the Effluent station ranked second among the stations for pooled species richness and by September 1986, the Effluent station ranked first (Figure 3).

In 1987, the number of species was lowest at the Effluent station both in spring and fall, and at all three stations the species richness increased from March to September (Figure 3). These conditions, observed during the continuing power outage of PNPS, resemble the observations made until 1985, i.e., during years when PNPS was operating more or less continuously. It seems, thus, that in 1987 the benthic community at the Effluent station still had not fully

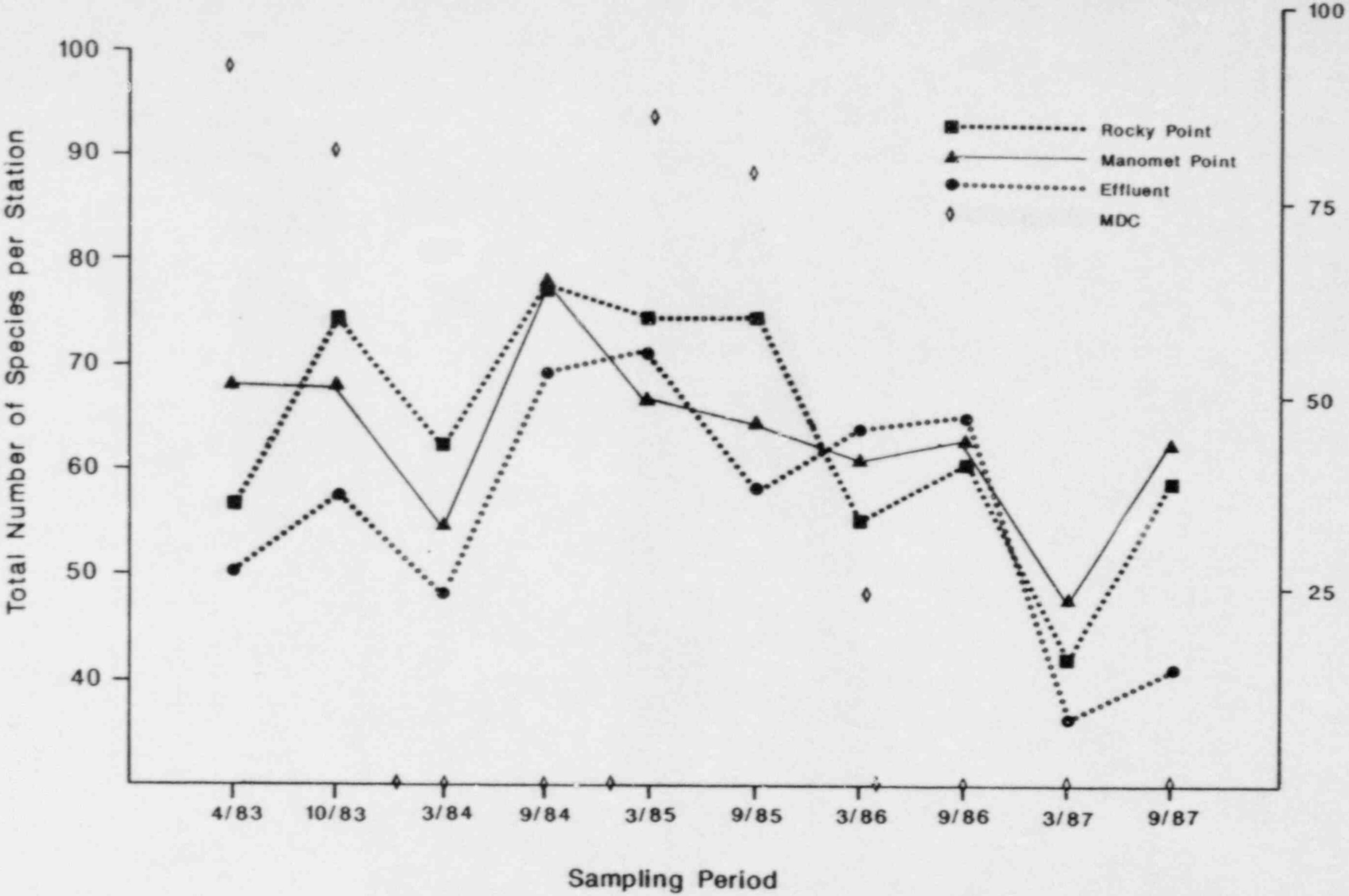

FIGURE 3. SPECIES RICHNESS FOR THE PERIOD APRIL 1983 THROUGH SEPTEMBER 1987 PLOTTED WITH THE MONTHLY PNPS CAPACITY FACTOR (MDC). VALUES OF APRIL 1983 INCLUDE JUVENILE AND INDETERMINATE INDIVIDUALS.

recovered from the effects of the thermal effluent discharged until early spring 1986. The results of the 1986 analysis seemed to indicate a more complete recovery of the fauna than do the results of the 1987 analysis. The lack of flow from circulating water pumps in spring and summer 1987 may have accounted for the low species richness in the fall of that year and in 1984.

FAUNAL DENSITY

Figure 4A presents total faunal densities at the Effluent and the reference stations during 1983 through 1987. As was reported in previous years, there seems to be no seasonal pattern at any of the three stations. There is also no consistent relationship between the densities at any two stations. Generally, densities are lower at the Effluent than at the reference stations, and the reference stations change in their ranking relative to each other. However, faunal densities at the Effluent station are occasionally higher than at one or even both reference stations. The contribution of the blue mussel *Mytilus edulis* (Figure 4B) to the total faunal density changed dramatically at all three stations, with extremely high densities occurring in fall 1984 at all stations and a second peak at the Effluent station in spring 1986. Except for this peak, *Mytilus* densities have been very low since the fall of 1985.

The MDC values shown in Figures 4 and 5 reveal that changes in faunal densities are not directly related to PNPS operations. Total faunal densities at the Effluent station during the two high-capacity years (1983 and 1985) differ in value as well as in the way they change from spring to fall (sharp increase in 1983, slight decrease in 1985); total densities during the two long outage periods in 1984 and 1986/87 differ dramatically in value. Since 1985, densities

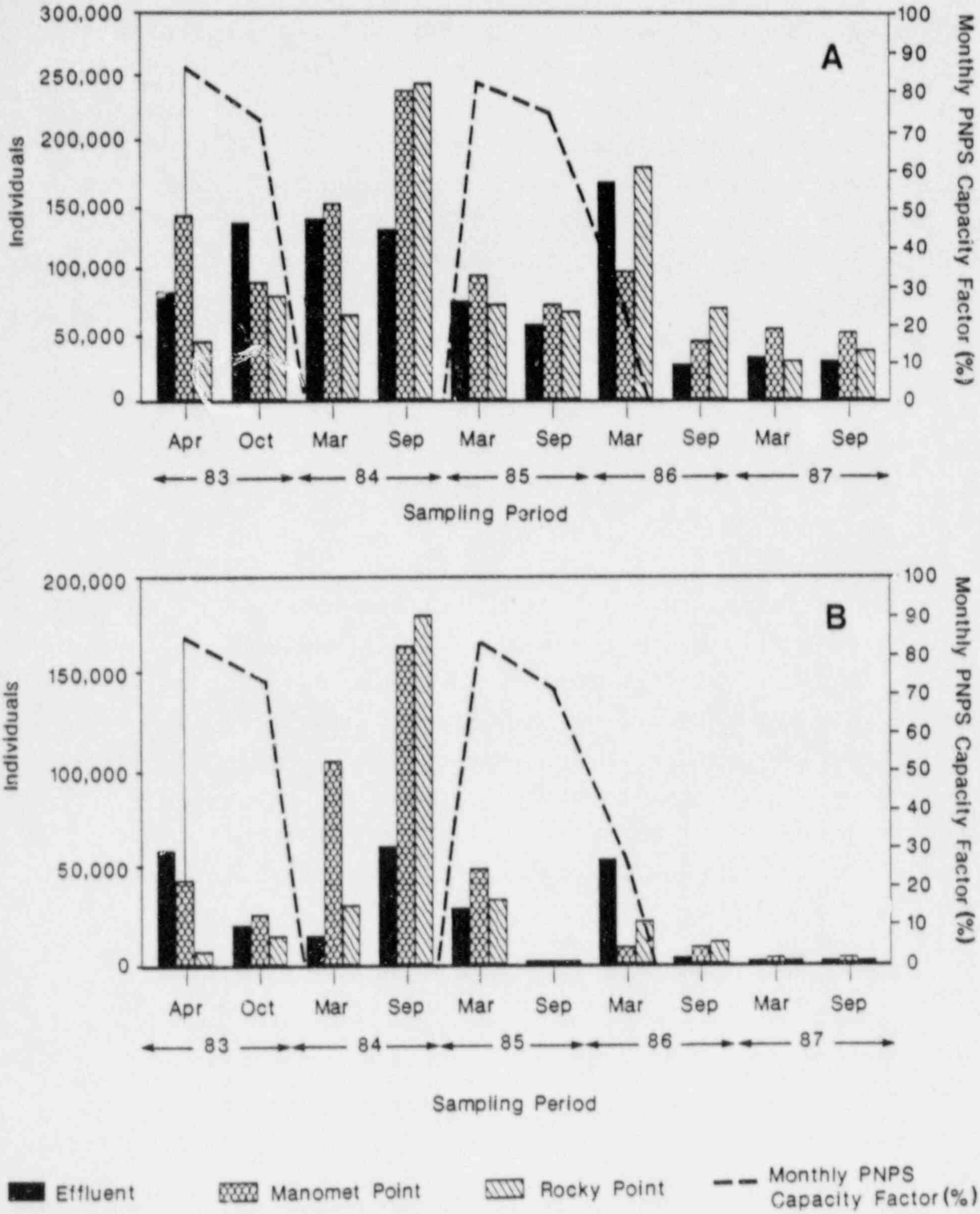

FIGURE 4. FAUNAL DENSITIES (m^2) FOR THE PERIOD APRIL 1983 THROUGH SEPTEMBER 1987 PLOTTED WITH THE MONTHLY PNPS CAPACITY FACTOR. A: TOTAL FAUNA, B: *MYTILUS EDULIS*

followed roughly the same pattern at all three stations. Changes in faunal densities at the Effluent station can therefore not be related to the degree of operation of PNPS, but must be interpreted as part of naturally occurring processes in Cape Cod Bay. The absence of environmental stress including high water temperatures and scouring by strong currents during the power outages at PNPS may influence the composition of rare species; these changes, however, are not detectable when the total fauna is analyzed.

SPECIES DOMINANCE

Composition of the 15 numerically dominant species at all three stations has remained relatively similar throughout this study. The same species made up the largest portion (generally >80 percent) of the faunal communities from season to season and year to year. Rankings of the top 15 dominants may vary, but the species composition has been fairly consistent at all three stations. Faunal species dominance has not been noticeably affected by PNPS operations.

SPECIES DIVERSITY

A seasonal pattern of low faunal diversity in spring followed by high diversity in fall has been observed at all three stations over the course of this study. This pattern is shown for the 1983 to 1987 period in Figure 5. For consistency with previous reports, Mytilus counts have been excluded from the calculations for the 1987 data. Figure 5 also shows that, in general, the Effluent station exhibits lower diversity values than do the reference stations.

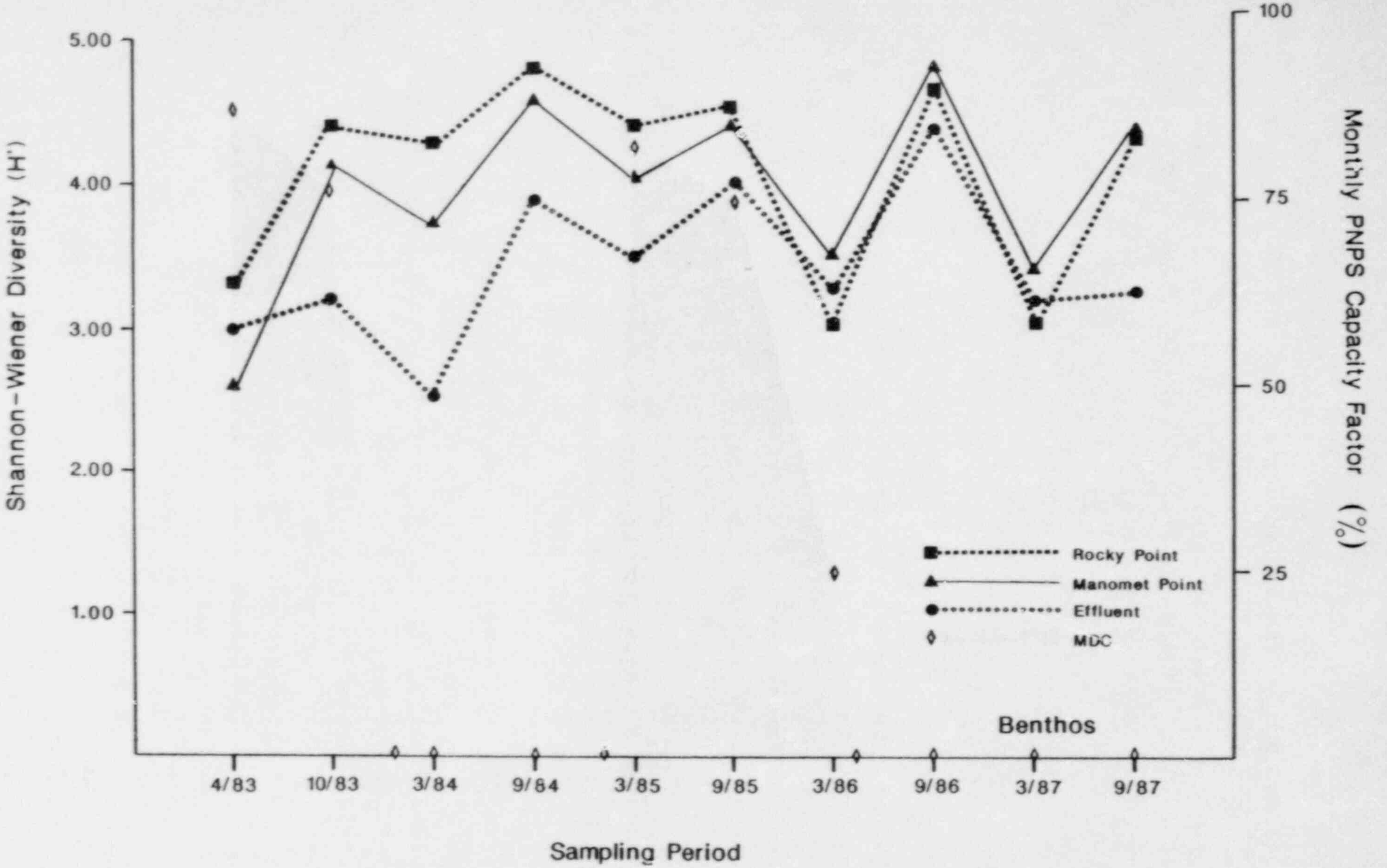

FIGURE 5. SHANNON-WIENER DIVERSITY (H') FOR DATA EXCLUDING <u>MYTILUS</u> <u>EDULIS</u> PLOTTED WITH THE MONTHLY PNPS CAPACITY FACTOR (MDC).

Deviations from this last trend, as observed in spring 1983, 1986, and 1987, do not appear to be related to PNPS operations. These deviations appear to reflect isolated incidents of reduced diversity at the reference stations, rather than increased diversity at the Effluent station.

SIMILARITY AMONG STATIONS

The results of cluster analyses discussed in Volume 1 show that the faunal community at the Effluent station is somewhat different from the communities at the reference stations. Prior to 1987, this difference was much more distinct; the increasing similarity between the Effluent and reference stations indicates the recovery of the benthic community at the Effluent station because of the continuing outage at PNPS. Figure 6 presents the results of the March 1987 analysis, where the reference station samples show only a slightly higher level of similarity with one another than with samples taken from the Effluent station. A similarity analysis of the combined spring and fall data resulted in clear patterns of seasonal changes in the benthic communities at all stations. The results of additional analyses indicated that differences among stations and seasonal fluctuations can be related to certain groups of species. Generally, the major differences between the faunal communities at the Effluent and reference stations were in the composition and density of subdominant species. These species play a significant role in influencing overall community structure and the effect that PNPS has on it.

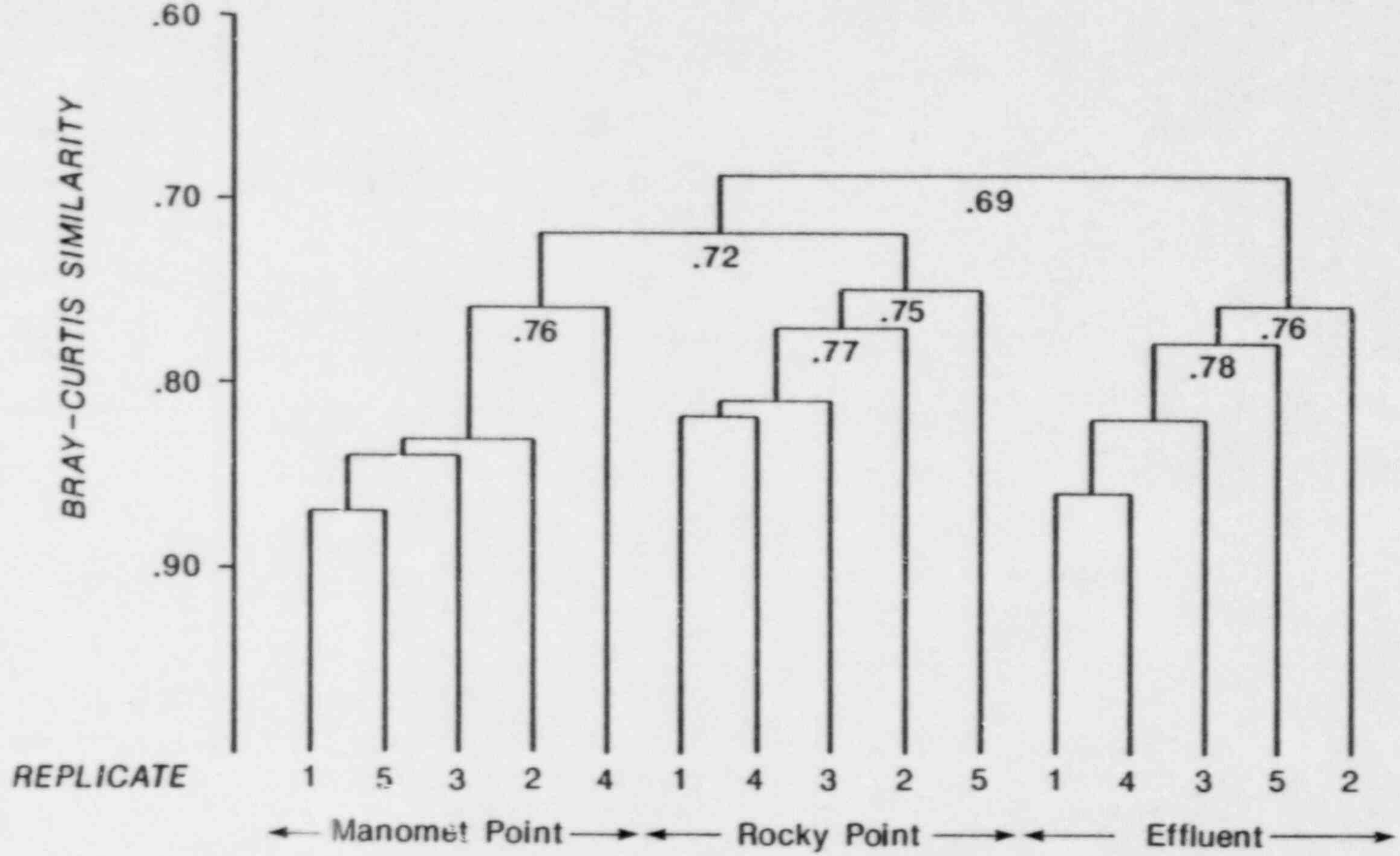

FIGURE 6. DENDROGRAM SHOWING RESULTS OF CLUSTER ANALYSIS OF MARCH 1987 DATA USING BRAY-CURTIS AND GROUP AVERAGE SORTING.

DISCUSSION--FAUNAL STUDIES

The results of faunal community analyses conducted during 1987 indicate only a minor difference between the Effluent station and the reference stations. Although species richness is still lower at the Effluent station than at the reference stations, the similarity analysis shows that the similarity between the Effluent and reference stations has increased considerably. Species richness declined greatly at the Effluent station compared to previous years; however, a similar decline was also observed at the reference stations. Differences in faunal densities among the stations are not correlated with PNPS operations and the species that contribute the majority of the individuals (typically greater than 80 percent) to the total fauna at the three stations differ only in relative rank. Seasonal trends in faunal diversity covary at the three stations and usually indicate depressed diversity at the Effluent station compared with the reference stations.

Logan and Maurer (1975) have hypothesized that faunal communities in the mouths of thermal effluent canals are in a "noninteractive, pioneer state." This state is reflected in high diversity, low species numbers, and low population densities caused by intermittently severe environments (i.e., temperature variations, as well as changes in turbidity). The results of the current study indicate that the faunal communities at the Effluent station exhibit characteristics somewhat different from those described by Logan and Maurer. Although species richness is typically depressed at the Effluent station, diversity is also depressed and faunal densities are not always lowest at the Effluent station. The community found at the Effluent station is one that is more commonly believed to be characteristic of a stressed environment.

Logan and Maurer state that the occurrence of high diversity in the path of a thermal effluent is probably caused by recolonization following periods of severe, intermittent environmental change. An example of such a change would be decreased ambient temperatures caused by storms, extreme tides, or plant shutdown. Data from the present study, therefore, seem to indicate that although there is an effect at the Effluent station, conditions at the station have been relatively stable for prolonged periods of time, resulting in sustained low diversity compared with the reference stations. This stability was maintained at least until 1984, when PNPS experienced a long shutdown.

Under "normal" PNPS operating conditions, the faunal communities at the Effluent station experience different temperature variations annually than are experienced at the reference stations (i.e., greater ambient temperatures in the summer and winter due to thermal loading); temperature variations result in differences in the community parameters discussed earlier. These annual variations were compounded by the extreme maxima and minima of operation experienced by PNPS from 1983 through 1987, creating environmental variability at the Effluent station on a different scale than is usually experienced. As has been noted, the impact of PNPS at the Effluent station is on the rarer, more transitional species rather than on the dominant species.

Although the effect of PNPS at the Effluent station is not extreme under normal conditions, erratic PNPS operation during recent years created prolonged perturbations at the Effluent station in the form of high power output (maximum impact) followed by no power output (maximum recovery), including variations in discharge current flow from full flow (maximum impact) to no flow (minimum impact). These fluctuations by PNPS have resulted in environmental impacts at the Effluent station that are less consistent than those seen prior to 1984, a fact which accounts for the changes in relative ranking of the three stations for several of the parameters measured in this study.

QUANTITATIVE ALGAL COMMUNITY STUDIES

ALGAL COMMUNITY DESCRIPTIONS

Like the faunal communities, the algal communities at the Effluent station are dominate by species that also dominate the reference stations. However, one indication of the effect of PNPS on algal communities at the Effluent station has been the presence of several less abundant species that do not occur at the reference stations. The most significant of these species is Gracilaria foliifera. G. foliifera, considered an important indicator of warm-water habitats (Boston Edison Co.,1982), was not found in any of the samples taken in 1987. This species had occurred regularly at the Effluent station during normal operational years. In 1986, a drastic decrease of G. foliifera was observed, the species being present in only two replicate samples out of ten, and the disappearance of this species in 1987 is clearly related to the continuing outage of PNPS. A similar decrease in G. foliifera abundance at the Effluent station was also noted in response to the outage of 1984 (Boston Edison Co., 1986).

Divers conducting qualitative transect surveys at the effluent discharge canal in 1987 reported G. foliifera as being completely absent; a significant decrease in abundance had been observed from March to December 1986. According to these qualitative and quantitative findings, the occurrence of G. foliifera is apparently related to the impact of the PNPS thermal effluent.

ALGAL COMMUNITY OVERLAP

Table 1 presents algal community overlap values between stations (i.e., the number of species shared by a given pair of stations) for the last five years. The general tendency of the two reference stations to be more similar to each other (higher overlap values) than to the Effluent station has again been confirmed by the values calculated for 1987. However, as in previous years, the overlap values for the various station pairs (Manomet Point vs. Rocky Point, Manomet Point vs. Effluent, and Rocky Point vs. Effluent) were not significantly different, indicating a relatively homogeneous distribution of algae among all stations. In September 1987, the overlap between the Manomet Point and Effluent stations was identical with the overlap between the two reference stations, thus approaching the unusual conditions reported in April 1983 and September 1985. It was suggested earlier (Boston Edison Co., 1987b) that these variations in species overlap are not directly caused by effects related to PNPS operations, but rather are part of naturally occurring, long-term variations in Cape Cod Bay. Overall, the continuation of the outage to almost two years did not cause any significant changes in the algal species composition, again indicating that effects of PNPS operations on the algal species composition are minimal.

ALGAL BIOMASS

The 1987 biomass data generally showed the same pattern observed in previous years except for 1986 (Boston Edison Co., 1987a). That is, biomass was low in spring and high in fall at all stations. The only exception to this pattern in 1987 was the Manomet Point station, which showed a decrease

TABLE 1. ALGAL COMMUNITY OVERLAP IN PERCENT BETWEEN STATIONS FOR THE PERIOD 1983-1987.

	1983		1984		1985		1986		1987	
	Apr	Oct	Mar	Sep	Mar	Sep	Mar	Sep	Mar	Sep
MP vs. RP	81.0	77.8	76.0	84.0	88.0	65.5	90.9	84.0	77.2	80.0
MP vs. EF	85.2	67.9	68.0	73.1	77.0	73.1	76.9	70.4	66.7	80.0
RP vs. EF	81.0	73.0	70.4	71.0	75.0	88.9	80.8	77.8	70.8	76.0

MP = Manomet Point
RP = Rocky Point
EF = Effluent

in algal biomass from spring to fall; in 1986, both reference stations had high algal biomass values in spring and considerably lower values in fall (Figures 7 to 9). The fact that the biomass values at the Rocky Point station followed the regular pattern in 1987 after showing irregularities in 1986 makes it very unlikely that the conditions noted in 1986 were a response to the outage. The changes are apparently part of natural processes occurring in Cape Cod Bay; this conclusion was suggested earlier (Boston Edison Co., 1987b) after statistical investigations of the 1986 data did not show any evidence of a correlation between the PNPS operations and biomass values at any station.

DISCUSSION--ALGAL STUDIES

The results of algal community studies presented for 1987 support the conclusions drawn earlier for the faunal studies. Measures of similarity between station pairs (in this case, Jaccard's coefficient of community) indicate a slightly higher degree of similarity between the reference stations compared with the Effluent station. This observation is typical for the study, and is caused by the variation of species considered rare in terms of their contribution to the total algal biomass at each station. One example of this type of species is Gracilaria foliifera, which occurred only near the effluent canal during the years when PNPS was normally operating. The continuing outage accounted for the disappearance of G. foliifera in 1987. However, biomass values for the major algal categories fail to show any patterns, either among stations or over time, that would indicate a significant effect of PNPS at the Effluent station. These observations are analogous to those noted earlier in this report for faunal species richness and faunal densities.

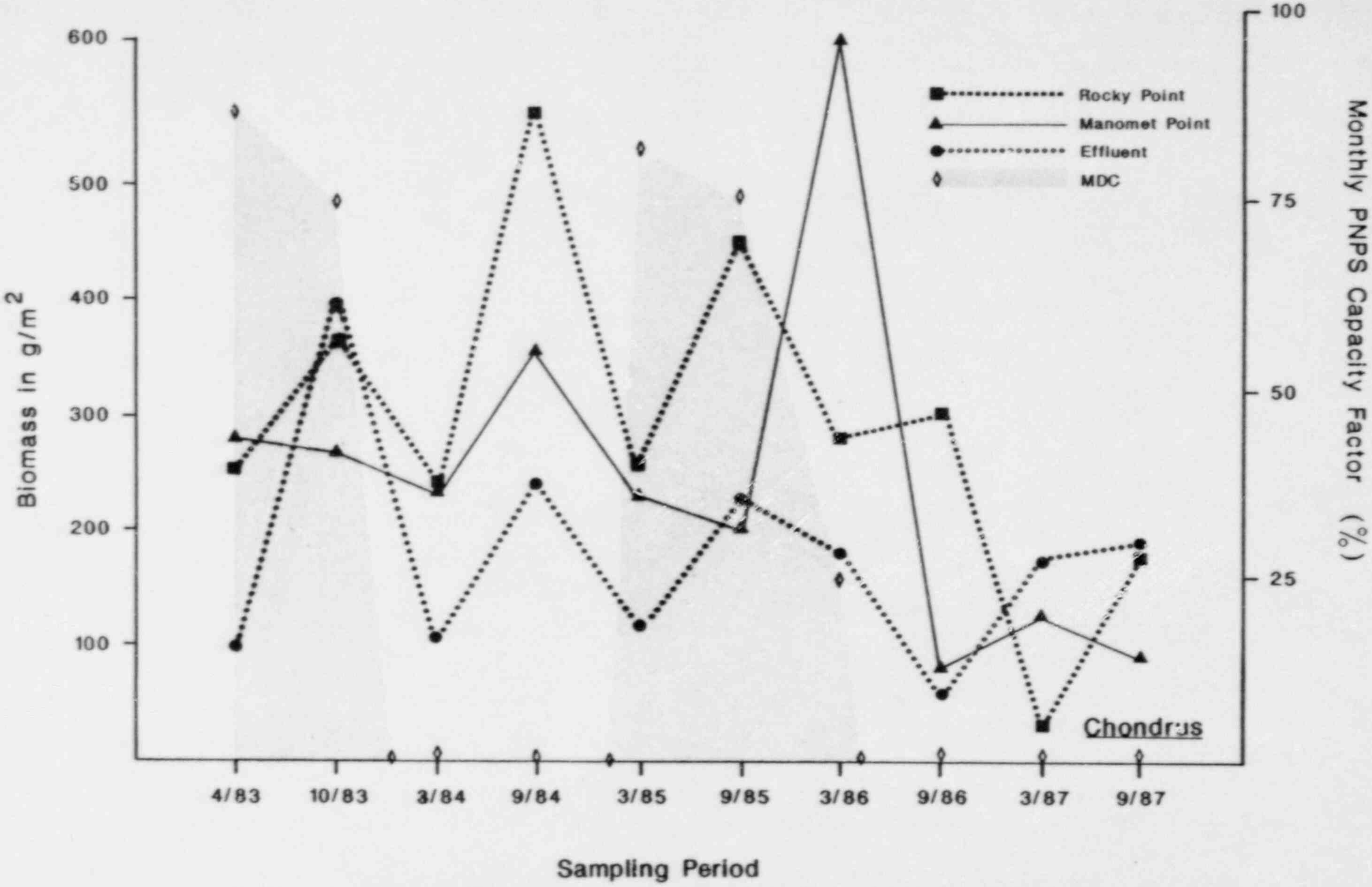

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FIGURE 7. SEASONAL FLUCTUATIONS IN TOTAL MEAN CHONDRUS BIOMASS AT THE MANOMET POINT, ROCKY POINT, AND EFFLUENT STATIONS DURING SPRING AND FALL SAMPLING PERIODS FOR THE COLLECTIONS BETWEEN APRIL 1983 AND SEPTEMBER 1987 PLOTTED WITH THE MONTHLY PNPS CAPACITY FACTOR (MDC).

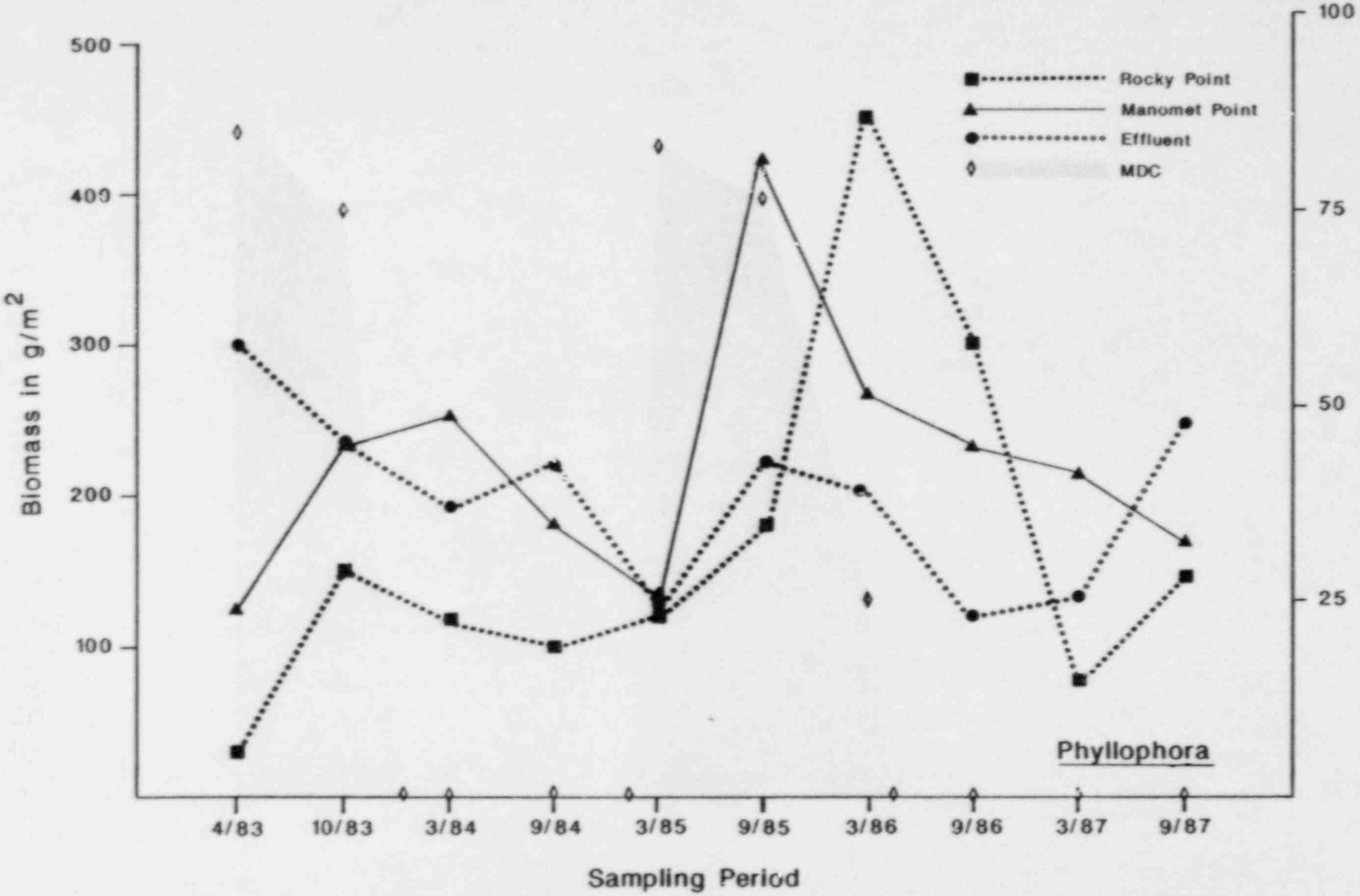

FIGURE 8. SEASONAL FLUCTUATIONS IN TOTAL MEAN PHYLLOPHORA BIOMASS AT THE MANOMET POINT, ROCKY POINT, AND EFFLUENT STATIONS DURING SPRING AND FALL SAMPLING PERIODS FOR THE COLLECTIONS BETWEEN APRIL 1983 AND SEPTEMBER 1987 PLOTTED WITH THE MONTHLY PNPS CAPACITY FACTOR (MDC).

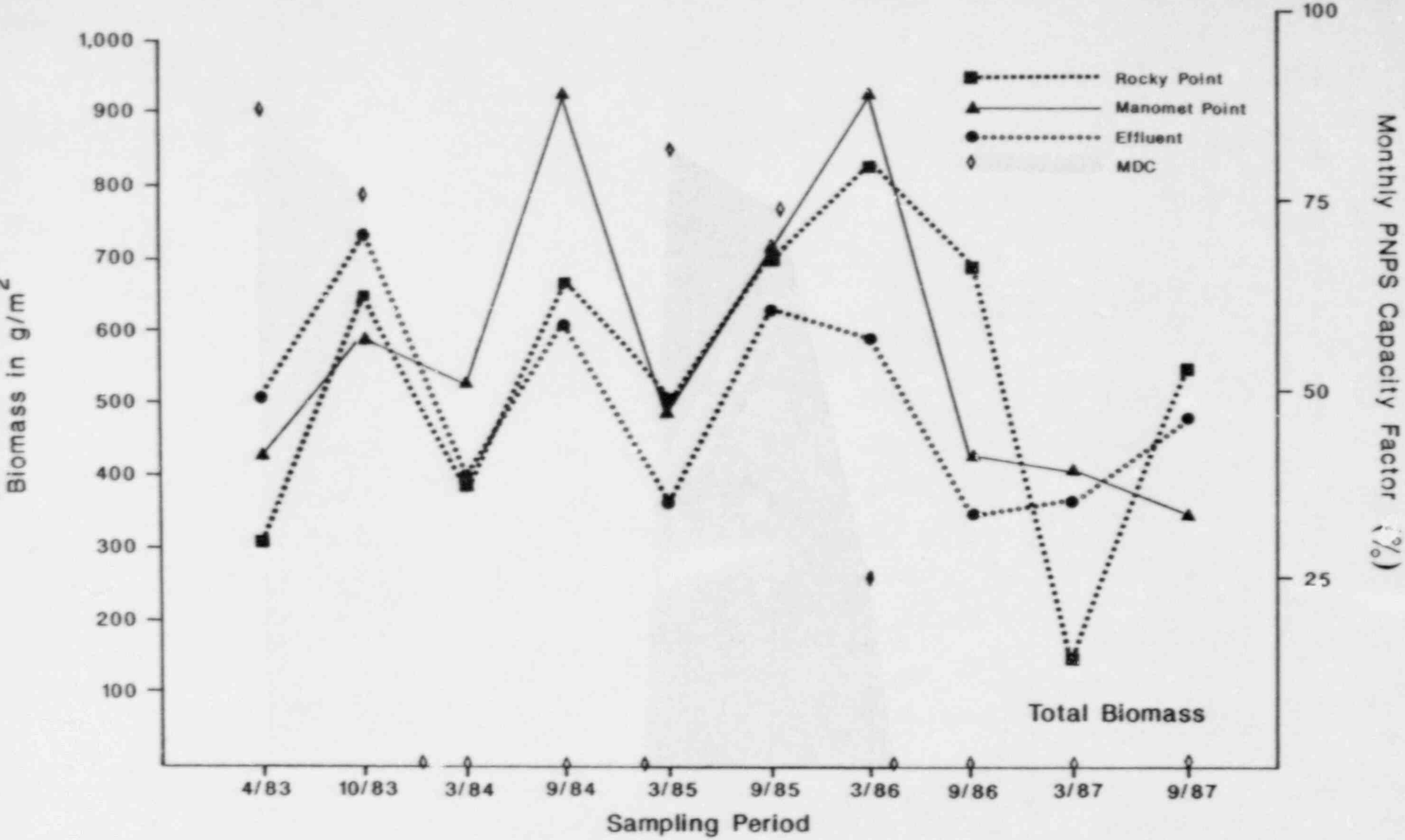

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FIGURE 9. SEASONAL FLUCTUATIONS IN TOTAL MEAN ALGAL BIOMASS AT THE MANOMET POINT, ROCKY POINT, AND EFFLUENT STATIONS DURING SPRING AND FALL SAMPLING PERIODS FOR THE COLLECTIONS BETWEEN APRIL 1983 AND SEPTEMBER 1987 PLOTTED WITH THE MONTHLY PNPS CAPACITY FACTOR (MDC).

Like the faunal communities found at the Effluent station, the algal communities have experienced perturbations over time that have affected species composition rather than overall abundance (biomass). More specifically, the impact of PNPS on the algal communities at the Effluent station is reflected in the presence or absence of several less dominant species. This impact seems to imply an effect on the opportunities available for new species to colonize the Effluent station rather than the reference sites and is considered less severe than what might be expected if the Effluent station were located closer to the areas of acute impact (i.e., closer to the mouth of the discharge canal).

QUALITATIVE TRANSECT SURVEYS

A lagged recovery response within the acute impact zone to the 12-month outage at PNPS during 1984 was reported in Semi-Annual Report No. 27 (Boston Edison Co., 1986). Evidence of this response included a downward trend in the extent of the total impact area that began in mid-1984 and continued through mid-1985. Figure 10 presents results for all qualitative transect surveys from 1983-1987. The total acute impact area is plotted along with the extent of the denuded zone and the monthly PNPS maximum dependable capacity factor. The stunted zone is represented by the difference between the denuded and total acute impact zones. Between December 1984 and December 1985 the total impacted area (denuded and stunted zones combined) was the smallest ever recorded, indicating a period of lagged recovery within this area in response to the lack of thermal effluent from PNPS. The downswing in areal extent reversed itself between September and December 1985, showing a lagged increase in size of the acute impact zone due to the continuation of normal operating conditions.

These results confirmed the lagged period of approximately six to nine months between the causal factor (cessation or resumption of effluent discharge) and associated response (decrease or increase in size of the acute impact zone). In 1987, the recolonization of the denuded and stunted zones by Chondrus advanced so far that it was difficult to distinguish the zone boundaries (Figure 11). The size (in square meters) was therefore not calculated. The considerable decrease of the acute impact zone in June 1987 was mostly the result of the shutdown of the circulating water pumps from March to August. Water current scouring is apparently a greater stress to algal colonization than an increase of the water temperature. The increase of the acute impact zone in September and December confirms this

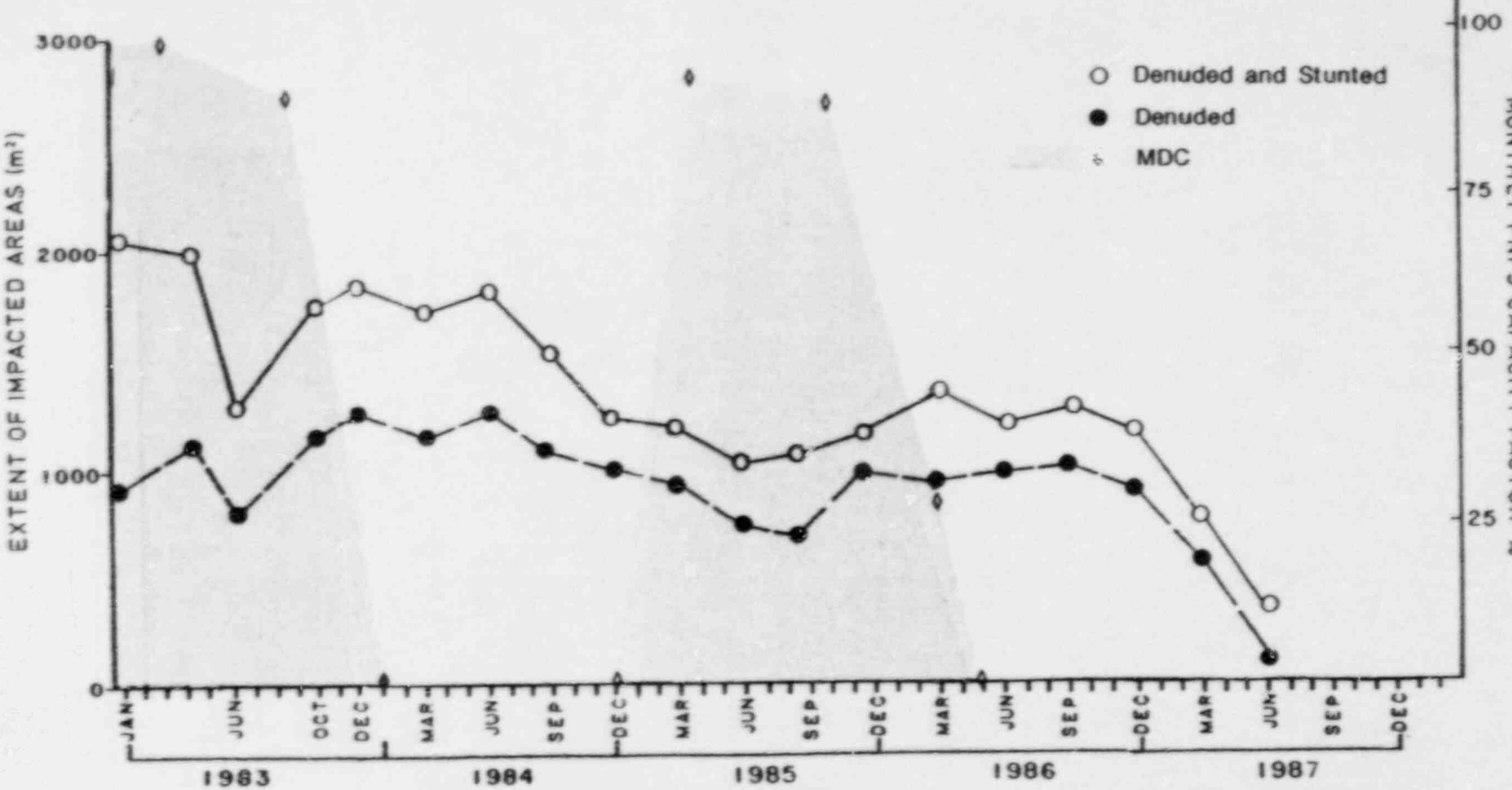

FIGURE 10. AREA OF DENUDED AND STUNTED ZONES IN THE VICINITY OF THE PNPS EFFLUENT CANAL PLOTTED WITH THE MONTHLY PNPS CAPACITY FACTOR (MDC). NO AREA MEASUREMENTS WERE MADE IN SEPTEMBER AND DECEMBER 1987 BECAUSE OF LACK OF DEFINITIVE DEMARCATIONS OF DENUDED AND STUNTED ZONES.

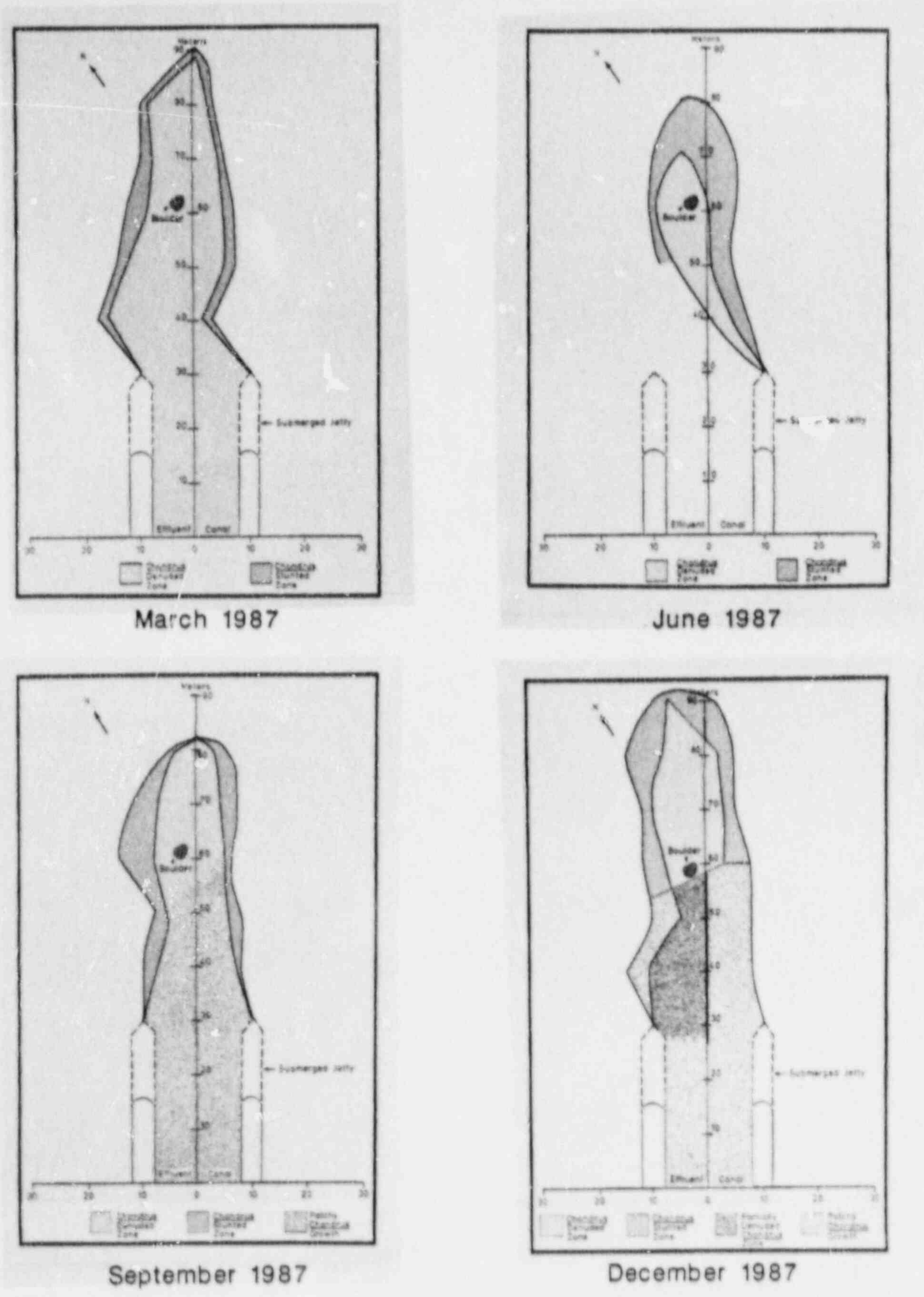

FIGURE 11. RESULTS OF 1987 QUALITATIVE TRANSECT SURVEYS OF THE PNPS ACUTE IMPACT ZONE OFF THE DISCHARGE CANAL.

assumption because it can be related to the resumption of circulating water pump operation in September.

CONCLUSIONS

The responses of the benthic communities to PNPS operations between 1983 and 1987 are presented in Table 2. The long power outage of 1986/87 resulted in a lagged recovery of the communities during 1987. This recovery was most obvious and most directly related to PNPS operations in the algal community of the acute impact zone. Overall, the full potential of PNPS has not been observed yet, because the cumulative operating rate of the plant has been only 50 percent to-date. The normal rate is about 75 percent.

FAUNAL STUDIES

- Species richness was lowest at the Effluent during both March and September 1987, indicating that the power outage had no effect on the number of species. However, depressed species richness may be the result of lacking flow from the circulating water pumps.

- Faunal densities were generally lowest at the Effluent in 1987, but results from 1983 through 1987 indicate that there is no direct relationship between PNPS operations and densities.

- Species composition of the top 15 dominants has been relatively similar among all stations and fairly consistent over time since 1983. Dominant species were not affected by PNPS and thus showed no response to the outage in 1987.

- Species diversity was generally lowest at the Effluent since 1983. The continuation of this trend in 1987 may be indicative of the extended period of time required for full recovery of faunal communities to the outage at PNPS.

TABLE 2. SUMMARY OF IMPACTS OF PNPS ON BENTHIC COMMUNITIES.

Study Component	Parameter	Impact of PNPS	1983-1987	Comments
	Species Richness	Effluent station ranks last relative to reference stations indicating impact from PNPS operations.	Effluent station ranked second in March 1985 and March 1986 and first in September 1986. Species richness declined from spring to fall 1985. Effluent station ranked last in 1987.	Outages during 1984 and 1986 resulted in increases in species richness values at the Effluent station. Fluctuating power output destabilized conditions and prolonged pioneer state, introducing new species at Effluent. Species richness in 1987 was low, apparently because of circulating water pump activity.
	Density	No detectable pattern overall.	No change in response to minimum (1984, 1986/87) or maximum (1983, 1985) output.	Relative ranks and degree of difference between the reference and surveillance stations have been inconsistent over the years of this study, indicating absence of a detectable effect at the Effluent station on faunal densities.
Quantitative Faunal Studies	Species Dominance	Dominant species relatively constant in occurrence at all three stations, exhibiting no impact from PNPS operations.	Composition of dominant species at all stations unaffected from 1983 to 1987.	Dissimilarity between surveillance and reference stations due to effect on species that contribute little to total fauna (by percent composition).
	Species Diversity	Reference stations exhibit higher species diversity than the Effluent station indicating impact from PNPS operations.	No significant changes in ranks of diversity among stations as a result of fluctuating power from 1983 to 1987.	Relatively stable diversity values at the Effluent station indicate stable conditions (i.e., sustained impact) with regard to this parameter.
	Measures of Similarity	Reference stations more similar to one another than to the Effluent station indicating impact from PNPS operations.	Reference stations continued to exhibit higher similarity with one another than with Effluent station, even during periods of high potential recovery at the Effluent station until 1986. In 1987, similarity between reference stations was equal to that between Effluent and both reference stations.	Cluster analyses reinforce contention that impact of PNPS is on subdominant species at the Effluent. Lagged recovery of faunal communities evident in 1987.

TABLE 2. (Continued).

Study Component	Parameter	Impact of PNPS	1983-1987	Comments
	Community Descriptions	Several species indicative of warm habitats have become established at the Effluent station indicating impact from PNPS operations.	Outages of 1984 and 1986/87 uphold indicator species hypothesis. Gracilaria foliifera and Laminaria spp. both respond to maximum and minimum output of PNPS.	Effluent algal communities, like the faunal communities, are distinguishable from reference stations by subdominant members of the communities.
Quantitative Algal Studies	Community Overlap	Greater community overlap between reference stations than between Effluent and reference stations indicating impact from PNPS operations.	No significant change in typical response to PNPS noted from 1983 to 1986. In the fall 1987 overlap between Effluent and reference stations increased.	Community overlap indicates a relatively stable impact at the Effluent requiring periods greater than 12 months for recovery. Overlap increase in September 1987 may indicate beginning recovery.
	Algal Biomass	No pattern evident in terms of relative algal biomass among all three stations.	Algal biomass unaffected by 1984 and 1986/87 outages.	Algal biomass categories, representing dominant algal components, do not exhibit a detectable impact from PNPS.
Qualitative Transect Survey	Acute Impact Zone	Denuded and stunted algal zones created by effluent discharge.	Lagged recovery at the effluent impact zones in response to outages in 1984 and 1986/87. Zones ill-defined after June 1987.	A lagged response is logical given the destructive nature of the impact in these zones. Scouring caused by circulating water pumps has greater effect than elevated water temperatures.

- Similarity between the Effluent and the reference stations increased considerably during 1987 and was as high as the similarity between the reference stations. From 1983 through 1986, similarity between the reference stations was much higher than between the Effluent and reference stations. The partial recovery of the fauna indicated by the similarity measure in 1987 is a lagged response to the outage at PNPS.

QUANTITATIVE ALGAL COMMUNITY STUDIES

- Algal communities at all stations were similar in 1987. No warm-water algae were found at the Effluent. During normal operational years, Gracilaria foliifera was regularly observed, but the species declined in 1986 because of lacking thermal effluent from PNPS.

- Algal community overlap among stations was not affected by PNPS operations. The number of species shared between the reference stations was generally higher than between the Effluent and reference stations since 1983, but the differences were not significant.

- Algal biomass was lowest at the Effluent station. However, it was not influenced by PNPS operations and since 1983 showed no response to maximum or minimum output.

QUALITATIVE TRANSECT SURVEYS

- The size of the acute impact zone was mainly influenced by the circulating water pump operation. A lagged recovery of the algal community occurred in 1987. Extensive recolonization resulted in a considerable decrease of the stunted and denuded zones in June. By September, the zones increased again in size because of resumption of circulating pump operation, but the boundaries were ill-defined.

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Ichthyoplankton Entrainment Monitoring
at Pilgrim Nuclear Power Station
January - December 1987
Volume 1 of 2
(Results)

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Boston Edison Company
Boston, Massachusetts

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Falmouth, Massachusetts

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April 6, 1988

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*Available upon request.

SECTION I

SUMMARY

Ichthyoplankton samples were collected from the Pilgrim Nuclear Power Station discharge canal in triplicate twice per month in January, February, October-December, and weekly from March through September. No sampling occurred in April due to circulating water system pump shutdown, and sampling during May through August occurred primarily with only one Salt Service Water System pump running.

Numerical Dominants - 1987: A total of 36 species were represented in the 1987 samples; 20 were represented by eggs, 33 by larvae. During the winter-early spring spawning season (December-April), egg collections contained small numbers of Atlantic cod and winter flounder. Rock gunnel and sculpin dominated among the larvae. The late spring-early summer ichthyoplankton season (May-July) was represented primarily by labrids, mackerel, rockling, and searobins among the eggs plus seasnails, winter flounder, rockling, menhaden, tautog, and silversides among the larvae. Late summer-autumn (August-November) collections produced primarily labrid, *Enchelyopus-Urophycis-Peprilus*, windowpane, and cod eggs as well as small numbers of tautog, hakes, windowpane, and fourbeard rockling larvae.

Multi-year Comparisons: Comparisons between 1987 monthly mean densities, per 100 m^3 of water, and those recorded over the 1975-1986 period suggest that searobin eggs were abundant in June 1987 as were Atlantic herring larvae in December. Eggs and larvae which appeared to be relatively uncommon in 1987 entrainment samples included among the eggs the *Enchelyopus-Urophycis-*

Peprilus group and fourbeard rockling during July and August, the labrids during July and August, mackerel during July, the *Paralichthys*-*Scophthalmus* group during July and August, and the hakes during August and September; among the uncommon larvae were sand lance during January through May, rock gunnel and sculpin in March, radiated shanny during May through June, mackerel during June and July, winter flounder during June, and rockling during July and August. The large number of low values during May-August appeared to be due to the operation of only one SSWS pump during that period.

Lobster Larvae: Lobster larvae were absent from the 1987 collections. The last time one was taken was in 1982 which represented the ninth since sampling began in 1974.

SECTION II

INTRODUCTION

This report summarizes results of ichthoplankton entrainment sampling conducted at the Pilgrim Nuclear Power Station (PNPS) discharge canal on a regular basis from January through December 1987. Work was carried out by Marine Research, Inc. (MRI) for Boston Edison Company (BECo) under Purchase Order No. 63653 in compliance with environmental monitoring and reporting requirements of NPDES Permit No. 0003557 (U.S. EPA and Massachusetts DWPC). In an effort to condense the volume of material presented in these reports, details of interest to some readers may have been omitted. Any questions or requests for additional information may be directed to Marine Research, Inc., Falmouth, Massachusetts.

SECTION III

METHODS AND MATERIALS

The entrainment sampling protocol at PNPS specified that samples will be coll.cted in triplicate twice monthly in January, February, October, November, December, and weekly March through September. All samples were collected with a 0.333-mm mesh, 60-cm diameter plankton net streamed in the discharge canal at low tide during daylight for 6 to 12 minutes depending on the abundance of plankton and detritus. In each case a minimum of 100 m^3 of water was sampled. Generally sampling at PNPS is completed from rigging mounted approximately 30 meters from the headwall of the discharge canal (Figure 1). However, in late March 1987 the single circulating water system (CWS) pump in operation since an extended plant outage began April 1986 was shut down for all but brief periods usually occurring at night; because of this no sampling was conducted in April. Beginning in May and continuing through August collections were made while one or two Salt Service Water System (SSWS) pumps were in operation. By sampling for 30-40 minutes per replicate upstream of the usual location nearer the headwall, 100 m^3 of water continued to be filtered for most samples. On three occasions (May 30, June 25, August 19) sampling was conducted while one CWS pump was in operation for brief periods. In September one CWS pump was put back in service and remained in regular use through December. Filtration volumes for each sample were obtained using General Oceanics Model 2030R digital flowmeters mounted in the mouth of the net. When only SSWS pumps were operating, a Model 2030R2 meter was used since it is more sensitive to low flow.

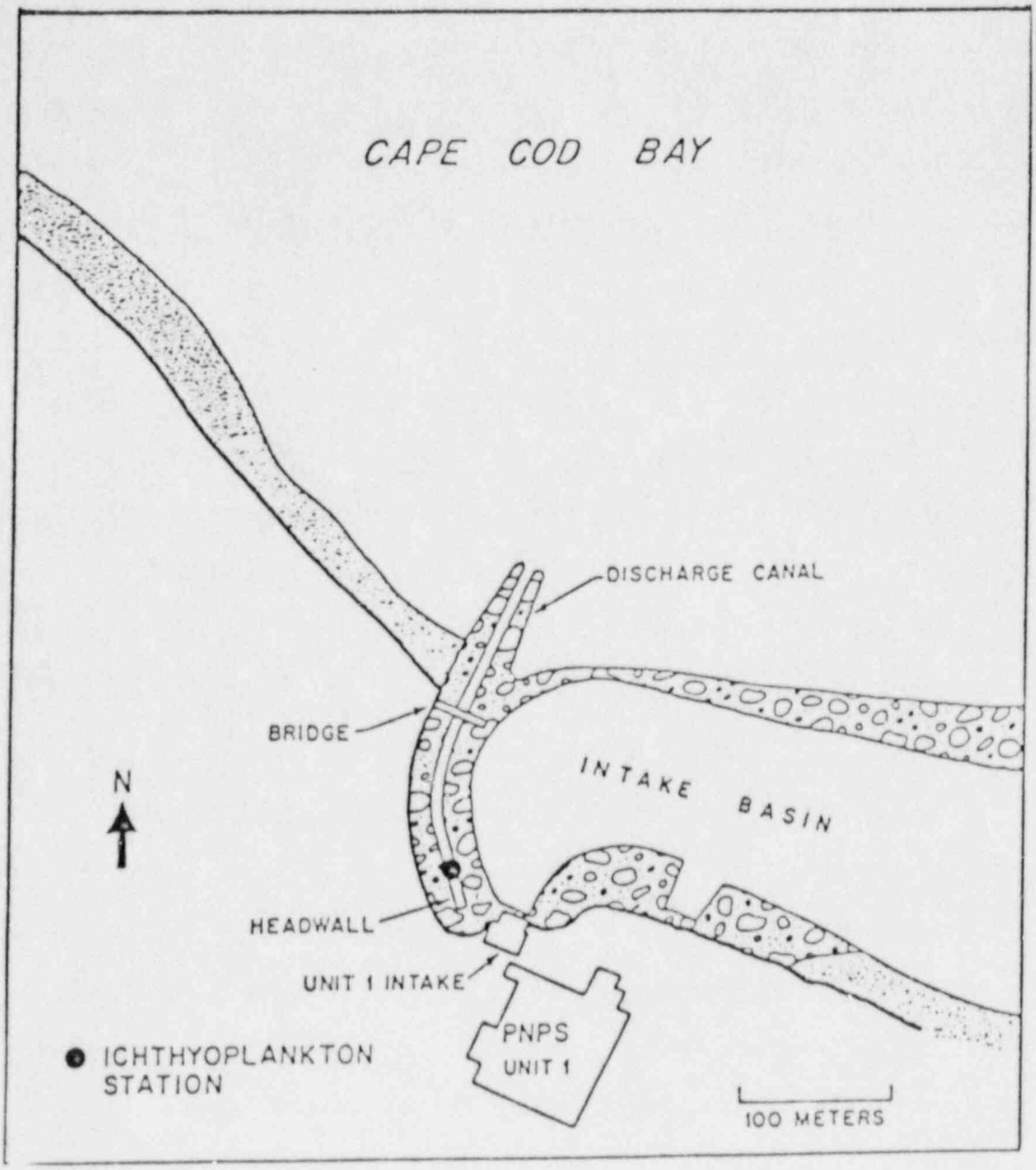


Figure 1. Entrainment sampling station in PNPS discharge canal.

All samples were preserved in 10% Formalin and returned to the laboratory for microscopic analysis. Fish eggs and larvae were identified to the lowest distinguishable taxonomic category and counted. Common and scientific names followed Robins et al. (1980). In most cases, species were identifiable. In certain cases, however, eggs--particularly in the early stages of development--could not be identified at the species level in the preserved samples. In such cases, species were grouped. A brief description of each of these egg groupings is given below.

- Gadidae-Glyptocephalus group (Atlantic cod, Gadus morhua; haddock Melanogrammus aeglefinus; pollock, Pollachius virens; and witch flounder, Glyptocephalus cynoglossus): egg diameters overlap, no oil globule present. Stage III eggs (those containing embryos whose tails have grown free of the yolk; Ahlstrom and Counts 1955) are separated based on relative size and pigmentation combinations. Haddock eggs are difficult to identify until shortly before hatching (late stage III). Because of this, some early stage III haddock eggs may have been identified as cod eggs. This error should be quite small judging from the relatively low numbers of late stage III haddock eggs and haddock larvae collected at PNPS. The gadidae-Glyptocephalus grouping was not considered necessary in January, February, and December because it is unlikely that witch flounder spawn during these months (Fahay 1983) and haddock spawning is not likely to occur in December nor in peak numbers during January and February (Hardy 1978). All eggs of the gadidae-Glyptocephalus type were therefore classified as either cod or pollock based on differing egg diameters during those three months.

• Enchelyopus-Urophycis-Peprilus group (fourbeard rockling, Enchelyopus cimbrius; hake, Urophycis spp.; and butterfish, Peprilus triacanthus): egg and oil globule diameters overlap. Stage III eggs are separated based on differences in embryonic pigmentation.

• Merluccius-Stenotomus-Cynoscion group (silver hake, Merluccius bilinearis; scup, Stenotomus chrysops; and weakfish, Cynoscion regalis): egg and oil globule diameters overlap. Stage III eggs are separated based on differences in embryonic pigmentation.

• Labridae-Limanda group (tautog, Tautoga onitis; cunner, Tautogolabrus adspersus; and yellowtail flounder, Limanda ferruginea): no oil globule present, egg diameters overlap. Stage III eggs are separated into labridae and yellowtail flounder based on differences in embryonic pigmentation. A high percentage of the two species of labrid eggs are distinguishable but only with individual, time-consuming measurement (Marine Research 1977a). Labrid eggs are therefore grouped in all three stages of development in PNPS samples.

• Paralichthys-Scophthalmus group (fourspot flounder, Paralichthys oblongus, and windowpane, Scophthalmus aquosus): oil globule and egg diameters as well as pigmentation are quite similar. Separation of these two species, even at stage III, remains uncertain. They are therefore grouped in all cases.

Eggs of the ·ay anchovy (Anchoa mitchilli) and striped anchovy (Anchoa hepsetus) are easi· distinguishable, but their larvae are not. Eggs of these fishes are the· fore listed by species while the larvae are listed simply as Anchoa spp.

Several other groups of eggs and larvae were not identified to species because adequate descriptions of each species are not available at this time. These groupings are as follows:

- Urophycis spp. - consists of the red hake (U. chuss), the spotted hake (U. regia), and the white hake (U. tenuis). Most larvae (and eggs) in this genus collected at PNPS are probably red hake (see summary in Hardy 1978).
- Menidia spp. - consists of the inland silverside (M. beryllina) and Atlantic silverside (M. menidia). Atlantic silverside larvae are probably more likely to occur as far north as Plymouth based on their more northern distribution.
- Ammodytes sp. - No species designation was given the sand lance because considerable taxonomic confusion exists in the literature (see for example Richards et al. 1963; Scott 1968, 1972; Winters 1970; Fahay 1983; Dalley and Winters 1987). Meyer et al. (1979) examined adults collected on Stellwagen Bank and classified them as A. americanus (= A. hexapterus). This population is probably the source of larvae entrained at PNPS.
- Prionotus spp. - consists of the northern searobin (P. carolinus) and the striped searobin (P. evolans).

Larval rainbow smelt (Osmerus mordax), cunner (Tautogolabrus adspersus), and winter flounder (Pseudopleuronectes americanus) were classified into three or four arbitrary developmental stages because these species have been of particular interest in studies at PNPS. These developmental stages and corresponding length ranges are given below.

Rainbow smelt

Stage I - from hatching until the yolk sac is fully absorbed (5-7 mm TL).

Stage II - from the end of stage I until dorsal fin rays become visible 6-12 mm TL).

Stage III - from the end of stage II onward (11.5-20 mm TL).

Cunner

Definitions of developmental stages are the same as for smelt larvae. Observed size ranges for each stage are: stage I, 1.6-2.6 mm TL; stage II, 1.8-6.0 mm TL: stage III, 6.5-14 mm TL.

Winter flounder

Stage I - from hatching until the yolk sac is fully absorbed (2.3-2.8 mm TL).

Stage II - from the end of stage I until a loop or coil forms in the gut (2.6-4 mm TL).

Stage III - from the end of stage II until the left eye migrates past the midline of the head during transformation (3.5-8 mm TL).

Stage IV - from the end of stage III onward (7.3-8.2 mm TL).

Generally entire samples were examined for fish larvae and all but the most abundant types of fish eggs. When a species was especially abundant, subsamples were obtained with a plankton splitter modified from Matoda (1959; see also Van Guelpen et al. 1982). Pure sample counts of eggs and larvae were used to establish a subsampling regime where the minimum number of specimens considered acceptable increased as the size of an aliquot decreased. (For example, 100 larvae were required for a one-half split; 200 were necessary for a one-quarter split.) In each case all aliquots were held separately in labeled beakers, the smallest split having been established based on visual observation and preceding samples. Sorting proceeded from the smallest aliquot with the most abundant species being dropped at the end of a particular split if the minimum number requirement was met. Based on the pure sample counts, mean error associated with this regime was 9.7% for eggs, 11.1% for larvae. Coefficients of variation, following 10 to 20 replicates each of 1/4 and 1/8 splits with three types of eggs and two types of larvae, ranged from 6.6 to 18.7% (mean = 12.9%). All final counts were converted to numbers per 100 m^3 of water.

In addition to fish eggs and larvae, all samples taken from May through October were examined for larval lobsters (Homarus americanus). Because they have been found to be uncommon at PNPS, no subsampling was done; each sample was examined in its entirety.

All entrainment samples were returned to 10% buffered Formalin-seawater solutions for storage of not less than three years to conform with NPDES Permit requirements.

When the Cape Cod Bay ichthyoplankton study was completed in 1976, a contingency sampling plan was added to the entrainment monitoring program. This plan was designed to be implemented if eggs or larvae of any dominant species proved to be "unusually abundant" in the PNPS discharge samples. The goal of this sampling plan was to determine whether circumstances in the vicinity of Rocky Point attributable to PNPS operation were causing an abnormally large percentage of ichthyoplankton populations there to be entrained or alternatively whether high entrainment levels simply were a reflection of unusually high population levels in Cape Cod Bay. "Unusually abundant" was defined as any mean density, calculated over three replicates, which was found to be 50% greater than the highest mean density observed during the same month from 1975 through 1986.

The contingency sampling plan consisted of taking additional sets of triplicates from the PNPS discharge on subsequent dates to monitor the temporal extent of the unusual density. An optional offshore sampling regime was also established to study the spatial distribution of the species in question. The offshore contingency program consisted of single, oblique tows at each of 13 stations (Figure 2) on both rising and falling tides for a total of 26 samples. Any contingency sampling required authorization from Boston Edison Company.

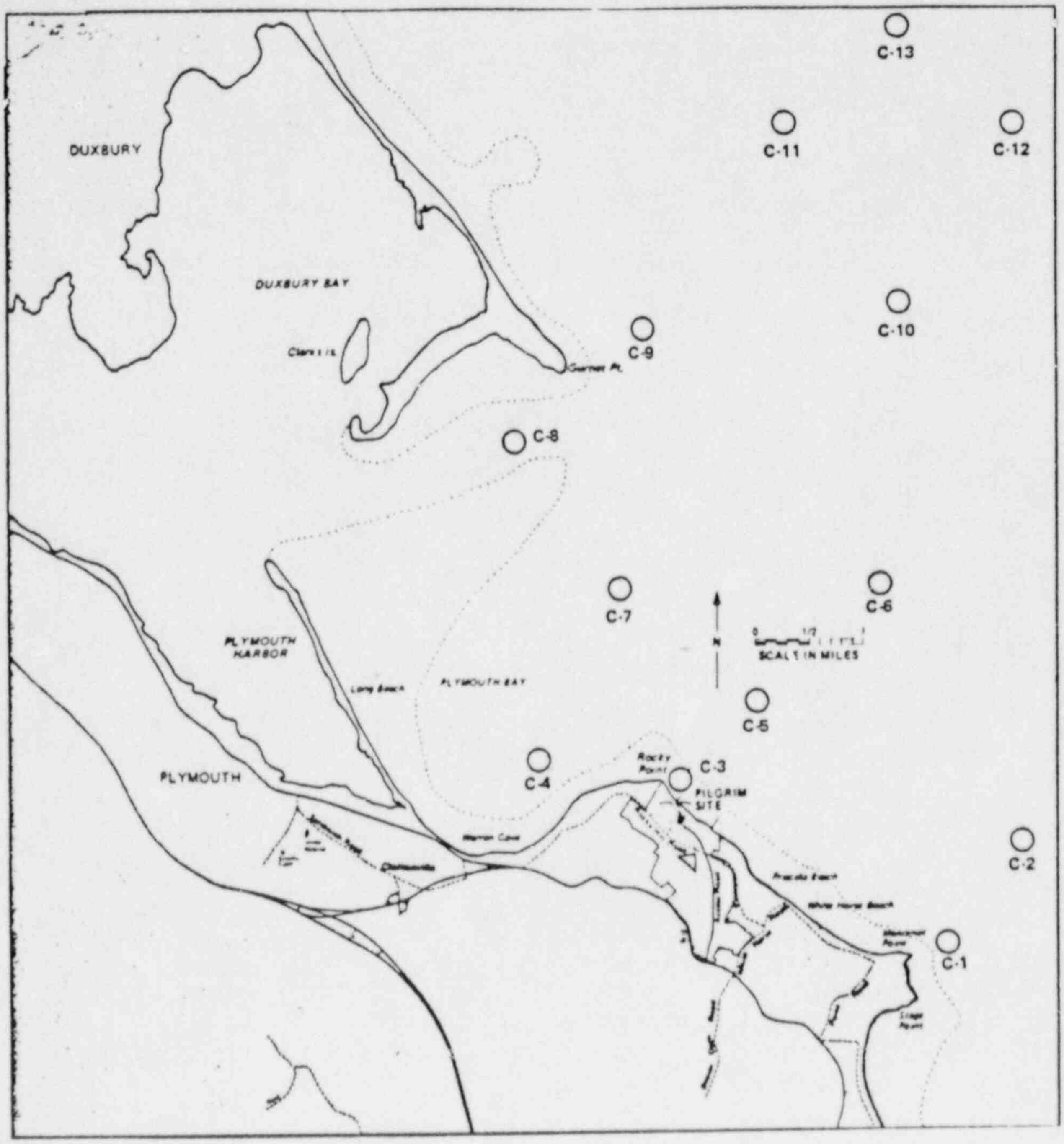


Figure 2. Location of entrainment contingency plan sampling stations, C-1 through C-13.

SECTION IV

RESULTS AND DISCUSSION

A. Ichthyoplankton Entrained - 1987

Population densities per 100 m^3 of water for each species listed by date, station, and replicate are presented for 1987 in Appendix A (available upon request). Table 1 lists all species represented in the 1987 collections, indicates the months eggs and/or larvae of each species were found, and for the more common species the months of peak abundance.

Ichthyoplankton collections are summarized below within the three primary spawning seasons observed in Cape Cod Bay: winter-early spring, late spring-early summer, and late summer-autumn.

Winter-early spring spawners (December-April).

Although sampling occurs at the end of the calendar year, December represents the beginning of the winter-early spring spawning season. Four species were collected in December 1987, two species of eggs and two species of larvae. Atlantic cod represented 88% of the eggs with a monthly mean of 6 per 100 m^3 of water and Atlantic herring (*Clupea harengus harengus*) represented 98% of the larvae with a mean of 7 per 100 m^3.

Six species were represented in the January collections followed by seven in February and eight in March (no sampling occurred in April). Samples taken during those three months contained relatively few eggs since species contributing most to entrainment during that period spawn demersal, adhesive eggs which are generally not subject to entrainment. Only Atlantic cod eggs were found in January and February with monthly

Table 1. Species of fish eggs (E) and larvae (L) obtained in ichthyoplankton collections from the Pilgrim Nuclear Power Station discharge canal, January-December 1987. Lines indicate peak periods for the more abundant species.

Species		Jan	Feb	Mar	Apr*	May	June	July	Aug	Sep	Oct	Nov	Dec
Atlantic menhaden	<u>Brevoortia tyrannus</u>						E L	L		E	L	L	
Atlantic herring	<u>Clupea harengus harengus</u>	-L-	L								L	-L——	L-
Anchovy	<u>Anchoa</u> spp.									L			
Rainbow smelt	<u>Osmerus mordax</u>					L							
Goosefish	<u>Lophius americanus</u>							E	E				
Fourbeard rockling	<u>Enchelyopus cimbrius</u>					-E—— L	E- -L-	E	E	-E—— -L——	E- L-	E L	
Atlantic cod	<u>Gadus morhua</u>	E	E	E		E	E				E	E L	-E-
Silver hake	<u>Merluccius bilinearis</u>									E L	E L	E L	
Atlantic tomcod	<u>Microgadus tomcod</u>		L	L									
Pollock	<u>Pollachius virens</u>											L	E
Hake	<u>Urophycis</u> spp.					E	-E-	E	E L	E L	E L		
Silversides	<u>Menidia</u> spp.						L	L					
Northern pipefish	<u>Syngnathus fuscus</u>									L			
Black sea bass	<u>Centropristis striata</u>									L	L		

Table 1 (continued).

Species		Jan	Feb	Mar	Apr*	May	June	July	Aug	Sep	Oct	Nov	Dec
Wrasses	Labridae					E	-E——	—E-	E	E			
Tautog	*Tautoga onitis*						L		L	L	L		
Cunner	*Tautogolabrus adspersus*						L			L	L		
Radiated shanny	*Ulvaria subbifurcata*					-L-	L						
Rock gunnel	*Pholis gunnellus*	L	-L——	—L-									L
Sand lance	*Ammodytes* sp.			L		L							
Atlantic mackerel	*Scomber scombrus*					-E—— L	—E- L	E					
Butterfish	*Peprilus triacanthus*					E	E						
Searobins	*Prionotus* spp.					E	-E——	—E-		L			
Grubby	*Myoxocephalus aenaeus*	L	-L——	—L-		L							
Longhorn sculpin	*M. octodecemspinosus*	L	L	L									
Shorthorn sculpin	*M. scorpius*		L	L									
Lumpfish	*Cyclopterus lumpus*						L						
Seasnail	*Liparis atlanticus*					-L-	L						
Gulf seasnail	*L. coheni*	L		L									
Smallmouth flounder	*Etropus microstomus*								E				

Table 1 (continued).

Species		Jan	Feb	Mar	Apr*	May	June	July	Aug	Sep	Oct	Nov	Dec
Summer flounder	*Paralichthys dentatus*									E	L		
Fourspot flounder	*P. oblongus*									E L	L		
Windowpane	*Scophthalmus aquosus*					-E ———	E-	E	E L	-E- -L-	E L		
Witch flounder	*Glyptocephalus cynoglossus*					E	E	E		E L	E		
American plaice	*Hippoglossoides platessoides*					E L	E L						
Yellowtail flounder	*Limanda ferruginea*					E	E		E	E	L		
Winter flounder	*Pseudopleuronectes americanus*					E -L-	L						
Number of species/month		6	7	8		17	18	10	7	15	14	6	4

*No sampling due to pump shutdown.

mean densities of 0.1 per 100 m^3 of water in both cases. March samples contained primarily winter flounder eggs which accounted for 97% of the egg total with a monthly mean density of 48 per 100 m^3 of water. Atlantic cod eggs continued to be taken and, assuming they contributed most to the gadidae-Glyptocephalus egg grouping, their mean density of 0.9 per 100 m^3 accounted for all remaining eggs in March. Since winter flounder eggs are demersal and adhesive, their densities in the PNPS discharge canal cannot be considered representative of densities in the waters around Rocky Point. Those which were collected from the discharge canal were probably dislodged from the bottom by currents, rough seas, or perhaps fish.

Larval collections during January-March consisted primarily of rock gunnel (Pholis gunnellus) and sculpin (Myoxocephalus spp.). Larval rock gunnel represented 25% of the January catch, 26% of the February catch, and 43% of the March catch; monthly mean densities were 0.5, 5, and 3 per 100 m^3 of water, respectively. Sculpin contributed 17% of the larvae in January, 67% in February, and 52% in March. For these species pooled monthly mean densities amounted to 0.3, 12, and 4 per 100 m^3 of water, respectively. Among the three species of sculpin larvae, grubby (Myoxocephalus aenaeus) were numerically dominant, accounting for 74% of all sculpin taken during the three-month period. Shorthorn sculpin (M. scorpius) ranked second at 22% and longhorn sculpin (M. octodecemspinosus) third at 4%. Atlantic herring contributed over half the larvae taken in January (52%), but at that time densities of all species were very low; the monthly herring mean density was 1 per 100 m^3 of water.

Late spring-early summer spawners (May-July).

Overall 17 species were represented in May, 18 in June, and 10 in July. Egg collections were dominated by the labrids, mackerel (Scomber scombrus), fourbeard rockling, and searobins (Prionotus spp.). The labrids, including the labridae-Limanda group, accounted for 19% of all eggs taken in May, 94% of those taken in June, and 98% of those taken in July; mean monthly densities were 21, 5277, and 719 per 100 m^3, respectively. Atlantic mackerel represented an additional 32% of the egg catch in May with a mean density of 36 per 100 m^3 of water, an additional 2% in June with a mean of 123 per 100 m^3, declining sharply to 0.01% in July with a mean of 0.1 per 100 m^3. Including eggs classified as Enchelyopus-Urophycis-Peprilus, fourbeard rockling contributed 34% of the May egg total with a mean monthly density of 37 per 100 m^3 of water, 0.8% of the June total with a monthly mean of 44, and 0.5% of the July total with a mean of 4 per 100 m^3. Searobin eggs accounted for 0.1, 1, and 0.9% of the May, June, July egg totals with respective mean monthly densities per 100 m^3 of 0.1, 77, and 7.

Numerical dominants among the larvae were seasnails (Liparis atlanticus) and winter flounder in May followed by fourbeard rockling, Atlantic menhaden (Brevoortia tyrannus), tautog in June, and silversides (Menidia spp.) and menhaden in July. Seasnails accounted for 48% of all larvae taken in May with a monthly mean density of 16 per 100 m^3 of water. Winter flounder added 37% of the total with a mean of 10 per 100 m^3 of water. In June rockling accounted for 42% of the month's larvae with a monthly mean density of 6 per 100 m^3; menhaden followed with a density of 2 per 100 m³, accounting for 18% of total. Tautog ranked third in June with a mean density of 2, representing an additional 15% of the catch. Only silversides and menhaden were taken in July. Silversides were slightly more abundant than menhaden with a mean density of 0.2 per 100 m³, accounting for 57% of the month's total compared with 0.1 for menhaden which accounted for the remaining 43%.

Late summer-autumn spawners (August-November).

The number of species collected generally declines during and particularly toward the end of this period; eight species were represented in August, 15 in September, 14 in October, and 6 in November. Egg collections were dominated numerically by declining numbers of labrids, the *Enchelyopus*-*Urophycis*-*Peprilus* group, windowpane, and late in the period by Atlantic cod. Combined with the labridae-*Limanda* grouping, which they probably dominated, labrid eggs accounted for 36% of all eggs taken in August, 8% of those taken in September; they were subsequently absent. Mean monthly densities for these eggs were 5 per 100 m³ of water in August and 2 per 100 m³ of water in September. Rockling and hake eggs combined with the *Enchelyopus*-*Urophycis*-*Peprilus* grouping represented 33% of the August eggs, 24% of the September eggs, 82% of the October eggs, and 23% of the November eggs. Mean densities were 5, 7, 3, and 0.4 during those four respective months. Assuming, based on the larval collections, that windowpane accounted for most eggs within the *Paralichthys*-*Scophthalmus* grouping, they represented 12, 64, 6, and 0% of the August, September, October, November totals, respectively. Atlantic cod eggs appeared in November and, combined with the undifferentiated Gadidae-Glyptocephalus group, accounted for 70% of all eggs at that time with a monthly mean density of 1 per 100 m^3 of water.

Late summer-autumn larval collections were dominated by small numbers of tautog, hakes, windowpane, and fourbeard rockling. Mean monthly tautog densities of 0.4 in August, 0.3 in September, 0.3 in October, and 0 per 100 m^3 on November represented 74, 6, 8, and 0% of those respective collections. Hake had mean monthly densities per 100 m^3 of 0.1 in August, 0.4 in September, 0.2 in October, and 0 in November, which accounted for 12, 9, 5, and 0% of those respective totals. Windowpane and rockling added 13 and 0% to the August catch with mean densities of 0.1 and 0 per 100 m^3 of water, 16 and 42% to the September catch with mean densities of 0.8 and 2 per 100 m^3, 7 and 47% to the October catch with mean densities of 0.3 and 2 per 100 m^3, and 0 and 13% to the November catch with monthly mean densities of 0 and 0.4 per 100 m^3.

B. Multi-year Ichthyoplankton Comparisons

Ichthyoplankton densities meeting the "unusually abundant" criterion did not occur in 1987; therefore no contingency sampling was performed under that program.

Table 2 presents a master species list for ichthyoplankton collected from the discharge canal at PNPS and indicates the years each species was taken from 1975 through 1987. The general period of occurrence within the year is also indicated for each species including the peak period for the numerical dominants. A total of 36 species were represented in the 1987 collections which was below the 1975-1986 average of 38. No new species were added to the list in 1987.

Table [illegible]. Species of fish eggs (E) and larvae (L) collected in the PNPS discharge canal, 1975-1987. General periods of occurrence for eggs and larvae combined are shown along the right side; for the dominant species periods of peak abundance are also shown in parentheses.

Species	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Period of Occurrence
Anguilla rostrata	J*	J	J		J	J								Feb - Jun
Alosa spp.		L	L	J	L						L			May - Jul
Brevoortia tyrannus	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	Apr(Jun)-(Oct)Dec
Clupea harengus harengus	L	L	L	L	L	L	L	L	L	L	L	L	L	Jan - Dec*
Anchoa spp.	L		L	L	L		L	L	L	L	L	L	L	Jun - Sep
A. mitchilli			E	E	E		E	E/L			E	E		Jun - Sep
Osmerus mordax	L	L	L	L	L		E/L	L	L		L	L	L	Apr - Jun
Lophius americanus	E/L	E	E/L	E/L	E/L	L	E/L	E/L	E/L	E/L	E/L	E	E	May - Oct
Brosme brosme	E/L	E/L	E/L		E/L	E/L	E	E	E					Apr - Jul
Enchelyopus cimbrius	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Apr(Jun)-(Sep)Dec
Gadus morhua	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Jan(Nov)-(Dec)Dec
Melanogrammus aeglefinus	L	E/L	E/L	E/L	L				L		E			Apr - Jul
Merluccius bilinearis	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	May(May)-(Jun)Nov
Microgadus tomcod			L	L		L	L	L	L	L	L	L	L	Jan - May
Pollachius virens	E/L	E/L	E	E/L	E/L	E/L	L			L	E/L	L	E/L	Jan-Jun,Nov,Dec
Urophycis spp.	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	Apr - Nov
Ophidiidae-Zoarcidae	L													Sep
Strongylura marina			L											Jul
Fundulus spp.		E	E											Jul
F. heteroclitus					E									Jun
F. majalis					J									Oct
Menidia spp.		L	L	L	L	E/L	E/L	E	E/L	L	L	L	L	May - Sep
M. menidia	E/L	E/L	E						L					May - Sep
Syngnathus fuscus	L	L	L	L	L	L	L	L	L	L	L	L	L	Apr - Oct
Centropristis striata	L					L			L	L	L	L	L	Jul - Oct

*Absent August and September; peaks = March-May and November-December.

Table 2 (continued).

Species	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Period of Occurrence
<u>Cynoscion</u> <u>regalis</u>						L					L	L		May - Sep
<u>Stenotomus</u> <u>chrysops</u>	L		L											Jun - Jul
<u>Menticirrhus</u> <u>saxatilis</u>	L				L									Jul - Aug
Labridae	E	E	E	E	E	E	E	E	E	E	E	E	E	Mar(May)-(Aug)Sep
<u>Tautoga</u> <u>onitis</u>	L	L	L	L	L	L	L	L	L	L	L	L	L	May(Jun)-(Aug)Oct
<u>Tautogolabrus</u> <u>adspersus</u>	L	L	L	L	L	L	L	L	L	L	L	L	L	May(Jun)-(Aug)Oct
<u>Lumpenus</u> <u>lumpretaeformis</u>	L						L			L	L	L		Jan - Jun
<u>Ulvaria</u> <u>subbifurcata</u>	L	L	L	L	L	L	L	L	L	L	L	L	L	Feb(Apr)-(Jun)Oct
<u>Pholis</u> <u>gunnellus</u>	L	L	L	L	L	L	L	L	L	L	L	L	L	Jan(Feb)-(Apr)Jun
<u>Cryptacanthodes</u> <u>maculatus</u>				L	L		L	L	L	L	L	L		Feb - Apr
<u>Ammodytes</u> sp.	L	L	L	L	E/L	L	L	L	L	L	L	L	L	Jan(Mar)-(May)Jun
<u>Gobiosoma</u> <u>ginsburgi</u>	L		L					L						Jul - Aug
<u>Scomber</u> <u>scombrus</u>	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	F/L	Apr(May)-(Jul)Sep
<u>Peprilus</u> <u>triacanthus</u>	E/L	E/L	E/L	E	E	E/L	E/L	L	E/L	E/L	L		E	May - Oct
<u>Prionotus</u> spp.	E/L	E		E	E	E/L	E/L	E	E	[illegible]/L	E/L	E/L	E/L	May(Jun)-(Aug)Sep
<u>Myoxocephalus</u> spp.	L	L	L	L	L	L	L	L	E/	[illegible]	E/L	L	L	Dec(Mar)-(Apr)Jul
<u>M</u>. <u>aenaeus</u>					L	L	L	L	L	[illegible]	L	L	L	Dec(Mar)-(Apr)Jul
<u>M</u>. <u>octodecemspinosus</u>						L	L	L	L	L	L	L	L	Jan(Mar)-(Apr)May
<u>M</u>. <u>scorpius</u>						L	L	L		L	L	L	L	Feb - Apr
<u>Aspidophoroides</u> <u>monopterygius</u>						L	L	L						Mar - Apr
<u>Cyclopterus</u> <u>lumpus</u>		L	L				L	L	E		L		L	Apr - Jul
<u>Liparis</u> spp.	L	L	L	L	L	L	L	L	L	L	L	L	L	Jan(Apr)-(Jun)Jul
<u>L</u>. <u>atlanticus</u>							L	L	L	L	L	L	L	Mar(Apr)-(Jun)Jul
<u>L</u>. <u>coheni</u>							L	L	L	L	L	L	L	Jan(Feb)-(Mar)Apr
<u>Etropus</u> <u>microstomus</u>	L								L		E	E/L	E	Jul - Oct

Table 2 (continued).

Species	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Period of Occurrence
Paralichthys dentatus	E/L								E/L		L		E/L	Sep - Nov
P. oblongus		E/L	E/L		L	E/L	E/L	E/L	E	L	L	L	E/L	May - Oct
Scophthalmus aquosus	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Apr(May)-(Sep)Oct
Glyptocephalus cynoglossus	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	Mar(May)-(Jun)Nov
Hippoglossoides platessoides	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Jan(Mar)-(Jun)Nov
Limanda ferruginea	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	Feb(Apr)-(May)Nov
Liopsetta putnami							L	E/L						Mar - Jun
Pseudopleuronectes americanus	E/L	E/L	L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Jan(Apr)-(Jun)Aug
Trinectes maculatus			E	E			E	E				E		May - Sep
Sphoeroides maculatus			L								L			Jul - Aug
Number of species*	41	36	43	35	37	35	40	38	37	34	42	37	36	

*For comparative purposes three species of *Myoxocephalus* were assumed for 1975-1978 and two species of *Liparis* for 1975-1980.

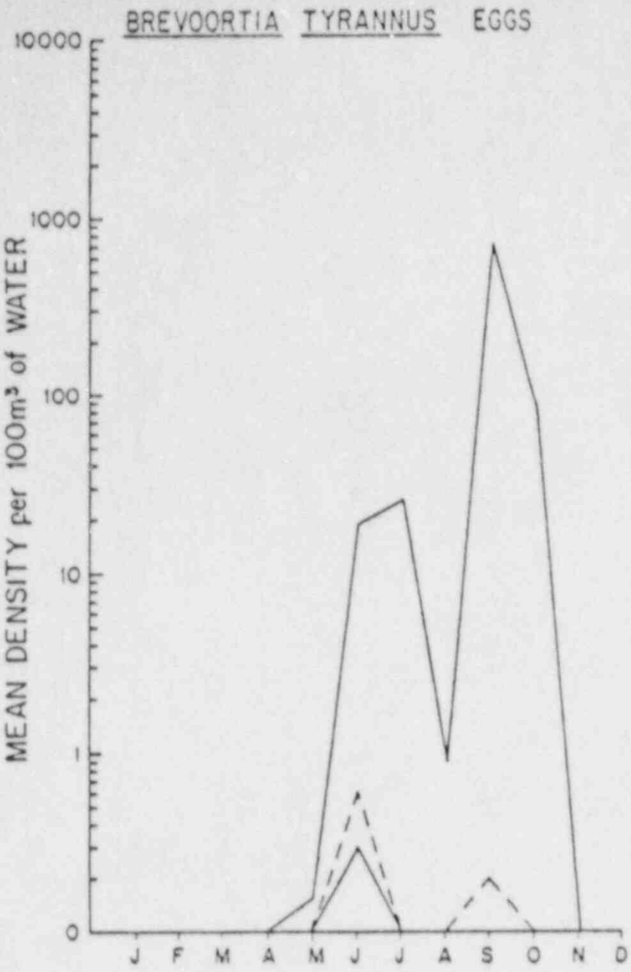
Monthly mean densities per 100 m³ of water were calculated for each of the numerically dominant fish eggs and larvae entrained at PNPS over the years 1975-1987 (Appendix B, available upon request). Based on these values, searobin eggs were abundant in June 1987 relative to past years as were Atlantic herring larvae in December. In both these cases the mean density for the month indicated was the highest observed over the 13-year period from 1975 through 1987. Eggs and larvae which appeared to be relatively uncommon in 1987 included among the eggs the Enchelyopus-Urophycis-Peprilus group and fourbeard rockling during July and August, the labrids during July and August, Atlantic mackerel during July, the Paralichthys-Scophthalmus grouping during July and August, and the hakes during August and September; among the uncommon larvae, sand lance during January through May, rock gunnel and sculpin in March, radiated shanny (Ulvaria subbifurcata) during May and June, Atlantic mackerel during June and July, winter flounder during June, fourbeard rockling during July and August. In each of these cases either the 1987 monthly mean densities were the lowest values recorded over the 1975-1987 period or only one other year ranked lower. The large number of low values during the May-August period, when only SSWS pumps were operational, suggests that entrainment densities were low due to changes in PNPS pump utilization, a subject discussed further in Volume II - Impact Perspective.

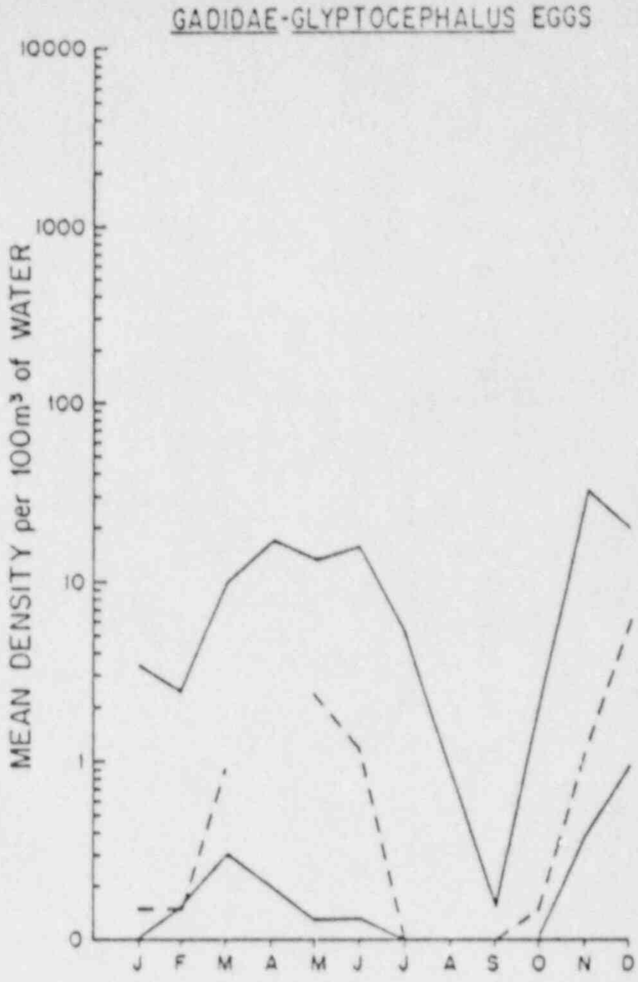
Monthly mean densities per 100 m³ of water for 1987 are shown in Figure 3 for the eight numerically dominant types of eggs, those accounting for 99% of the 1987 egg total, as well as total eggs (all species combined). Figure 4 shows comparable data for the ten numerically dominant larval species, those accounting for 84% of the catch, as well as total larvae (all species combined). For each category shown the highest and lowest monthly means obtained from 1975 through 1986 are joined by solid lines with 1987 monthly means joined by dashed lines. Mean densities for Atlantic menhaden, gadidae-Glyptocephalus, and Atlantic mackerel eggs, as well as radiated shanny and Atlantic mackerel larvae, remained within the range of densities established over past years. Densities for the remaining species ran below previous low values for at least one month with the exception of searobin eggs in June, total eggs in March, and Atlantic herring larvae in December and January, which exceeded previous respective high values. The relatively high total egg value for March resulted from the entrainment of many winter flounder eggs which appeared to be due to rough seas on two sampling dates; as mentioned earlier, heavy weather disturbs the bottom near shore and stirs demersal winter flounder eggs up into the water column where they are more likely to be entrained.

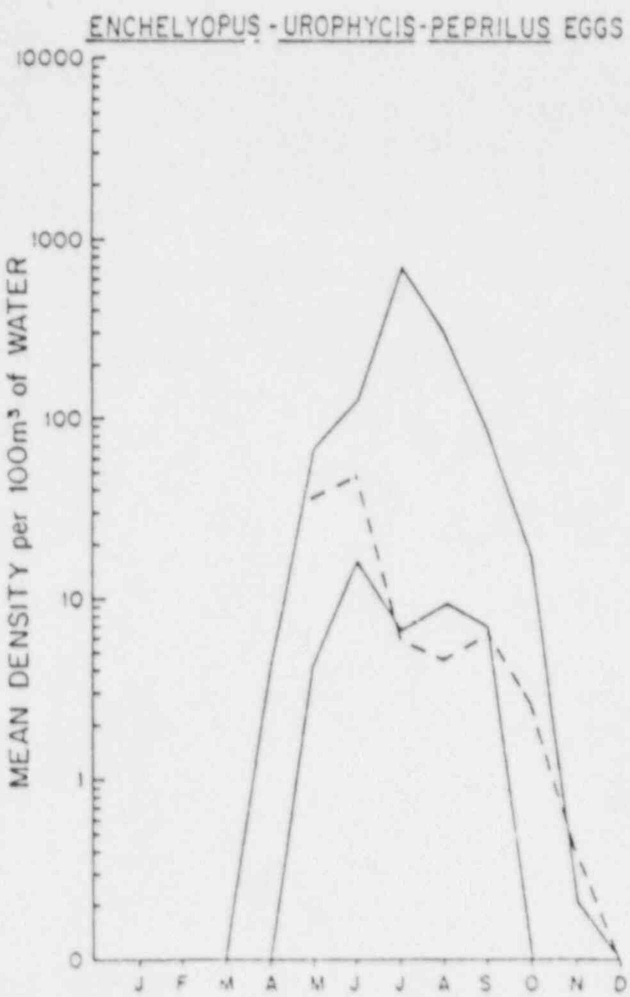
Ichthyoplankton populations sampled over a long time series typically display density variations of one order of magnitude, and two orders of magnitude are not unheard of (see Figures 3 and 4). Variations in spawning stock size and condition, food availability, predator densities, and physical variables such as water temperature and wind all contribute to the level of observed ichthyoplankton densities. In many cases the 1987 monthly densities which extended above or below all previous values at PNPS did so only slightly. In those cases such as searobin eggs (June) where a 1987 value was markedly high, conditions may have been particularly good for production of that species.

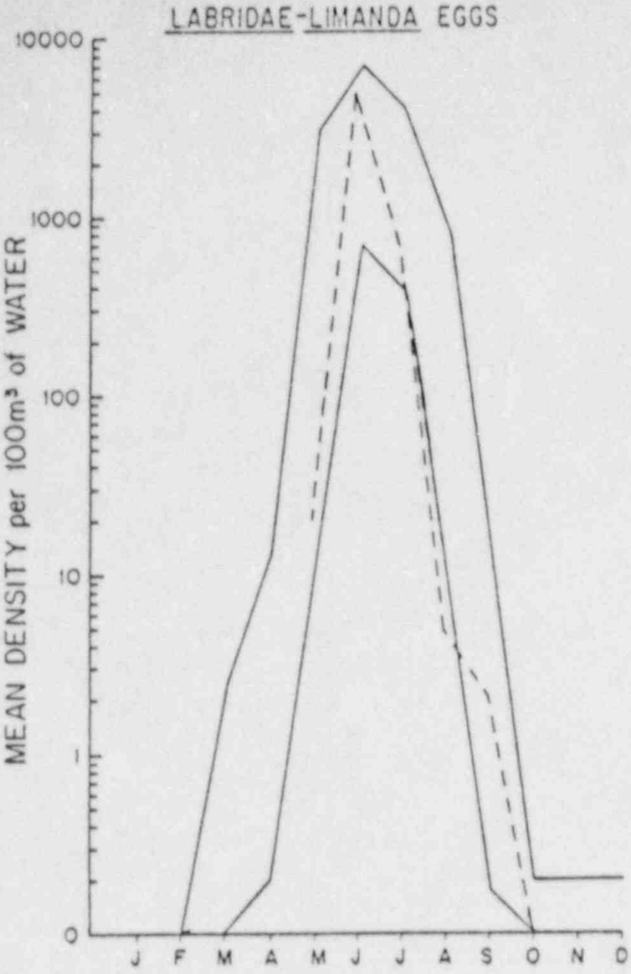
Figure 3. Mean monthly densities per 100 m^3 of water in the PNPS discharge canal for the eight numerically dominant egg species and total eggs, 1987 (dashed line). Solid lines show high and low values over the 1975-1986 period.

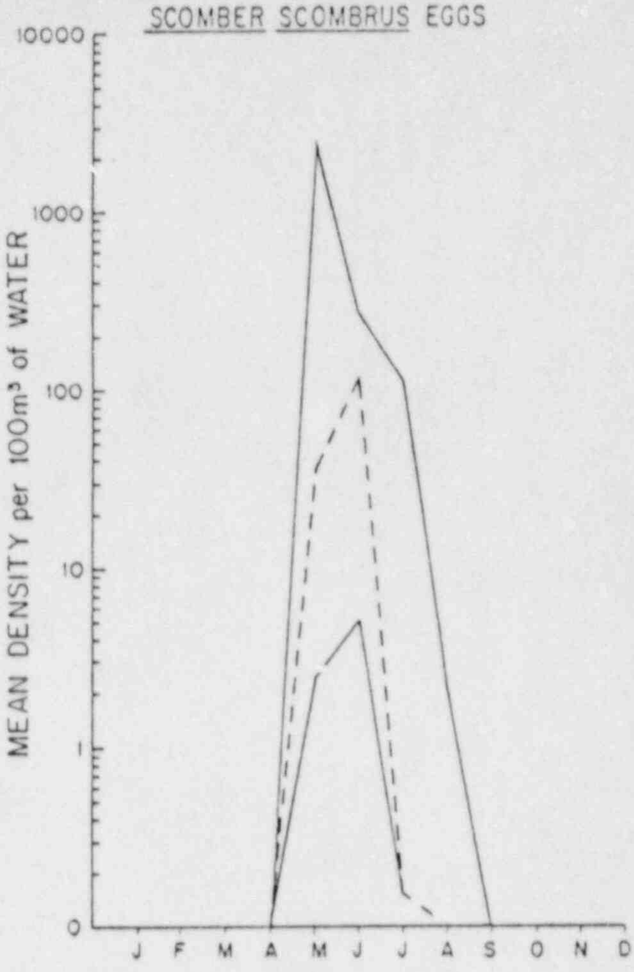
Brevoortia tyrannus	*Scomber scombrus*
Gadidae-*Glyptocephalus*	*Prionotus* spp.
Enchelyopus-*Urophycis*-*Peprilus*	*Paralichthys*-*Scophthalmus*
Labridae-*Limanda*	*Hippoglossoides platessoides*
	Total eggs

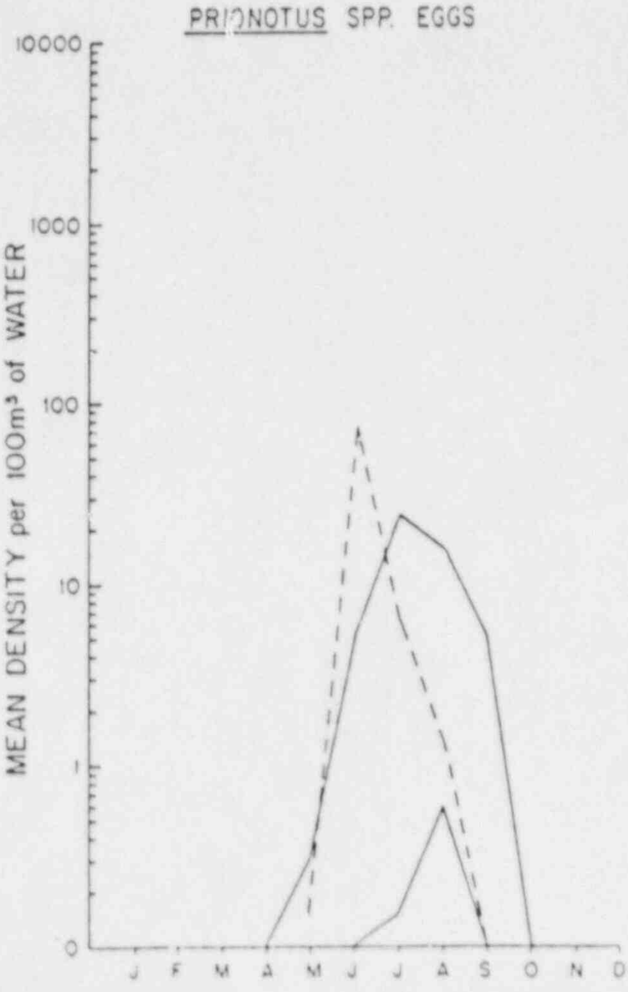

BREVOORTIA TYRANNUS EGGS
MEAN DENSITY per 100m³ of WATER
10000
1000
100
10
1
0
J F M A M J J A S O N D


GADIDAE-GLYPTOCEPHALUS EGGS
MEAN DENSITY per 100m³ of WATER
10000
1000
100
10
1
0
J F M A M J J A S O N D

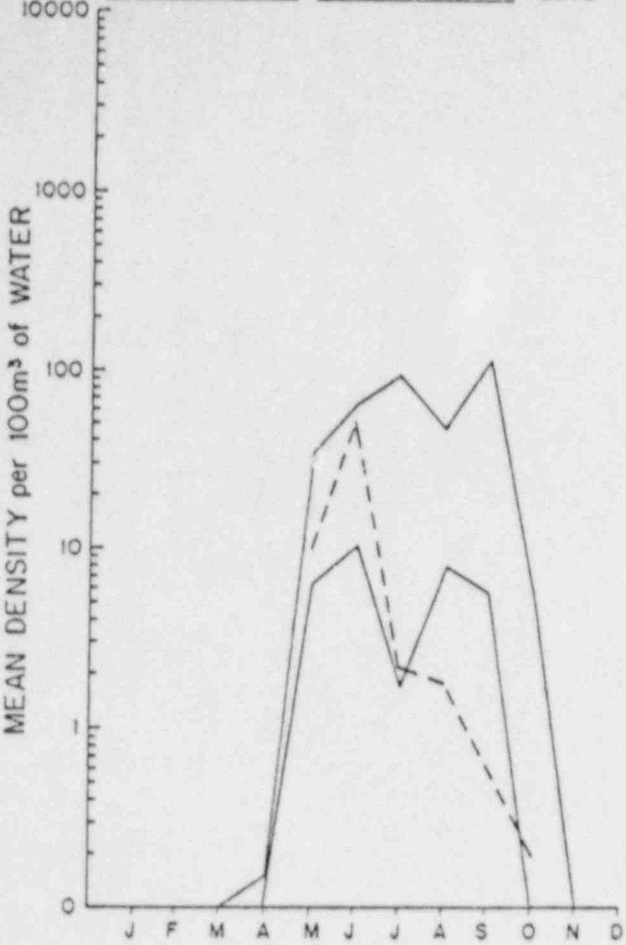

ENCHELYOPUS-UROPHYCIS-PEPRILUS EGGS
MEAN DENSITY per 100m³ of WATER
10000
1000
100
10
1
0
J F M A M J J A S O N D


LABRIDAE-LIMANDA EGGS
MEAN DENSITY per 100m³ of WATER
10000
1000
100
10
1
0
J F M A M J J A S O N D

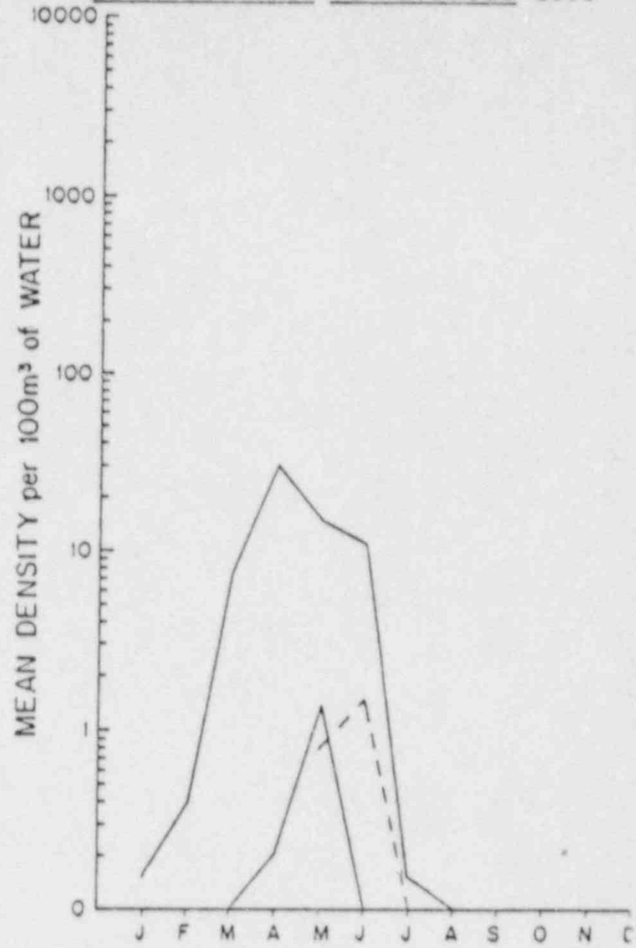

SCOMBER SCOMBRUS EGGS
MEAN DENSITY per 100m³ of WATER
10000
1000
100
10
1
0
J F M A M J J A S O N D


PRIONOTUS SPP. EGGS
MEAN DENSITY per 100m³ of WATER
10000
1000
100
10
1
0
J F M A M J J A S O N D

PARALICHTHYS-*SCOPHTHALMUS* EGGS



HIPPOGLOSSOIDES PLATESSOIDES EGGS



TOTAL EGGS

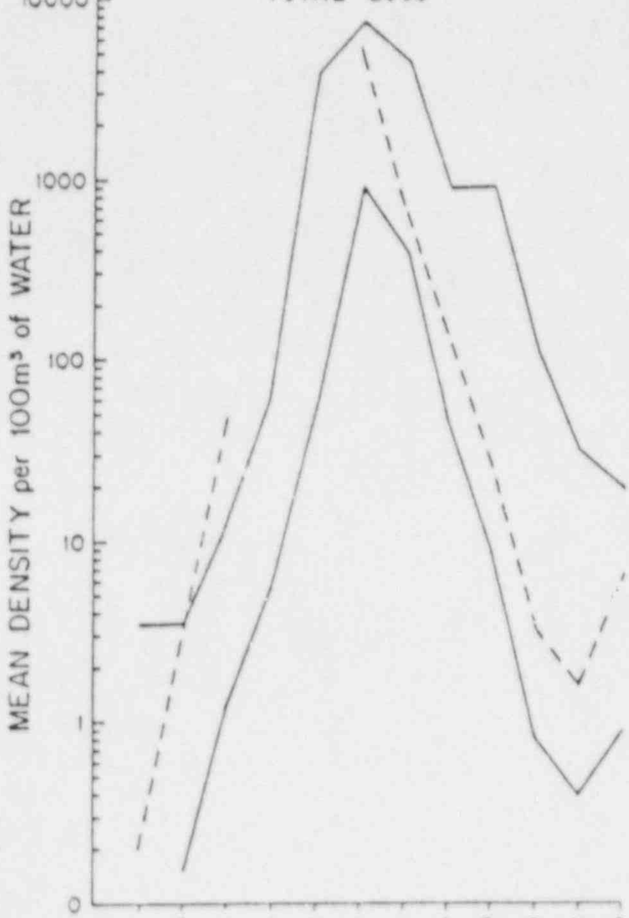
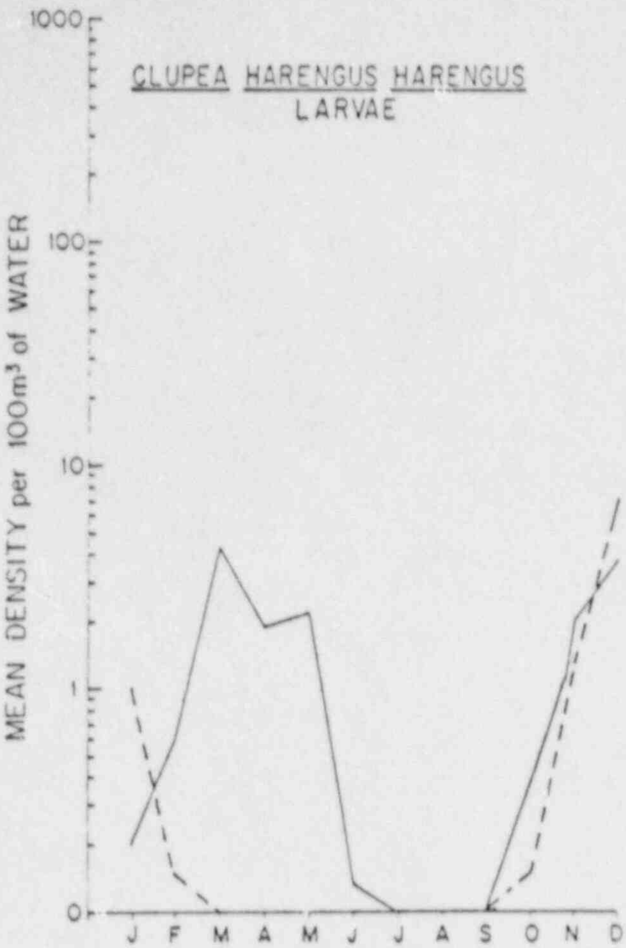
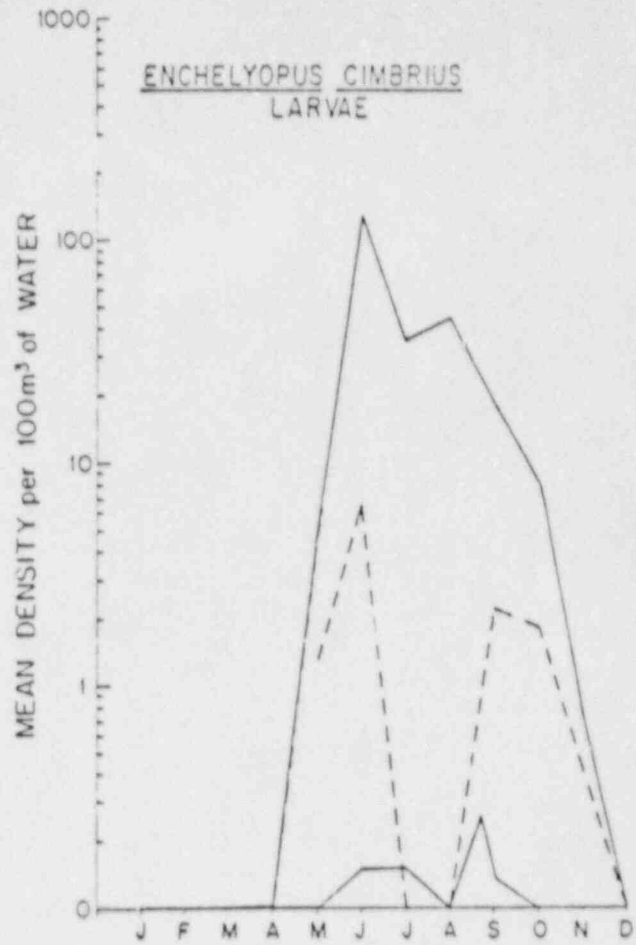


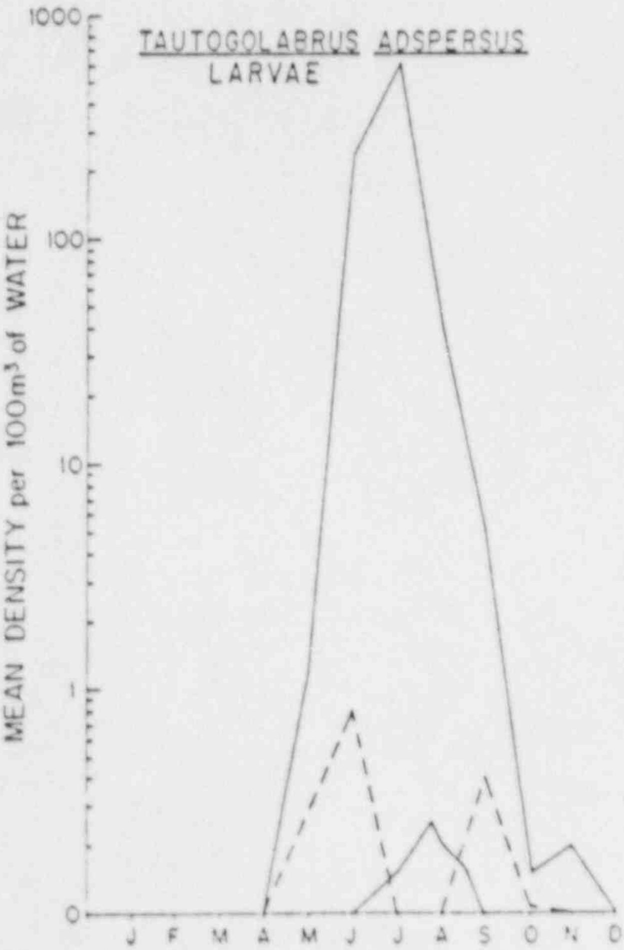
Figure 4. Mean monthly densities per 100 m³ of water in the PNPS discharge canal for the ten numerically dominant larval species and total larvae, 1987 (dashed line). Solid lines show high and low values over the 1975-1986 period.

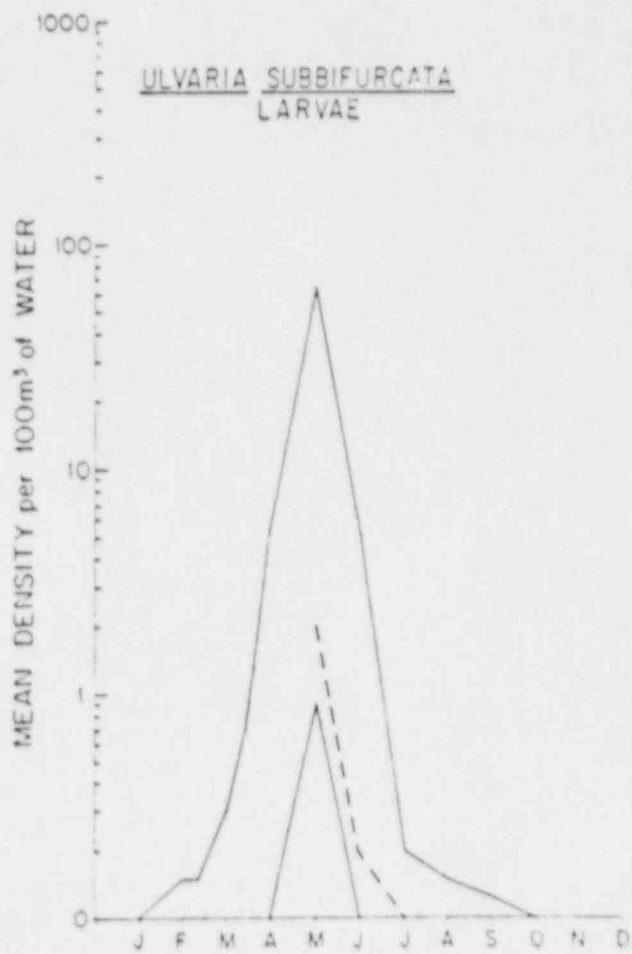
Clupea harengus harengus	Ammodytes sp.
Enchelyopus cimbrius	Scomber scombrus
Tautogolabrus adspersus	Myoxocephalus spp.
Ulvaria subbifurcata	Liparis spp.
Pholis gunnellus	Pseudopleuronectes americanus

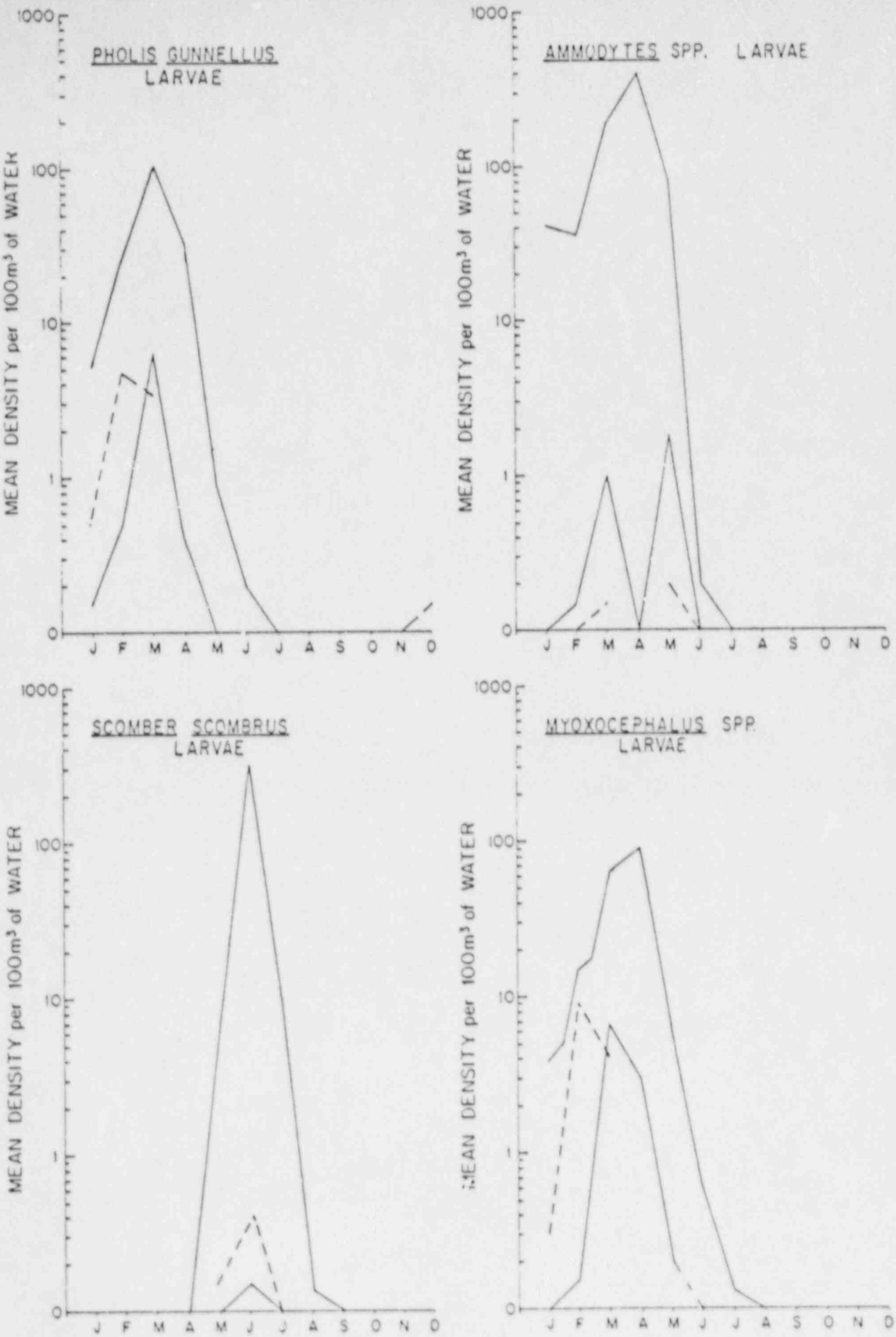
Total larvae


CLUPEA HARENGUS HARENGUS
LARVAE
MEAN DENSITY per 100m³ of WATER
1000
100
10
1
0
J F M A M J J A S O N D

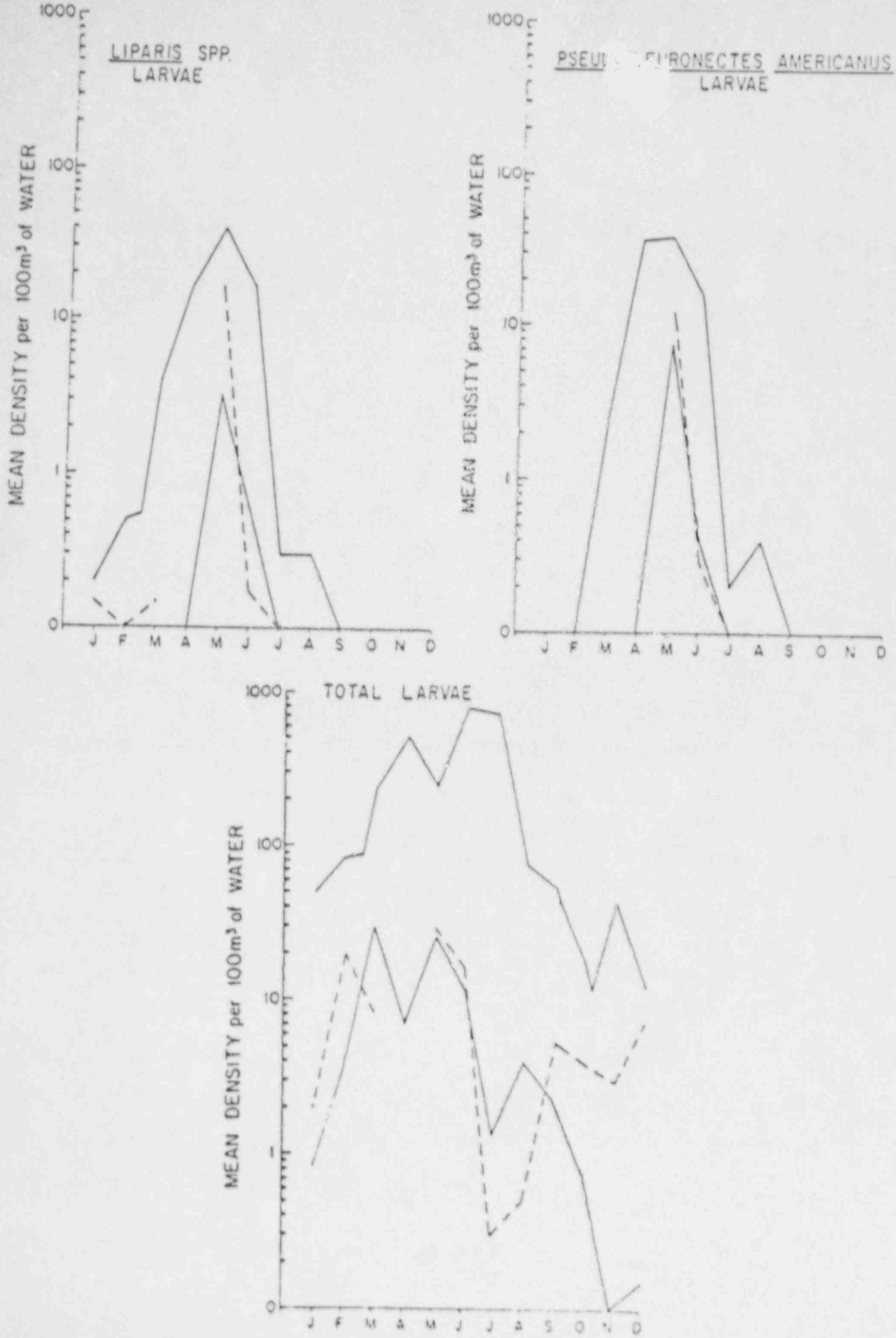

ENCHELYOPUS CIMBRIUS
LARVAE
MEAN DENSITY per 100m³ of WATER
1000
100
10
1
0
J F M A M J J A S O N D


TAUTOGOLABRUS ADSPERSUS
LARVAE
MEAN DENSITY per 100m³ of WATER
1000
100
10
1
0
J F M A M J J A S O N D


ULVARIA SUBBIFURCATA
LARVAE
MEAN DENSITY per 100m³ of WATER
1000
100
10
1
0
J F M A M J J A S O N D



PHOLIS GUNNELLUS LARVAE
AMMODYTES SPP. LARVAE
SCOMBER SCOMBRUS LARVAE
MYOXOCEPHALUS SPP. LARVAE
MEAN DENSITY per 100m³ of WATER
1000
100
10
1
0
J F M A M J J A S O N D


LIPARIS SPP.
LARVAE
PSEUI EURONECTES AMERICANUS
LARVAE
TOTAL LARVAE
MEAN DENSITY per 100m³ of WATER
1000
100
10
1
0
J F M A M J J A S O N D

C. Lobster Larvae Entrained

No larval lobsters were found in the 1987 entrainment samples. The last time one was taken was in June of 1982, making a total of nine over the 1974-1987 period. These collections are tabulated as follows:

1983-1987: none found.

1982: 1 larva - stage I on June 14.

1981: 1 larva - stage IV on June 29.

1980: none found.

1979: 1 larva - stage I on July 14.

1978: none found.

1977: 3 larvae - 1 stage I on June 10; 1 stage I on June 17.

1976: 2 larvae - 1 stage I on July 22; 1 stage IV-V on August 5.

1975: 1 larva - stage I, date unknown.

1974: none found.

The lobster larvae collected in 1976 were obtained during a more intensive lobster larvae program which employed a 1-meter net, collecting relatively large sample volumes, in addition to the standard 60-cm plankton net (Marine Research 1977b). Both larvae taken in 1976 were collected in the meter net; none were found in the routine ichthyoplankton samples.

The scarcity of larval lobsters in PNPS entrainment samples is most interesting considering that, in 1980, 918 tons of legal-sized lobsters were landed in Plymouth County by commercial lobstermen with a value of four million dollars (Lawton et al. 1983). Among lobstermen working inshore waters, this increased to 1381 tons valued at $6.8 million in 1985 (Hoopes 1986) and 1485 tons values at $7.5 million in 1986 (Hoopes 1987). Neuston sampling conducted in the northwest sector of Cape Cod Bay (Lawton et al. 1983; Matthiessen and Scherer 1983) also indicated that larvae were not particularly abundant there. To support such a strong fishery it would appear young lobsters must arrive in the Plymouth area from other regions. Sampling around Rocky Point from 1974 through 1977 showed considerably more late-stage larvae than young larvae (Lawton et al. 1983). That, coupled with the prevailing counterclockwise Cape Cod Bay currents, suggests that larvae may arrive from the north. Sampling at the mouth of the Cape Cod Canal suggests that large numbers of larvae enter Cape Cod Bay from Buzzards Bay and perhaps the Canal itself (Matthiessen and Scherer 1983; Matthiessen 1984). Regardless of source, larval lobsters appear to be especially uncommon in PNPS entrainment samples. This is supported by Lawton et al. (1983) who caught only eight larvae in twenty neuston tows near shore around Rocky Point in 1975. In addition to their apparent scarcity in near-shore waters, larval lobsters' neustonic habits may reduce the probability of their entrainment since they would contact the intake skimmer wall which might prevent some from passing to the condensers.

SECTION V

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APPENDIX A*

Densities of fish eggs and larvae, per 100 m^3 of water, recorded in the PNPS discharge canal by species, date, and replicate, January-December 1987.

*This Appendix is available upon request.

APPENDIX B*

Mean monthly densities and range per 100 m^3 of water for the dominant species of fish eggs and larvae entrained at PNPS, January-December, 1975-1987.

*This Appendix is available upon request.

Ichthyoplankton Entrainment Monitoring at Pilgrim Nuclear Power Station

January - December 1987

Volume 2 of 2

(Impact Perspective)

Submitted to
Boston Edison Company
Boston, Massachusetts

by
Marine Research, Inc.
Falmouth, Massachusetts

March 11, 1988
revised
April 6, 1988

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SECTION I
SUMMARY

Ichthyoplankton collections were made in the Pilgrim Nuclear Power Station (PNPS) discharge canal in triplicate twice per month in January and February, weekly from March through September, and twice per month from October through December; no sampling occurred in April due to circulating water pump shutdown. Specific results appear in "Ichthyoplankton Entrainment Monitoring at Pilgrim Nuclear Power Station, January-December 1987:, Volume 1, Results. Volume 2 offers a general discussion of more impact-related issues.

Ichthyoplankton densities meeting the "unusually abundant" criterion defined under the contingency sampling program did not occur in 1987. Total numbers of eggs potentially entrained at 1987 were estimated at 3,440,242,677 and total numbers of larvae at 47,870,538. Data collected in 1987 when only one SSWS pump was operating support results obtained in 1984, suggesting that fish larvae are less susceptible to entrainment by the small SSWS pumps when compared to the main circulating water system pumps.

SECTION II

INTRODUCTION

This report addresses results of PNPS ichthyoplankton entrainment sampling with an accent on potential impact assessment. Discussions are based on results presented in "Ichthyoplankton Entrainment Monitoring at Pilgrim Nuclear Power Station January-December 1987", Volume 1 - Results. Work was conducted by Marine Research, Inc. (MRI) for Boston Edison Company (BECo) under Purchase Order No. 63653 in compliance with environmental monitoring and reporting requirements of NPDES Permit No. 0003557 (U.S. EPA and Massachusetts DWPC). In a continuing effort to condense the volume of material presented in this and related reports, details of interest to some readers may have been omitted. Any questions or requests for additional information may be directed to Marine Research, Inc., Falmouth, Massachusetts.

Plate 1 shows the ichthyoplankton sampling net being deployed in the PNPS discharge canal.

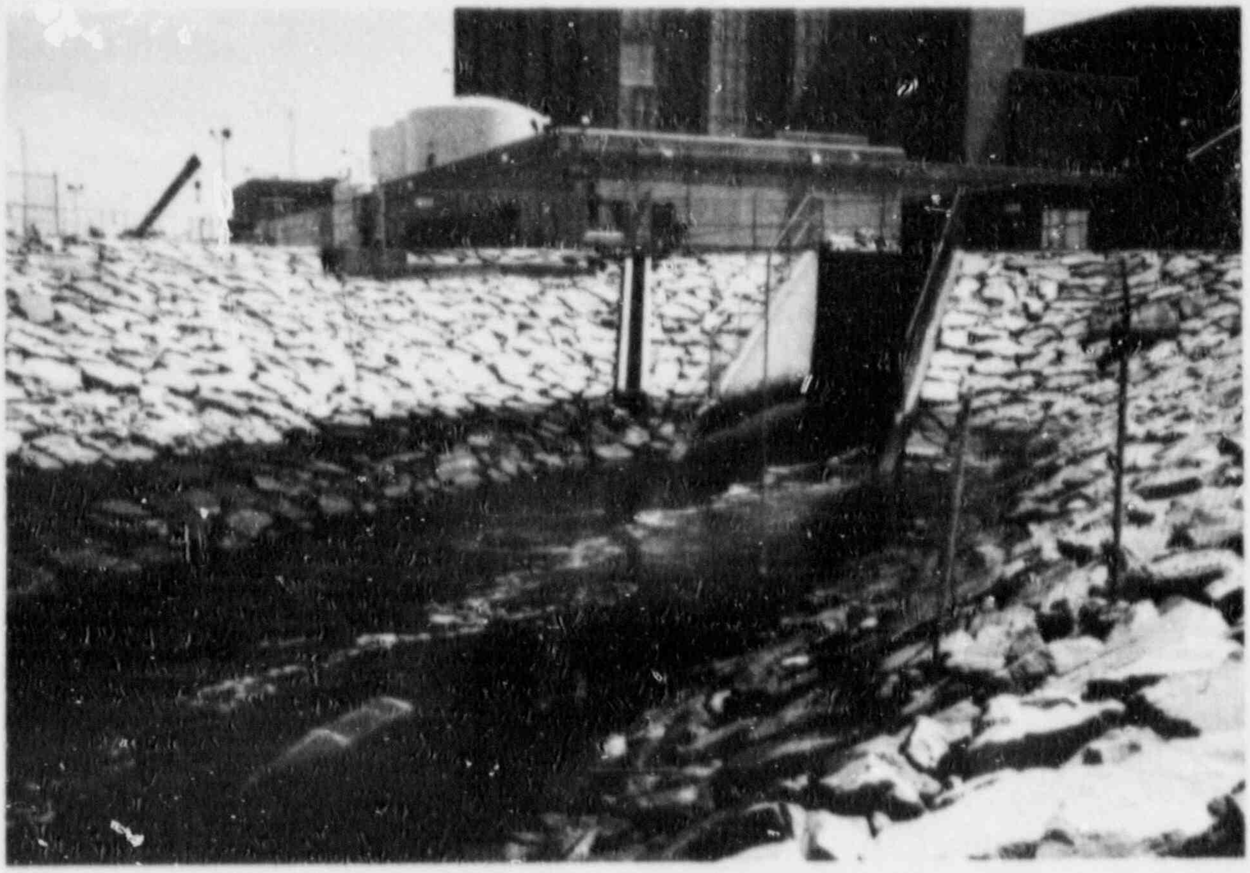

Plate 1. Plankton net streaming in the discharge canal at Pilgrim Station for the collection of fish eggs and larvae (lobster larvae are also recorded). A single, six-minute collection can contain several thousand eggs and larvae representing 20 or more species.

SECTION III

IMPACT PERSPECTIVE

A. Contingency Sampling Plan

Ichthyoplankton densities meeting the "unusually abundant" criterion, defined as exceeding by 50% the highest mean density over three replicates recorded during the same month from 1975 through 1986, did not occur in 1987 or in 1986. This compares with four occurrences in 1985, six in 1984, one in 1983, eight in 1982, seven in 1981, and twelve in 1980 (Table 1). No specific events occurred prior to 1980 primarily because "unusually large" was not precisely defined early in the contingency plan.

In past years it was standard practice for BECo, in consultation with regulatory personnel, to authorize the collection of an additional set of triplicate entrainment samples following the recording of an "unusually large" density at PNPS. In most cases the additional sets were taken within two days of the original. In all but three cases when this occurred mean densities dropped back to levels within the range established over previous years, indicating that the "unusual" density probably reflected the entrainment of a high density ichthyoplankton patch rather than a more widespread phenomenon. In the three cases where high densities persisted (larval rock gunnel, April 1982; larval rock gunnel, February 1985; larval Atlantic menhaden, June 1981) additional entrainment sampling at about two-day intervals indicated that high densities continued for up to two weeks. Since no changes in PNPS operation occurred, it appeared in those situations that productivity was generally high relative to previous years.

Table 1. Ichthyoplankton densities, per 100 m³ of water, which reached the "unusually large"* level in PNPS entrainment samples, 1980-1987.

Species	Month	"Unusually large" density (year)	Previous high density (year)
EGGS			
Brevoortia tyrannus	June	74.2 (1980)	6.2 (1978)
	September	1961.9 (1982)	1.4 (1979)
		1065.8 (1982)	" "
	October	37.8 (1980)	0.2 (1978)
Enchelyopus-Urophicis-Peprilus	September	71.3 (1980)	30.1 (1979)
Urophycis spp.	September	152.8 (1980)	22.3 (1978)
Labrid-Limanda & labrid	July	12917.0 (1981)	8116.8 (1975)
Scomber scombrus	May	15261.3 (1985)	572.0 (1980)
		1457.6 (1985)	" "
LARVAE			
Brevoortia tyrannus	June	7.1 (1981)	4.2 (1980)
		495.9 (1981)	" "
		34.7 (1981)	" "
	October	11.7 (1980)	1.8 (1976)
	November	24.3 (1980)	3.2 (1978)
Enchelyopus cimbrius	August	204.6 (1983)	36.0 (1980)
Urophycis spp.	September	105.6 (1984)	22.3 (1981)
Tautogolabrus adspersus	June	624.5 (1981)	378.8 (1977)
	July	296.5 (1980)	138.5 (1974)
		2162.5 (1981)	296.5 (1980)
	September	20.3 (1980)	1.5 (1975)
Tautoga onitis	August	21.6 (1984)	4.1 (1974)
	September	9.2 (1980)	4.8 (1975)
Pholis gunnellus	February	19.6 (1984)	7.4 (1975)
		13.8 (1984)	" "
		47.5 (1985)	19.6 (1984)
	March	70.2 (1980)	36.9 (1975)
		210.5 (1984)	70.2 (1980)
		415.2 (1984)	" "
	April	74.0 (1982)	12.1 (1977)
		74.7 (1982)	" "
		34.0 (1982)	" "
		22.4 (1982)	" "
		23.5 (1982)	" "

Table 1 (continued).

Species	Month	"Unusually large" density (year)	Previous high density (year)
LARVAE (continued)			
Ammodytes sp.	January	31.1 (1980)	13.5 (1975)
		104.4 (1985)	31.1 (1980)
Scomber scombrus	June	2700.0 (1981)	128.0 (1975)
Myoxocephalus spp.	March	153.6 (1980)	97.0 (1975)
	April	303.6 (1982)	53.1 (1981)

*"Unusually large" was defined as 50% greater than the previous high density observed during the same month 1975-1987.

B. Ichthyoplankton Entrainment - General

Entrainment of ichthyoplankton at PNPS represents a direct negative environmental impact since fish eggs and larvae pass through the plant in large numbers each day and are subjected to elevated temperatures, mechanical forces, and chlorination. When PNPS is not on line, ichthyoplankton may still be subjected to mechanical forces and chlorination. Although survival has been demonstrated for some species of fish eggs at PNPS such as the labrids (45%; Marine Research 1978, 1982) and among larvae at other power plants (Ecological Analysts 1981), mortality is assumed to be 100% as a conservative approach to PNPS impact assessment.

To place fish egg and larval densities recorded in the PNPS discharge canal, expressed as numbers per 100 m³ of water, in some perspective, they were multiplied by plant flow rates over each respective period of occurrence. This was completed for each of the numerically dominant species as well as total eggs and larvae. Mean monthly densities were multiplied by 17,461.44, the full load flow capacity of PNPS in 100 m³ units per 24-hour day, then by the number of days in each respective month. Values for each month in which a species or species group occurred were then summed to arrive at a seasonal entrainment value in each case (Figures 1 and 2). Among the eight numerically dominant groups, numbers of eggs entrained ranged from 338,403 for Atlantic menhaden (Brevoortia tyrannus) to 3,168,423,687 for the labrid-Limanda group. For all eggs combined a value of 3,440,242,677 was obtained. Among the ten dominant species of larvae values ranged from 162,391 for sand lance (Ammodytes sp.) to 9,554,900 for seasnail (Liparis spp.) and amounted to 47,870,538 for all larvae combined. These numbers indicate

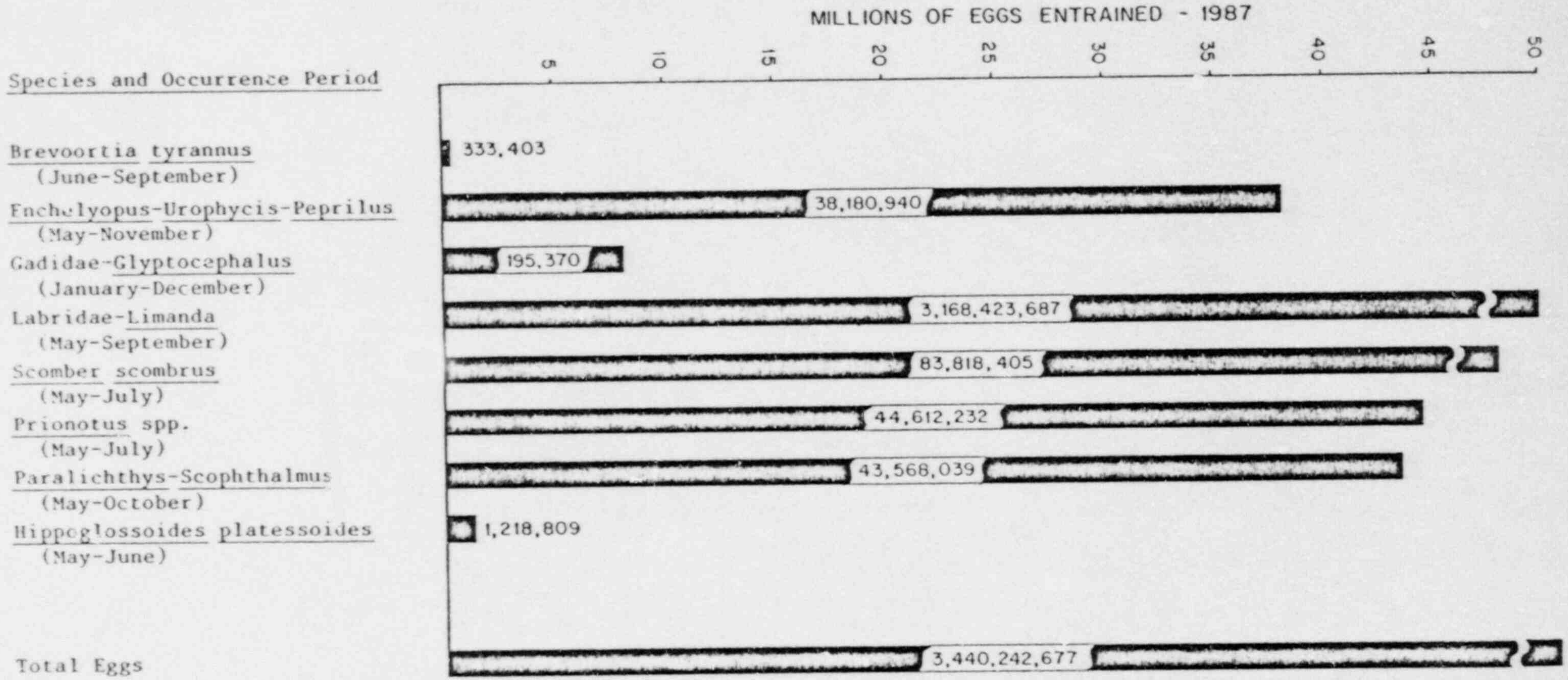

Figure 1. Number of eggs estimated to have been entrained by PNPS in 1987 had it operated at 100% capacity by species or species group (dominants only) including all egg species combined. The period of occurrence observed in 1987 is also indicated.

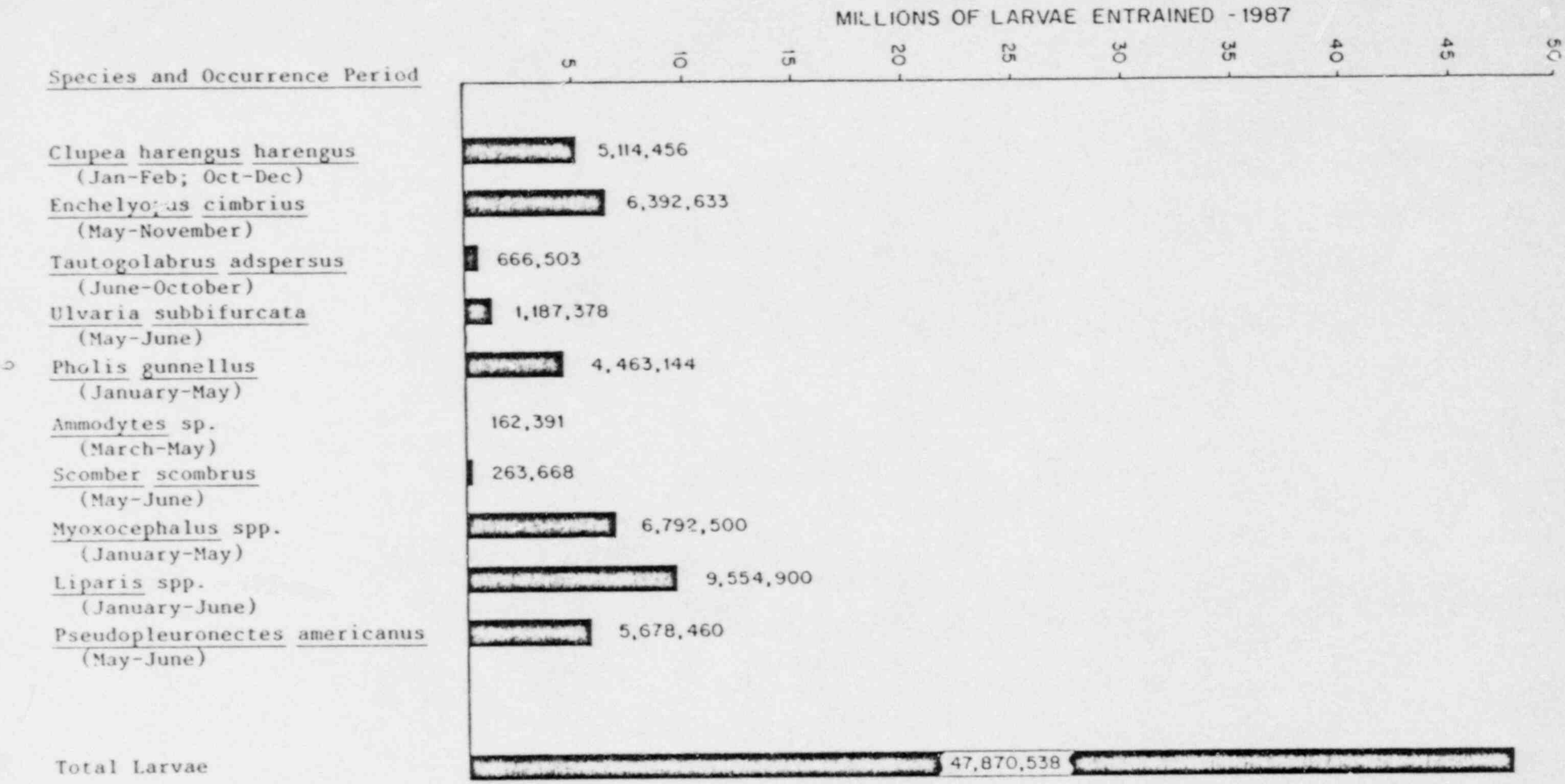

Figure 2. Numbers of larvae estimated to have been entrained by PNPS in 1987 had it operated at 100% capacity for each dominant species including all larvae combined. The period of occurrence observed in 1987 is also indicated.

the tremendous quantities of eggs and larvae which can be entrained by the circulating seawater system at PNPS during a year and are presumed to be lost from the population.

C. Ichthyoplankton Entrainment - Specific

The effects of entrainment on populations of Atlantic menhaden, winter flounder (*Pseudopleuronectes americanus*), pollock (*Pollachius virens*), cunner (*Tautogolabrus adspersus*), rainbow smelt (*Osmerus mordax*), Atlantic silversides (*Menidia menidia*), and alewives (*Alosa pseudoharengus*) were assessed by Stone and Webster (1975) using flow rates for two units at Pilgrim Station. Using conservative assumptions and ignoring density-dependent compensation among non-entrained ichthyoplankton, no appreciable adverse impact on indigenous populations was predicted to occur. Modeling studies conducted on five species of larval fish which appear to be more abundant in western Cape Cod Bay than in the remainder of the Bay (tautog, *Tautoga onitis*; seasnail; radiated shanny, *Ulvaria subbifurcata*; sculpin, *Myoxocephalus* spp.; rock gunnel, *Pholis gunnellus*) suggested that the percentage of original larval production contributing to entrainment by PNPS Unit 1 was less than 1.0 (Marine Research 1978). For twelve additional categories of eggs and larvae considered to be more widely distributed in Cape Cod Bay, percentages contributing to entrainment were smaller, the highest being 0.12% (labrid-*Limanda* eggs).

If entrainment of ichthyoplankton at PNPS represented a significant cause of mortality in western Cape Cod Bay, the losses might be reflected in finfish collections in the PNPS area. A review of indices of relative abundance based on otter trawl and gill net sampling by Massachusetts Division of Marine Fisheries personnel (Lawton et al. 1986) does not indicate any long-term steady declines among Atlantic herring (Clupea harengus harengus), pollock, silver hake (Merluccius bilinearis), cunner, tautog, Atlantic menhaden, or windowpane (Scophthalmus aquosus). On the other hand winter flounder and yellowtail flounder (Limanda ferruginea) have shown declines in the PNPS area during recent years. In both these cases however, commercial landings and stock assessment research indicate that these declines appear to be widespread, extending all along the Massachusetts coastline (Foster 1987, Howe et al. 1988). Therefore, these specific declines appear to be the result of natural population variation probably coupled with overfishing.

D. Potential Pump Effects

PNPS has been involved in a long-term outage which began in April 1986 and continued into 1988. During most of this period only one of two main circulating water system (CWS) pumps was operating (flow = 155,000 gpm, or 9.78 m^3 per second, compared with 310,000 gpm, or 19.56 m^3 per second, when the plant operates with two pumps). As discussed in Volume 1, Methods and Materials, beginning in late March 1987 intermittent use of a single circulating seawater pump made it basically unavailable for entrainment sampling, leaving only one or occasionally two Salt Service Water System (SSWS) pumps in service, each with a capacity of about 2500 gpm, or 0.16 m^3 per second. From May through August 1987 sampling continued with only the SSWS pump(s) providing flow for entrainment sampling, as occurred in 1984.

To compare the response of ichthyoplankton to different pump regimes, densities per 100 m^3 of water were compared for single SSWS pump periods (1987), two SSWS pump periods (1984), single CWS pump periods (1986), and two CWS pump periods (1983, 1985). Comparisons involving 1987 data were restricted primarily to the May through August period when sampling was possible and the stated pump schedules were consistently maintained.

When collections were made using only the relatively small SSWS pumps, an original assumption was made that plankton would continue to be sampled in proportion to their abundance in the Rocky Point area since larval fishes, especially the small ones, show little directional swimming ability and certainly eggs drift passively. Results reported in the 1986 annual entrainment report (Marine Research 1987) indicated that April-August 1984 larval collections were so low that local populations did not appear to be impacted in similar proportion by the SSWS pumps as by the CWS pumps. Figures 3 and 4 taken from Marine Research (1987) show monthly mean densities, per 100 m^3 of water, April-August, for total eggs and total larvae, 1983-1986. Monthly mean densities for larvae in April, June, and July of 1984 (the first year sampling occurred with only two SSWS pumps operating) were all the lowest on record, 1975-1986, as were May and July mean egg densities. Data for 1987 were added to Figures 3 and 4 for the same period when only one (or, on 2 of 14 sampling occasions, two) SSWS pumps were operating; data obtained on May 30, June 25, and August 19, 1987, were omitted because these samples were taken during brief periods of single CWS pump operation. Clearly May-August larval densities for 1987 were exceptionally low each month (Figure 4), even when compared with 1984. Egg densities in 1987 ranked lowest over the five-year period only for August. These data were examined further using a nonparametric, single classification, Kruskal-Wallis test with mean densities, per 100 m^3 of water, for each sampling date from May through August, 1983-1987. No significant difference was apparent among years for eggs ($p = 0.05$) but

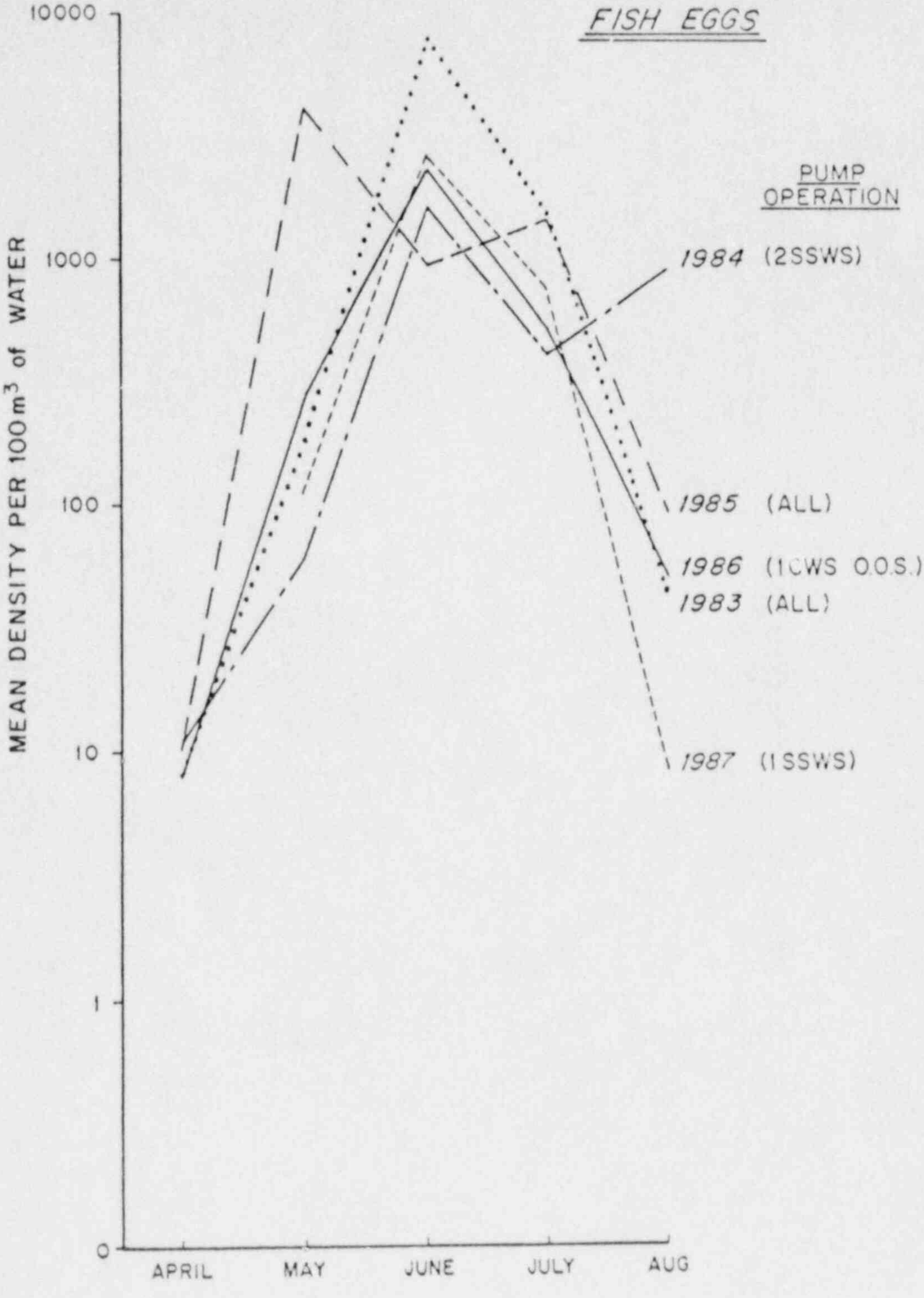

Figure 3. Mean monthly densities, per 100 m³ of water, for total eggs entrained at PNPS, April-August 1983-1987. Pump regime operating during the period is indicated for each year.

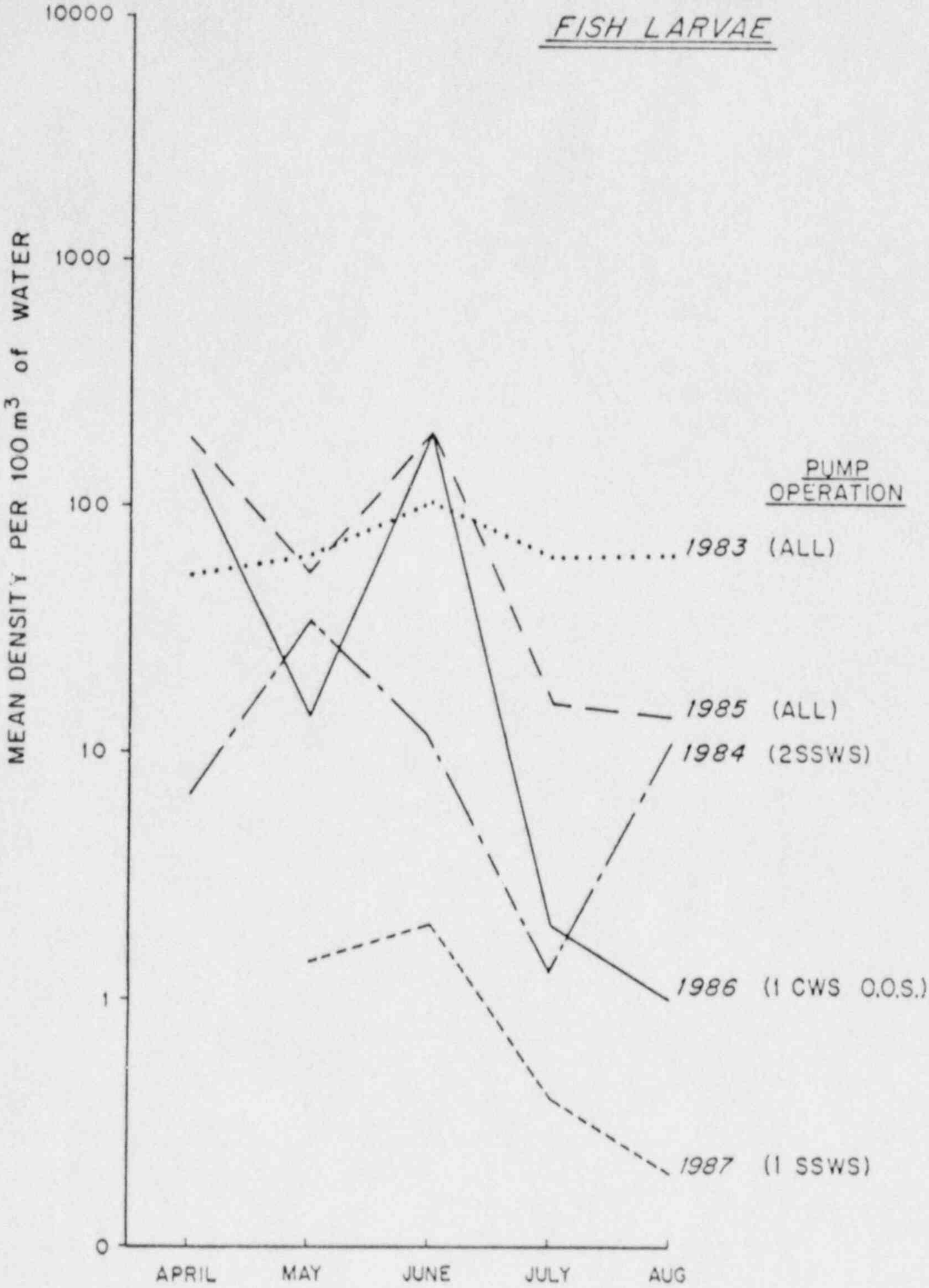

Figure 4. Mean monthly densities, per 100 m³ of water, for total larvae entrained at PNPS, April-August 1983-1987. Pump regime operating during the period is indicated for each year.

a very highly significant difference ($p < 0.001$) was found for larvae. Nonparametric multiple comparisons among years for larvae showed no difference between 1985 and 1983 values, no difference between 1984 and 1986 although these years were different from 1985 and 1983; 1987 appeared significantly different from all other years. The summed ranks as well as results of the multiple comparisons (indicated by vertical bars) were as follows:

Eggs	Larvae
1983 - 536	1983 - 689
1985 - 519	1985 - 685
1986 - 505	1986 - 506
1984 - 444	1984 - 422
1987 - 426	1987 - 182
H = 7.718 n.s.	H = 30.408***

The apparent reduced susceptibility of larvae to the SSWS pumps was further indicated by sampling on May 30, 1987 when collections were made while one CWS pump was placed into service for a short period. On May 28 no larvae were obtained while sampling under the influence of one SSWS pump. Two days later on May 30 a mean density of 132 larvae per 100 m^3 was obtained consisting of eight species. On June 4, again with only one SSWS pump operating, two larval species were taken with a combined mean density of 2 per 100 m^3 of water.

A comparison of the number of species recorded from May through August over the 1983-1987 period indicated that 1987 was clearly the lowest with 13 overall (23 with inclusion of the 3 dates when one CWS pump was in use); 1984 and 1986 followed with 29 each, 1983 had 32, and 1985 had 34. The low species count in 1987 was due primarily to a scarcity of larvae. Only four species of larvae were recorded over the May-August period of 1987 compared with 24 in 1984, 26 in 1986, 29 in 1983, and 31 in 1985. Numbers of egg species were somewhat more consistent with 9 being taken in 1987 compared with 15 in 1984, 17 in 1985 and 1986, and 18 in 1983. Including May 30, June 25, and August 19 when a single CWS pump was in service brought the 1987 totals up to 15 species of eggs and 16 species of larvae.

The low densities of larvae in 1984 and the strikingly low densities in 1987 over the spring and summer period strongly suggest that ichthyoplankton populations near PNPS were not impacted in similar proportion by the SSWS pumps as by the main circulating seawater pumps. A sharp decline in larval densities occurred between 1984 and 1987 values, suggesting that dropping from two to one SSWS pump prevented many larvae from being entrained. The intermediate values for 1986, when one CWS pump was in service, ranking between 1984 and 1983,1985 suggests a direct relationship between pump flow and larval entrainment; although 1986 was not shown to be significantly different from 1984, it was very nearly so, $q = 2.73$ vs 2.77 for $p = 0.05$. Apparently the relatively low flow of the SSWS pumps has very limited influence on drawing larvae into the intake embayment area and subsequently through the PNPS condensers. These results could reflect mainly physical flow effects acting upon free-floating larvae or perhaps an active larval swimming ability, permitting an increasing number of them to avoid entrainment as pump capacity declines. For example, at some point water entrained by the PNPS intake separates from the prevailing Cape Cod Bay current and enters the intake area. The area over which the flow separation occurs is presumably more widespread and the action more forceful (the velocity higher) when two seawater pumps operate than when only one seawater pump operates or one or two SSWS pumps operate. Passive larvae and eggs should be entrained in proportion to their abundance, but more active larvae may swim, to the extent of their ability, to remain within the Cape Cod Bay water mass. Also the more widespread the influence of a particular pumping rate, the higher the probability that high-density ichthyoplankton patches will be entrained. The role which vertical distribution plays may be of great importance as well, as the smaller pumps probably draw water over a more restricted vertical profile, one which may not coincide with the presence of many eggs and larvae.

Although no significant difference was detected among eggs, it is interesting that years did rank in the same order as the larvae with the two CWS pump years (1983, 1985) showing the highest values followed in decreasing order by the single CWS pump year (1986), the two SSWS pump year (1984), and the single SSWS pump year (1987).

It is important to keep in mind that all comparisons based on different pump capacities were made without knowledge of ichthyoplankton population levels around Rocky Point. The observed rankings could have been due entirely or in part to differences in production among the five years, although that would appear to be an extraordinary coincidence given the well-defined relationship between ichthyoplankton densities and PNPS flow.

SECTION IV

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IMPINGEMENT OF ORGANISMS AT

PILGRIM NUCLEAR POWER STATION

(January - December 1987)

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April 1988

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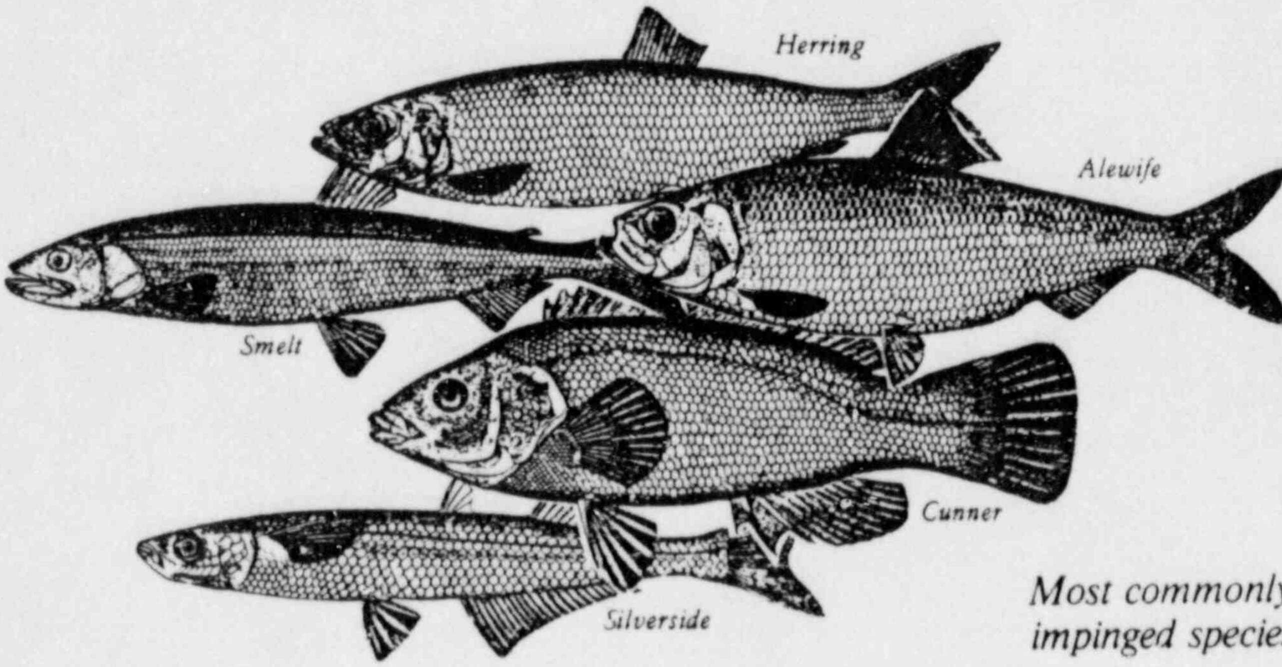

Most commonly impinged species

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SECTION I

SUMMARY

Fish impingement rate averaged 0.28 fish/hour during the period January-December 1987, which is the second lowest rate in the last several years because of low or no circulating water pump operation during the year. Rainbow smelt (Osmerus mordax) accounted for 27.7% of the fishes collected. Atlantic silverside (Menidia menidia), cunner (Tautogolabrus adspersus), lumpfish (Cyclopterus lumpus) and winter flounder (Pseudopleuronectes americanus) accounted for 18.2, 9.5, 6.8 and 6.8%, respectively, of the fishes impinged. The peak impingement month was December when rainbow smelt and Atlantic silverside were most represented. Initial impingement survival for all fishes from static screen wash collections was approximately 29%, and from continuous screen washes 43%. Delayed mortality data was not available do to failure of the screenwash survival pools or sampling in the screenhouse during portions of 1987.

At full-load yearly (January-December) operation of Pilgrim Nuclear Power Station (PNPS) the estimated impingement was 2,460 fishes (187 lbs.). The PNPS capacity factor was 0.0% during 1987.

The collection rate (no./hr.) for all invertebrates captured from January-December 1987 was 1.61. Blue mussel (Mytilus edulis), sand shrimp (Crangon septemspinosa) and polychaete worms were most numerous, accounting for approximately 71.8, 7.9 and 4.5%, respectively, of the invertebrates impinged. Mixed species of algae collected on intake screens amounted to 563 pounds.

SECTION 2

INTRODUCTION

Pilgrim Nuclear Power Station (lat. 41°56' N, long. 70°34' W) is located on the northwestern shore of Cape Cod Bay (Figure 1) with a licensed capacity of 655 MWe. The unit has two circulating water pumps with a capacity of approximately 345 cfs each and five service water pumps with a combined capacity of 23 cfs. Water is drawn under a skimmer wall, through vertical bar racks spaced approximately 3 inches on center, and finally through vertical travelling water screens of 3/8 inch wire mesh (Figure 2). There are two travelling water screens for each circulating water pump.

This document is a report pursuant to operational environmental monitoring and reporting requirements of NPDES Permit No. 0003557 (USEPA) and No. 359 (Mass. DWPC) for Pilgrim Nuclear Power Station, Unit I. The report describes impingement of organisms and survival of fishes carried onto the vertical travelling water screens at Unit I. It presents analysis of the relationships among impingement, environmental factors, and plant operational variables.

The report is based on data collected from screen wash samples during January-December 1987.

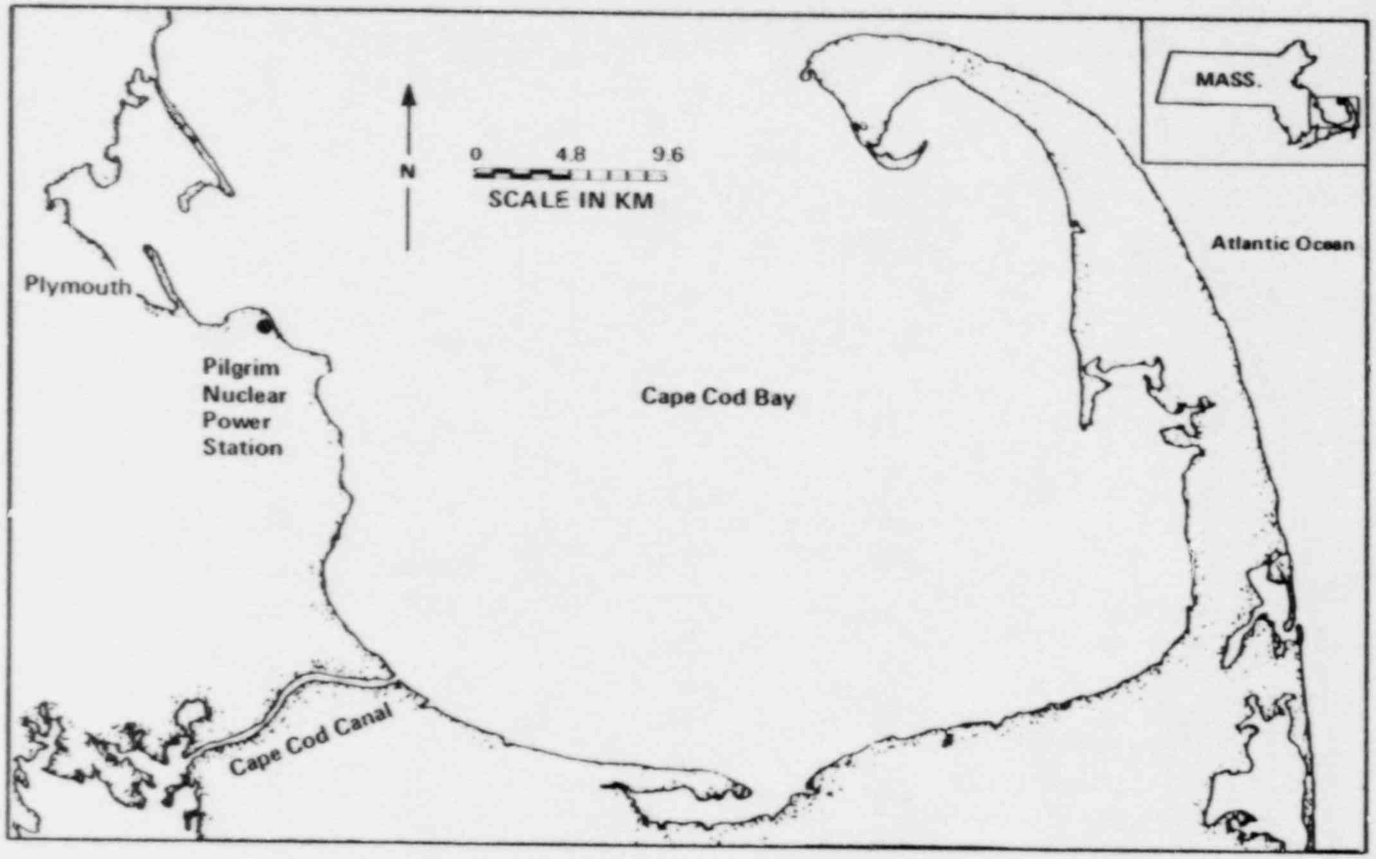

Figure 1. Location of Pilgrim Nuclear Power Station.

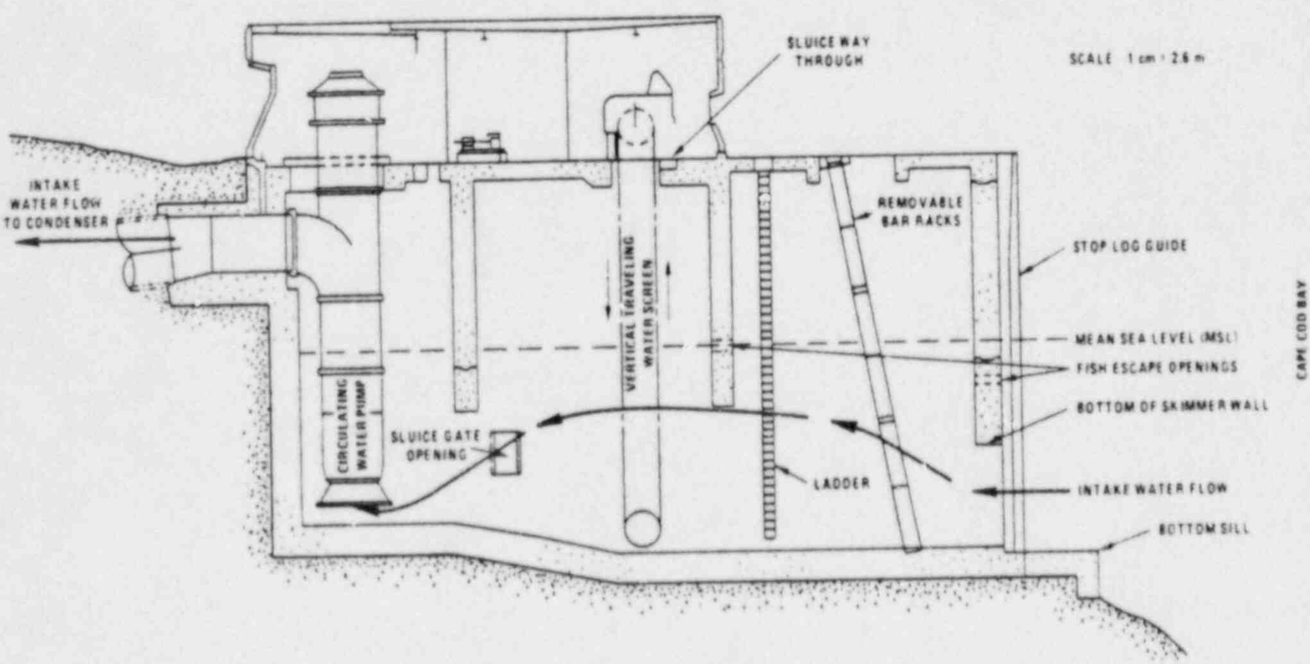

Figure 2: Cross-section of intake structure of Pilgrim Nuclear Power Station.

SECTION 3

METHODS AND MATERIALS

Three screen washings each week were performed from January-December 1987 to provide data for evaluating the magnitude of marine biota impingement. The total weekly collection time was 24 hours (three separate 8-hour periods: morning, afternoon and night). Two collections represented dark period sampling and one represented light period sampling. At the beginning of each collection period, all four travelling screens were washed. Eight hours later, the screens were again washed (minimum of 30 minutes each) and all organisms collected. When screens were being washed continuously, one hour collections were made at the end of the regular sampling periods, and they represented two light periods and one dark period on a weekly basis.

Water nozzles directed at the screens washed impinged organisms and debris into a sluiceway that flowed into a trap. The original trap was made of galvanized screen (3/8-inch mesh) attached to a removable steel frame and it collected impinged biota shortly after being washed off the screens. A second trap was designed and used for sampling, in conjunction with sluiceway survival studies, consisting of a section of half 18" corrugated metal pipe with 3/16-inch nylon, delta mesh netting attached. Impinged biota sampled by this trap were collected at the end of a 300' sluiceway where initial, one-hour and latent (56-hour) fish survival were determined for static (8-hour) and continuous screenwash cycles. Plates 1 and 2 provide views of the beginning and end of this sluiceway structure which was constructed in 1979.

Variables recorded for organisms were total numbers, and individual total lengths (mm) and weights (gms) for up to 20 specimens of each species. A random sample of 20 fish or invertebrates was taken whenever the total number for a species exceeded 20; if the total collection for a species was less than 20, all were measured and weighed. Field work was conducted by Marine Research, Inc.

Intake seawater temperature, power level output, tidal stage, number of circulating water pumps in operation, time of day and date were recorded at the time of collections. The collection rate (#/hour) was calculated as number of organisms impinged per collecting period divided by the total number of hours in that collecting period. All common and scientific names in this report follow the American Fisheries Society (1980) and Smith (1964).

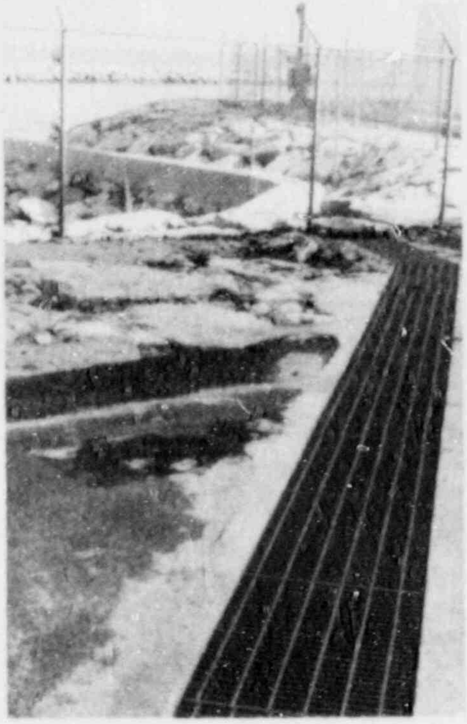

Plate 1. The 300 foot long Pilgrim Station, concrete screenwash sluiceway is molded from 18" corrugated metal pipe, and meanders over breakwater rip rap.

Plate 2. Fish survival testing is done at the end of the sluiceway where it discharges to ambient temperature intake waters.

SECTION 4

RESULTS AND DISCUSSION

4.1 Fishes

In 527 collection hours, 148 fishes of twenty-four species (Table 1) were collected from Pilgrim Nuclear Power Station intake screens during January-December 1987. The collection rate was 0.28 fish/hour. This annual impingement rate is the second lowest in several years because of limited or no circulating water pump operation for 1987. Rainbow smelt (Osmerus mordax) was the most abundant species in 1987, accounting for 27.7% of all fishes collected (Table 2). Atlantic silverside (Menidia menidia) cunner (Tautogolabrus adspersus), lumpfish (Cyclopterus lumpus) and winter flounder (Pseudopleuronectes americanus) accounted for 18.2, 9.5, 6.8 and 6.8% of the total number of fishes collected and identified to lowest taxon.

Rainbow smelt occurred predominantly in monthly samples from January and December. Hourly collection rates per month for them ranged from 0 to 0.89. Rainbow smelt impinged in December accounted for 61% of all this species captured in impingement collections from January-December 1987. They averaged 110 mm total length and 8 grams in weight. Their impingement indicated no relationship to tidal stage or diel factors. It is unusual for them to be the dominant fish in the annual impingement catch, as happened previously in 1978. A review of historical data shows them to be impinged in greatest numbers during the month of December. Rainbow smelt have been one of the most abundant species impinged at Pilgrim Station as illustrated for the past 10 years in Table 3.

Table 1. Monthly Impingement For All Fishes Collected From Pilgrim Station Intake Screens, January-December 1987

Species	Jan.	Feb.	March	April	May	June	July	Aug*	Sept	Oct	Nov	Dec	Total
Rainbow smelt	10	1							2		3	25	41
Atlantic silverside	1		5							2		19	27
Cunner									3	7	4		14
Lumpfish									6	2	2		10
Winter flounder	2									1	6	1	10
Atlantic tomcod						1			2	1		1	5
Grubby	1		1			2			1				5
Tautog									1			4	5
Alewife									4				4
Little skate									3	1			4
Yellowtail flounder	1								2		1		4
Northern searobin									1	2			3
Pollock						1	1					1	3
Silver hake											2		2
Windowpane												2	2
Atlantic herring									1				1
Black sea bass											1		1
Blackspotted stickleback												1	1
Blueback herring											1		1
Radiated shanny	1												1
Rock gunnel						1							1
Striped killifish												1	1
Threespine stickleback					1								1
Winter skate										1			1
TOTALS	16	1	6	0	1	5	1	-	26	17	20	55	148
Collection Time (hrs.)	25	9	5	1	2	94	72	0	111	77	103	28	527
Collection Rate (#/hr.)	0.64	0.11	1.20	0.00	0.50	0.05	0.01	-	0.23	0.22	0.19	1.96	0.28

*No impingement samples taken because traveling water screens were tagged out.

Table 2. Species, Number, Total Length(mm), Weight(gms) and Percentage For All Fishes Collected From Pilgrim Station Impingement Sampling, January-December 1987

Species	Number	Length Range	Mean Length	Weight Range	Mean Weight	Percent of Total Fish
Rainbow smelt	41	71-220	110	2-44	8	27.7
Atlantic silverside	27	65-143	105	2-12	5	18.2
Cunner	14	50-130	84	1-34	11	9.5
Lumpfish	10	18-50	36	0.1-3	2	6.8
Winter flounder	10	58-249	120	1-81	27	6.8
Atlantic tomcod	5	54-195	132	1-80	29	3.4
Grubby	5	63-105	85	3-20	9	3.4
Tautog	5	56-78	69	3-8	6	3.4
Alewife	4	66-130	93	2-18	8	2.7
Little skate	4	430-510	471	576-1,725	913	2.7
Yellowtail flounder	4	44-80	58	1-30	9	2.7
Northern searobin	3	80	80	7	7	2.0
Pollock	3	95-230	145	7-112	44	2.0
Silver hake	2	295	295	152	152	1.4
Windowpane	2	47-72	60	2-4	3	1.4
Atlantic herring	1	128	128	13	13	0.7
Black sea bass	1	74	74	7	7	0.7
Blackspotted stickleback	1	42	42	1	1	0.7
Blueback herring	1	70	70	4	4	0.7
Radiated shanny	1	58	58	1	1	0.7
Rock gunnel	1	-	-	-	-	0.7
Striped killifish	1	83	83	7	7	0.7
Threespine stickleback	1	65	65	1	1	0.7
Winter skate	1	854	854	-	-	0.7

Table 3. Annual Impingement Collections (1978-1987) For the 10 Most Abundant Fishes From Pilgrim Station Intake Screens During January - December 1987

Species	1978	1979	1980	1981	1982	1983	1984	1985*	1986	1987**	Totals
	Number of Impinged Fishes Collected From January - December										
Rainbow smelt	3,019	87	95	13	60	57	5	8	278	41	3,663
Atlantic silverside	722	1,173	14	5,466	133	97	22	174	44	27	7,872
Cunner	61	22	116	55	63	16	6	27	26	14	406
Lumpfish	1	4	4	0	12	9	13	5	5	10	63
Winter flounder	34	34	15	15	27	20	5	39	76	10	275
Atlantic tomcod	31	30	4	5	14	17	12	18	16	5	152
Grubby	51	14	9	24	13	38	15	36	30	5	235
Tautog	0	2	0	2	2	2	2	2	2	5	17
Alewife	131	28	8	11	25	8	12	37	25	4	289
Little skate	1	3	0	1	1	4	2	2	1	4	19
Totals	4,051	1,397	265	5,592	350	268	94	348	503	125	12,991
Collection Time (hrs)	1,442	494.25	603.75	574.5	687	763	1,042	465	806	527	11,072.5
Collection Rate (#/hr)	2.81	2.83	0.44	9.73	0.51	0.35	0.09	0.75	0.62	0.24	1.17

*No CWS pumps were in operation 29 March - August 1984.
**No CWS pumps were in operation 18 February - 8 September 1987.

Atlantic silverside was most represented in December impingement collections but are generally dominant in the early Spring period. This species has been typically collected in large numbers, usually dominating other species on an annual basis (Table 3).

Cunner dominated the impingement catch in October (7 specimens) and were relatively prevalent in September and November samples. Historically, cunner impingement at Pilgrim Station has been greatest in Summer-early Fall. In 1985 they were first in numbers impinged. This species annually is one of the dominant fish collected from the intake screens.

Lumpfish were greatest in September. They are characteristically impinged in largest numbers during the early Winter period although their overall impingement in the past has been relatively low.

Winter flounder occurred predominantly in November, possibly reflecting this species offshore wintering movement. It has been one of the abundantly impinged fish over the years, primarily during February/March when its inshore spawning migration is underway. Monthly intake water temperatures, and impingement rates for the five dominant species in 1987 are illustrated in Figure 3.

There was one impingement incident (20 fish or greater/hr.) at Pilgrim Station in 1987, when one circulating water pump was in operation. The incident involved 11 rainbow smelt, 10 Atlantic silverside, 1 winter flounder and 1 tantog on December 16. All large fish impingment mortalities (>1,000 fish) have occurred while both circulating water pumps were operating.

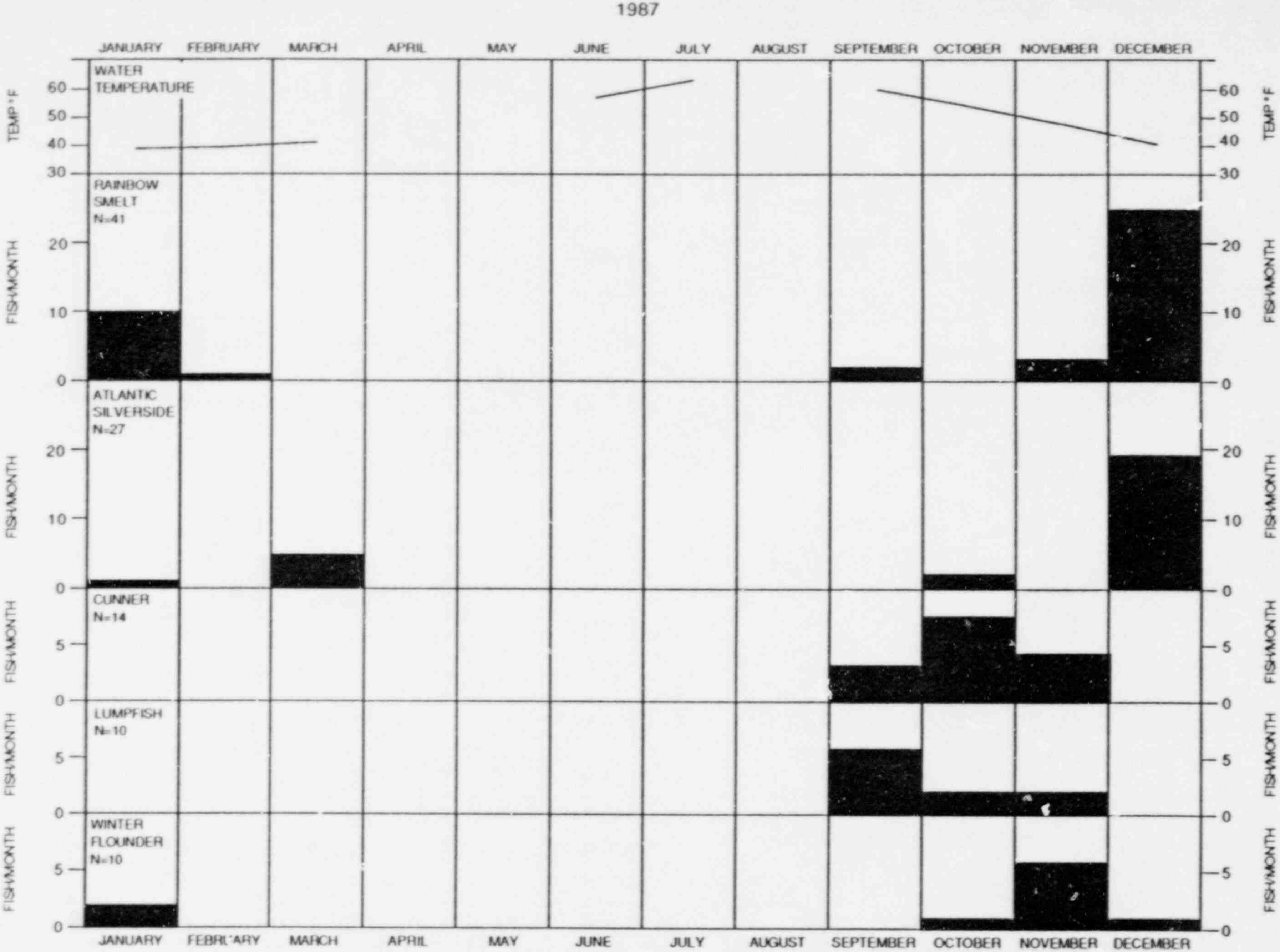

Figure 3. Trends of Intake Water Temperature, and Number of Fish Captured by Month from Pilgrim Station Intake Screens for the Five Most Abundant Species Collected, January-December 1987. Only Minimal Sampling was Possible from February- May, and No Sampling in August.

Ten large fish incidents have been documented since operation commenced and most (6) have involved impingement as the causative agent (Table 4). However, at least in two of these the possibility of pathological influence was implicated as indirectly contributing to the mortalities. They were the Atlantic herring (Clupea harengus harengus) (tubular necrosis) and rainbow smelt (Osmerus mordax) (piscine erythocytic necrosis) impingement incidents in 1976 and 1978, respectively.

Fish impingement rate at Pilgrim Station has been shown to be significantly related to the number of circulating pumps operating (Lawton, Anderson et al, 1984). Reduced water pumping capacity has lowered total impingement, particularly during the April-mid-August 1984 and portions of the mid-February-August 1987 periods when no circulating water pumps were operating. The significance of this relationship is supported by the fact that total fish impingement and rate of fish impingement were several times lower in 1984 than in 1985 and 1986, despite a greater number of collecting hours in 1984. In 1987, far fewer collecting hours were possible when both circulating pumps were off than in these other years which limits comparisons to them. However, total fish impingement rates in both 1984 and 1987 were several times lower than in 1985 and 1986 when at least one circulating pump was always in operation. Figure 4 illustrates the relationship between fish impingement rate and number of circulating pumps operating which demonstrates, for the most part, the reduction effect of no pumps vs. 1 or 2 pumps.

Table 4. Approximate Number and Cause for Most Notable Fish Mortalities at Pilgrim Nuclear Power Station, 1973-1987

Date	Species	Number	Cause
April 9-19, 1973	Atlantic Menhaden	43,000	Gas Bubble Disease
August/September, 1973	Clupeids	1,600	Impingement
April 2-15, 1975	Atlantic Menhaden	5,000	Gas Bubble Disease
August 2, 1975	Atlantic Menhaden	3,000	Thermal Stress
August 5, 1976	Alewife	1,900	Impingement
November 23-28, 1976	Atlantic Herring	10,200	Impingement
August 21-25, 1978	Clupeids	2,300	Thermal Stress
December 11-29, 1978	Rainbow Smelt	6,200	Impingement
March/April, 1979	Atlantic Silverside	1,100	Impingement
September 23-24, 1981	Atlantic Silverside	6,048	Impingement

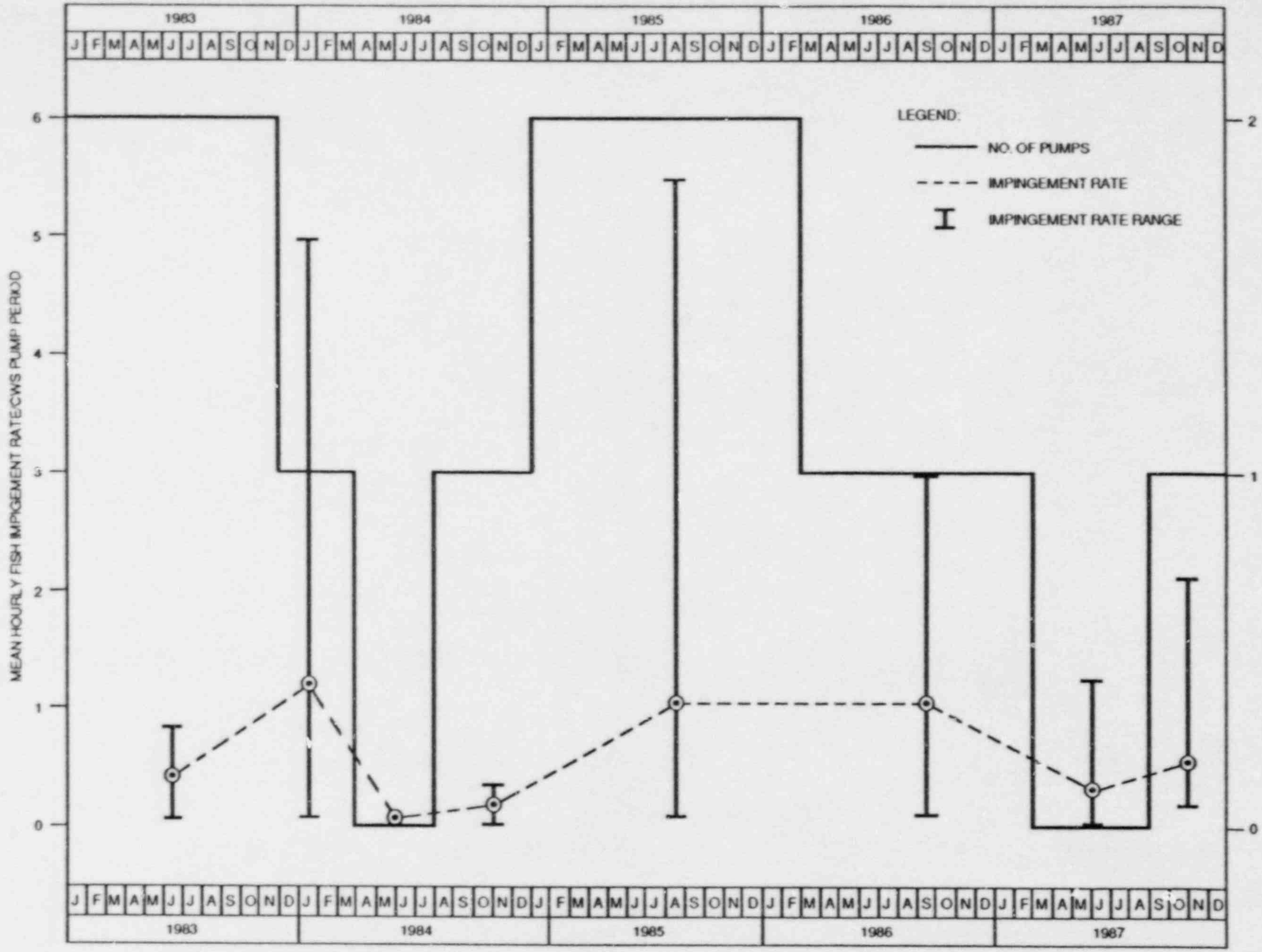

Figure 4. Relationship of Pilgram Station Circulating Water System (CWS) Pumps' Operation (Pump Flow) to Fish Impingement Rate for the Period 1983-1987.

Projected fish impingement rates were calculated assuming 100% operation of Pilgrim Nuclear Power Station during the period January-December 1987. Table 5 presents hourly, daily and yearly impingement rates for each species captured (rates are rounded to significant figures). For all fishes combined the respective rates are 0.28, 6.74, and 2,460. The yearly rate of 2,460 fishes impinged is 13.1% of the 15-year (1973-1987) mean annual projection of 18,793 fishes (Table 6). This is the second lowest, yearly fish impingement rate since 1975 at Pilgrim Station. It may be attributed to low circulating water pump operation (as in 1984) and/or population variances of the dominant species.

Over the 15-year period (1973-1987) it has been operating, Pilgrim Station has had a mean annual impingement rate of 2.15 fishes/hr., ranging from 0.13 (1984) to 10.02 (1981) (Table 6). Anderson et al. (1975) documented higher annual impingements at seven other northeast power plants in the early 1970's. Maine Yankee Atomic Power Company (1978), at their Nuclear Generating Station, had a mean impingement rate of approximately 58 fishes/hr. from late 1972 - late 1977. Stupka and Sharma (1977) showed annual impingement rates at numerous power plant locations for dominant species and compared to these, rates at Pilgrim Station are lower than at most other sites. However, in terms of the number of fish species impinged, Pilgrim Station displays a far greater variety than other power plants in the Gulf of Maine area (Bridges and Anderson, 1984).

Table 5. Impingement Rates Per Hour, Day and Year For All Fishes Collected From Pilgrim Station Intake Screens During January - December 1987, Assuming 100% Operation of Pilgrim Unit 1*

Species	Rate/Hr.	Rate/Day	Rate/January-December 1987*	Dominant Months Of Occurrence
Rainbow smelt	0.08	1.87	682	December
Atlantic silverside	0.05	1.23	449	December
Cunner	0.03	0.64	233	October
Lumpfish	0.02	0.46	166	September
Winter flounder	0.02	0.46	166	November
Atlantic tomcod	0.009	0.23	83	September
Grubby	0.009	0.23	83	June
Tautog	0.009	0.23	83	December
Alewife	0.008	0.18	66	September
Little skate	0.008	0.18	66	September
Yellowtail flounder	0.008	0.18	66	September
Northern searobin	0.006	0.14	50	October
Pollock	0.006	0.14	50	June-July
Silver hake	0.004	0.09	33	November
Windowpane	0.004	0.09	33	December
Atlantic herring	0.002	0.05	17	September
Black sea bass	0.002	0.05	17	November
Blackspotted stickleback	0.002	0.05	17	December
Blueback herring	0.002	0.05	17	November
Radiated shanny	0.002	0.05	17	January
Rock gunnel	0.002	0.05	17	June
Striped killifish	0.002	0.05	17	December
Threespine stickleback	0.002	0.05	17	May
Winter skate	0.002	0.05	17	October
Totals	0.28	6.74	2,460	

*Rates have been rounded to significant figures.

Table 6. Impingem nt Rates Per Hour, Day and Year For All Fishes Collected From Pilgrim Station Intake Screens During 1973-1987, Assuming 100% Operation of Pilgrim Unit 1*

Year	Rate/Hr.	Rate/Day	Rate/Year	Dominant Species (Rate/Year)
1973	1.41	33.89	12,371	Clupeids** (7,473)
1974	0.58	13.85	5,056	Clupeids** (4,542)
1975	0.19	4.54	1,659	Atlantic silverside (702)
1976	6.67	160.17	58,461	Atlantic herring (45,065)
1977	1.06	25.44	9,286	Atlantic silverside (2,735)
1978	4.04	97.03	35,416	Rainbow smelt (29,357)
1979	3.24	77.69	28,280	Atlantic silverside (20,733)
1980	0.66	15.78	5,769	Cunner (1,683)
1981	10.02	240.42	87,752	Atlantic silverside (83,346)
1982	0.93	22.39	8,173	Atlantic silverside (1,696)
1983	0.57	13.65	4,983	Atlantic silverside (1,114)
1984+	0.13	3.13	1,143	Atlantic silverside (185)
1985	1.14	27.46	10,022	Atlantic silverside (3,278)
1986	1.26	30.34	11,075	Atlantic herring (3,760)
1987++	0.28	6.74	2,460	Rainbow smelt (682)
Means	2.15	51.49	18,793	

*Rates have been rounded to significant figures.

**Herrings (clupeids) identified as a general category in 1973 and 1974 consisted of alewife, blueback herring and Atlantic menhaden.

+No CWS pumps were in operation 29 March - 13 August 1984.

++No CWS pumps were in operation 18 February - 8 September 1987.

Monthly intake water temperatures recorded during impingement collections at Pilgrim Station were generally higher the first half of 1987 and lower the second half than the comparable mean monthly temperatures for the 10-year interval 1978-1987 (Table 7). The January - March water temperatures exceeded any previous highs for these months in that 10-year period.

In general, 1982/1983/1985/1986 displayed relatively warm water temperatures, 1978/1981/1984/1987 were average years, and 1979/1980 were cold water years. Pilgrim station intake temperatures approximate ambient water temperatures. A fairly even distribution of both cold water species (i.e., lumpfish, rainbow smelt and winter flounder) and warm water species (i.e., tautog, alewife and cunner) was impinged in 1987.

4.2 Invertebrates

In 527 collection hours, 848 invertebrates of 17 species (Table 8) were recorded from Pilgrim Station intake screens, from January-December 1987. The annual collection rate was 1.61 invertebrates/hour. Unlike the fishes and the invertebrates in 1984, the 1987 invertebrate impingement rate was not much less than in 1985 and 1986 despite very low circulating water pump capacity available in 1987. Blue mussel (Mytilus edulis) (71.8%) dominated the catch with the great majority being captured in January when 1 circulating pump was functional. The sand shrimp (Crangon septemspinosa) and polychaete worms accounted for 7.9 and 4.5%, respectively, of the total invertebrates enumerated. An unusual occurrence has been the collection of so many blue mussels in 1986 and 1987 which from 1982-1985 were impinged in very low numbers. This could be an effect of the Pilgrim Station outage which precludes the use of thermal backwashes for macrofouling control.

Table 7. Monthly Means of of Intake Temperature (°F) Recorded During Impingement Collections at Pilgrim Nuclear Power Station, 1978-1987

Month	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	(X) 1978-1987
	Year										
January	38.42	35.97	35.61	33.55	38.88	*	31.95	*	36.75	34.47	35.72
February	38.71	34.98	33.40	36.08	37.05	*	32.68	*	30.36	32.88	34.52
March	40.70	37.18	37.84	37.62	40.25	*	39.04	*	35.51	34.98	37.89
April	*	44.98	41.85	*	43.14	43.60	37.60	41.77	39.92	40.67	42.53
May	*	48.84	50.55	*	47.26	49.73	45.99	48.18	49.56	47.22	48.41
June	56.68	56.11	56.31	*	57.54	55.10	52.74	49.49	54.39	50.04	54.26
July	63.00	61.51	58.96	67.00	59.44	55.98	61.01	52.78	55.56	56.03	59.12
August	*	63.29	63.44	64.62	61.46	60.23	63.68	58.02	56.73	60.48	61.33
September	58.21	58.26	63.74	60.91	61.06	59.04	53.70	55.89	53.75	58.59	59.32
October	52.73	58.58	57.75	55.88	55.38	55.60	*	54.64	51.94	52.80	55.04
November	47.49	52.23	52.01	45.71	49.64	50.36	*	46.33	48.75	49.22	49.08
December	41.30	44.00	42.22	42.30	41.43	44.55	*	39.34	40.86	40.41	41.84
Mean											48.25

* Temperatures were incompletely recorded during PNPS outages in these months.

Table 8. Monthly Impingement For All Invertebrates Collected From Pilgrim Station Intake Screens, January-December 1987

Species	Jan.	Feb.	March	April	May	June	July	Aug*	Sept	Oct	Nov	Dec	Total
Blue mussel	387	87	25	5	65	36	2		2				609
Sand shrimp	6	4	32									25	67
Polychaete	16	2	9		8		1					2	38
Rock crab	9	1		1	4	6	3		1			5	30
Green crab						13	5		4	1	1	1	25
Nemertean	1		10			3	1				1		16
Horseshoe crab						8	1		1	1			11
Green seaurchin	2				3	2	1				1		9
Isopod	1				1						1	5	8
Cancer spp.											7		7
Longfin squid									6				6
Nudibranch	5		1										6
Common starfish						2			2		1		5
Nereis sp.	5												5
Lady crab										1	3		4
Littorina sp.	1												1
Purple seaurchin									1				1
TOTALS	433	94	77	6	81	70	14	-	17	3	15	38	848
Collection Time (hrs.)	25	9	5	1	2	94	72	0	111	77	103	28	527
Collection Rate (#/hr.)	17.32	10.44	15.40	6.00	40.50	0.74	0.19	-	0.15	0.04	0.15	1.36	1.61

*No impingement samples taken because traveling water screens were tagged out.

Sand shrimp were the most abundant invertebrates impinged in March and December. February-April impingement is characteristic of them at Pilgrim Station. Polychaete worms were impinged in highest numbers in January, and rock crab (Cancer irroratus) impingement peaked in January, also. The greatest collections of green crabs (Carcinus maenus), the fifth most impinged invertebrate, were in June.

No specimens of the commercially important American lobster (Homarus americanus) were captured in 1987. This is unusual as during most years some lobsters are impinged.

Approximately 563 pounds of mixed algae species were collected during 1987 impingement sampling for a rate of 1.1 pounds/hr. As expected, this rate (like 1984) is lower than normal because of low circulating pump availability in 1987.

4.3 Fish Survival

Fish survival data collected in 1987 while impingement monitoring was conducted are shown in Table 9. Static screen wash collections provided the greatest numbers of fishes and revealed an overall survival rate of 29.1%. Fishes collected during continuous screen washes fared better, as expected, showing a survival rate of 43.5%. Typically fishes have a higher survival rate during continuous screen washes because of reduced exposure time to the effects of impingement. However, reduced intake currents in 1984, associated with limited circulating water pump operation, may have been a factor in

Table 9. Survival Summary for the Fishes Collected During Pilgrim Station Impingement Sampling, January-December 1987. Initial, One-Hour and Latent (56-Hour) Survival Numbers Are Shown Under Static (8-Hour) and Continuous Wash Cycles.

Species	Number Collected		Number Surviving						Total Length (mm)	
	Static Washes	Cont. Washes	Initial Static	Initial Cont.	1-Hour* Static	1-Hour* Cont.	56-Hour* Static	56-Hour* Cont.	Mean	Range
Rainbow smelt	16	25	0	3	0	3	0	0	110	71-220
Atlantic silverside	10	17	0	4	0	2	0	0	105	65-143
Cunner	6	8	5	8	5	8	4	8	84	50-130
Lumpfish	9	1	6	1	-	1	-	1	36	18-50
Winter flounder	7	3	2	3	-	3	-	1	120	58-249
Atlantic tomcod	5	0	1	-	-	-	-	-	132	54-195
Grubby	3	2	3	1	-	1	-	1	85	63-105
Tautog	1	4	0	4	0	-	0	-	69	56-78
Alewife	4	0	0	-	0	-	0	-	93	66-130
Little skate	4	0	1	-	1	-	1	-	471	430-510
Yellowtail flounder	2	2	1	1	-	1	-	1	58	44-80
Northern searobin	2	1	1	1	-	1	-	1	80	80
Pollock	3	0	0	-	0	-	0	-	145	95-230
Silver hake	2	0	1	-	-	-	-	-	295	295
Windowpane	0	2	-	1	-	-	-	-	60	47-72
Atlantic herring	1	0	0	-	0	-	0	-	128	128
Black sea bass	1	0	1	-	1	-	1	-	74	74
Blackspotted stickleback	0	1	-	1	-	-	-	-	42	42
Blueback herring	1	0	0	-	0	-	0	-	70	70
Radiated shanny	0	1	-	1	-	1	-	0	58	58
Rock gunnel	1	0	1	-	-	-	-	-	-	-
Striped killifish	0	1	-	1	-	1	-	1	83	83
Threespine stickleback	0	1	-	0	-	0	-	0	65	65
Winter skate	1	0	0	-	0	-	0	-	854	854
All Species:										
Number	79	69	23	30	-	-	-	-		
(% Surviving)			(29.1)	(43.5)						

* Limited data for some species because survival pool was down in June and part of December 1987, or fishes were sampled in the screenhouse.

higher static wasn survival then because of less stress on impinged individuals although this wasn't apparent from 1987 results. Only initial survival rates are reported because 1-hour and 56-hour data were rendered incomplete when survival pools were out of service during all of June and part of December, samples were collected in the screenhouse, or fishes were lost.

Among the ten numerically dominant species impinged in 1987, cunner, lumpfish, winter flounder, grubby and tautog demonstrated initial survival rates 50% or greater. Rainbow smelt showed 7.3% survival, Atlantic silverside 14.8%, Atlantic tomcod 20%, alewife 0%, and little skate 25%.

SECTION 5

CONCLUSIONS

1. The average Pilgrim collection rate for the period January-December 1987 was 0.28 fish/hour. The impingement rates for fish in 1984 and 1987 were several times lower than in 1985 and 1986 because of much reduced circulating water pump capacity during the former years.

2. Twenty-four species of fish were recorded in 527 impingement collection hours during 1987. In 1985 and 1986 several times the number of fishes were sampled as compared to 1984, despite more collection hours in 1984. This illustrates the importance that the number of circulating pumps operating has on the quantity of impinged organisms. Less collecting hours for portions of 1987 precluded this comparison with other years.

3. At full-load (conservative assumption) yearly operation the estimated maximum January-December 1987 impingement rate was 2,460 fishes (187 lbs.). This projected annual fish impingement rate is the second lowest since 1975 at Pilgrim Station.

4. The major species collected and their relative percentages of the total collections were rainbow smelt, 27.7%; Atlantic silverside, 18.2%; cunner, 9.5%; lumpfish, 6.8%; and winter flounder, 6.8%.

5. The peak in impingement collections occurred during January and December for rainbow smelt. Rainbow smelt hourly impingement rate varied from 0 to 0.39

6. Monthly intake water temperatures, which reflect ambient water temperatures, were generally higher for the first half and lower for the second half of 1987 than the ten-year monthly averages for the period 1978-1987. January - March mean water temperatures were the highest recorded for these months in the last ten years.

7. The hourly collection rate for invertebrates was 1.61. Blue mussel dominated the samples. Sand shrimp and polychaete worms were 7.9 and 4.5% of the enumerated catch. No American lobsters were collected.

8. Impinged fish initial survival was approximately 29% during static screen washes and 43% during continuous washes for pooled species. Of the ten fishes impinged in greatest numbers during 1987, five showed initial survival rates 50% or greater.

SECTION 6

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SUMMARY REPORT:
FISH SPOTTING OVERFLIGHTS
IN WESTERN CAPE COD BAY
IN 1987

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Biologist

April 1988

Regulatory Affairs and Programs

Boston Edison Company

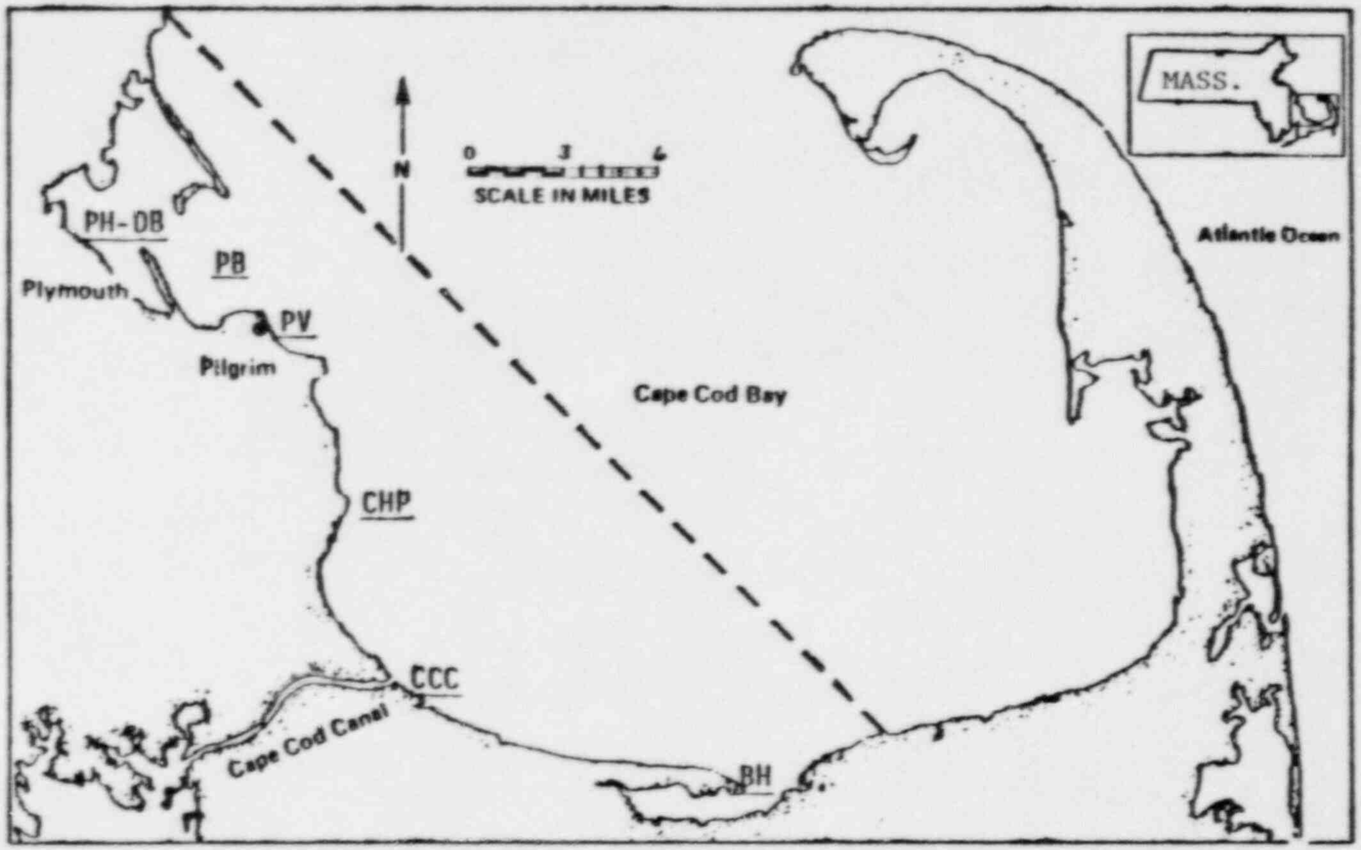
SUMMARY REPORT:
FISH SPOTTING OVERFLIGHTS IN
WESTERN CAPE COD BAY IN 1987

Weekly fish spotting overflights were made north, south and in the vicinity of Pilgrim Nuclear Power Station (PNPS) from March-November 1987. Five main groupings of fish were noted by the overflight pilot who was trained to spot fish for commercial fishing operations. The five groupings are: 1) herring, consisting primarily of Atlantic herring (Clupea harengus harengus), alewife (Alosa pseudoharengus) and/or blueback herring (Alosa aestivalis); 2) Atlantic menhaden (Brevoortia tyrannus); 3) pollock (Pollachius virens); 4) Atlantic mackerel (Scomber scombrus); and 5) baitfish, consisting primarily of any species too small to identify but most likely being composed of Atlantic silverside (Menidia menidia), rainbow smelt (Osmerus mordax), sand lance (Ammodytes spp.) or the juveniles of other species. In addition, sightings of other marine species, such as bluefish (Pomatomus saltarix) or whales (Cetacea), are occasionally reported.

Figure 1 shows the general area covered by the PNPS fish overflight program, although reports of fish concentrations are received from further north or south, also. Plates 1 and 2 show an overflight airplane and a typical fish school as it appears when viewed from the airplane.

This summary report is meant for general information purposes only, as it is not possible to quantify with reasonable accuracy the data from this qualitative a program. Nevertheless, this program is very valuable and useful in being responsive to NPDES Permit requirements, documenting barrier net effectiveness by confirming large quantities of fishes in the Pilgrim area, and alerting BECo. and regulatory personnel of the potential for a discharge-related fish mortality.

Figure 1. <u>FISH SURVEILLANCE OVERFLIGHTS</u>
(Critical Area)



PH-DB Plymouth Harbor-Duxbury Bay
PB Plymouth Bay
PV Pilgrim Vicinity
CHP Center Hill Point
CCC Cape Cod Canal
BH Barnstable Harbor

Note: Critical surveillance area is west of the dashed line in the vicinity of the specific locations noted. Generic observations should also be made in the course of the plane's flight to and from the critical area.

Plate 1. The airplane used for fish spotting overflights in the Pilgrim Station area is typical of the ones used in commercial area fishing operations.

Plate 2. A fish school appears as a dark shadow from the airplane, and it takes an experienced pilot to distinguish its composition from submerged objects.

Table 1 summarizes location, approximate poundage and seasonal information for the five groupings of fishes defined above. Below are some interpretive comments based on general trends illustrated by fish observation data for the five predominant fish groups from March-November 1987:

1. Herring - This is a mixed species category but probably consists mostly of Atlantic herring. These fish were in the Cape Cod Bay region primarily in the fall, in the area of PNPS. The alewife and blueback herring were prevalent in April and June. All of the herring observed during these months, north and south of PNPS, probably represented these species. The majority of pounds of herring observed by fish overflights represents Atlantic herring as borne out by commercial catch statistics. Relatively low poundage sightings were made of herring during 1985-1987, possibly reflecting population fluctuations for these species. However, 105,000 pounds of Atlantic herring were observed 1/2 mile east of PNPS on October 19. No fish mortalities occurred, although in November 1976 over 10,000 Atlantic herring were killed by impingement on PNPS intake traveling screens.

2. Atlantic Menhaden - This species is of concern at Pilgrim because of past gas bubble disease mortalities in the discharge canal and thermal plume. As can be seen from Table 1, menhaden may occur over the entire Cape Cod Bay region in millions of pounds from late-spring through fall. Overflight pilots are particularly adept at identifying this species as commercial ventures depend heavily on accurate observations for success. The first menhaden north of Cape Cod in 1987 were observed on May 10 in Wellfleet Bay. The great

TABLE 1. Approximate Location, Relative Species Poundage and Seasonality from Fish Observation Overflights in the Western Cape Cod Bay Area in 1987

LOCATION	SPECIES	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER
North of Pilgrim	Herring		17,000					20,000	40,000	68,000
	Menhaden			22,000	1,885,000*	790,000	31,500	45,000	17,000	
	Pollock									
	Baitfish									
	Mackerel					10,000				
Pilgrim Vicinity	Herring								105,000	
	Menhaden				18,000					
	Pollock									
	Baitfish									
	Mackerel									
South of Pilgrim	Herring	15,000	37,500	130,000	15,000		+			60,000
	Menhaden			34,000	275,000					
	Pollock									
	Baitfish		5,000							
	Mackerel					390,000				
Totals	Herring	15,000	54,500	130,000	15,000		+	20,000	145,000	128,000
	Menhaden			56,000	2,178,000*	790,000	31,500	45,000	17,000	
	Pollock									
	Baitfish		5,000							
	Mackerel					400,000				

*Regulators notified (EPA/DWPC).

+Unestimated poundage.

majority of menhaden were sighted north of PNPS during June and July. On June 21, 18,000 pounds of menhaden were spotted 1/2 mile east of PNPS. Regulatory agencies (EPA and Mass. DWPC/DMF) are notified when fish are in the thermal plume area, but with a year-long outage at PNPS no thermal discharge was present. The last menhaden observed in 1987 were 12,000 pounds in Plymouth Harbor on October 19.

3. <u>Pollock</u> - No pollock were observed from 1985-1987 which is unusual. No serious incidents have occurred involving them at PNPS although they have been seen schooling within the intake embayment near the traveling screens. Pollock, while at times schooling in the intake, have never been impinged on the PNPS intake screens in proportion to their abundance.

4. <u>Atlantic Mackerel</u> - These fish support a valuable commercial fishery and are reported most frequently south of PNPS. In 1987, there were five observations made of Atlantic mackerel schools, all in July. On July 7 30,000 pounds were spotted 1/2 mile south of PNPS and 200 yards offshore. The other sightings were mostly well south of the Station, in the vicinity of the Cape Cod Canal.

   Mackerel occur in relatively large numbers usually during the Summer - early Fall months, and no notable incidents involving them have occurred at Pilgrim Station. They are an offshore species for the most part but have been observed in previous years schooling in the PNPS intake embayment, where bluefish predation on them has occurred.

5. <u>Baitfish</u> - This category is a catchall and may include large numbers of small unidentified fish. On April 21, 5,000 pounds of sand lance

were observed east of the Cape Cod Canal. Sand lance, as well as most species in this grouping, regularly inhabit the PNPS intake area in numbers too small to be seen by overflights.

Baitfish could represent the offspring of fishes in the above categories as well as Atlantic silversides, rainbow smelt and sand lance. Some of these species are significant in impingement collections at PNPS.

6. Other - There were several other spottings made in 1987 which fall outside the above categories. Included were bluefish, whales, and sharks. Bluefish were seen in July and September within a few miles of PNPS. Finback whales were noted in March and September, also in the proximity of the Station.

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888-1155

MEMORANDUM

TO: Members of the Administrative-Technical Committee, Pilgrim Power Plant Investigations

FROM: Robert Lawton, (Acting) Recording Secretary, Massachusetts Division of Marine Fisheries

SUBJECT: Minutes of the 68th meeting of the Pilgrim Administrative-Technical Committee

DATE: September 30, 1987

The 68th Pilgrim Administrative-Technical (A-T) Committee meeting was called to order by Chairman Szal on 29 September, 1987 at 10:16 a.m. at the headquarters of the Massachusetts Division of Fisheries and Wildlife in Westborough, Massachusetts. The following agenda items were addressed.

I. Minutes of the 67th Meeting

Corrections to the 67th Committee minutes were tendered by Mr. Anderson and are attached in an addendum to these minutes. Mr. Szal motioned that the 67th meeting minutes be accepted with the corrections incorporated. Mr. Maietta seconded the motion, which passed unanimously.

II. Pilgrim Station Operational Review

Mr. Anderson reviewed the plant outage which began in April 1986. To date, Pilgrim Station has been "off-line" for 18 months. Reloading fuel at the plant began the weekend of September 26-27, 1987; the procedure should take 10 days to accomplish. Plant officials anticipate "start-up" of Pilgrim Station by mid-to-late November 1987; and if no setbacks are encountered, full power operation should be obtained four to six weeks later (January 1988).

III. Fisheries Subcommittee Report

Mr. Finn (Chairman) presented the recommendations of the Fisheries subcommittee. It was recommended to the full A-T Committee that the Mass. Division of Marine Fisheries continue to conduct environmental studies at

Pilgrim Station, with no major changes in scope of work for 1988 and 1989. A six-point monitoring program would be carried out in 1988.

1. Lobster Catch Program

The catch of one commercial lobsterman will be monitored biweekly in the vicinity of Pilgrim Station throughout the inshore fishery season (approximately April-October). In addition, 50 research lobster traps will be fished with standardized effort from June-September. This program provides an important check on a valuable resource. Two years of data from the research pots during the outage can be compared with data to be obtained during plant operation.

2. Demersal Fish (Nearshore Trawl)

Trawl data were examined to determine if major events would be missed by reducing effort to monthly sampling of the groundfish community. The analysis showed that monthly samples during winter (Jan.-Mar.) are adequate, but that monthly samples for the rest of the year would miss much information. As a result, it is recommended that sampling be reduced to monthly during winter but be kept biweekly from spring through fall.

3. Gill Net (Pelagic Fish)

Although this program is funded by the Radiological Monitoring Program, it provides information on the occurrence and abundance of pelagic and benthipelagic fishes not sampled by other gear types. Sampling is conducted a minimum of once a month throughout the year.

4. Fish Observational Dives

This program continues to provide qualitative data on the impacts of the plant on fish, especially mid-August to mid-September, when weekly SCUBA dives can provide an early warning of a possible fish kill. This study also provides corroborative information on the width of the "denuded and stunted" zones during the summer for the benthic program. A supplemental station will be sampled when time and conditions allow off the outer intake breakwater, but otherwise the program will go on as it is at present.

5. Shorezone Fish (Haul Seine)

An additional smaller seine was added in 1987 to better sample flatfish. This program is especially important if the power plant increases capacity by 10% in the future, as it measures fish populations that could be adversely affected by entrapment and impingement.

6. Shorefront Sport Fish Survey

The watchmen at the Shorefront have voluntarily carried out this creel survey in conjunction with the Division since 1986.

A discussion followed on funding for the study. Mr. Anderson then discussed with the Committee the policy of Boston Edison Company for selecting contractors to conduct environmental studies at Pilgrim Station. The policy for many years has been sole source funding for the major contractors. The A-T Committee recommended that Boston Edison retain the same contractors in 1988 in order to ensure quality and continuity of the data bases. The Committee acknowledged the work of the Division of Marine Fisheries - their proven prior performance both in field sampling and in publications. It was also felt that there is a certain credibility in a state agency doing the work.

Dr. Finn moved to accept the recommendations of the Fisheries subcommittee. Dr. Deegan second, and the motion was carried. The two Division Committee members abstained from voting.

IV. Benthic Subcommittee Report

The proposed benthic monitoring program at Pilgrim Station for 1988 was presented by Mr. Anderson in the absence of Dr. Don Miller, chairman of the Benthic Subcommittee. Battelle, the benthic contractor, had recommended to the Benthic Subcommittee that a 10-year data base be obtained at the present level of effort which will take us through 1991. Subsequently, Battelle will give a long-term look at the data by doing a time-series analysis. The results will serve as guidelines for future monitoring efforts.

The subcommittee report presents a program of study that is believed to represent the very least that should be done to maintain a prognosticative monitoring program. The 1988 program includes to quantitative samplings (March and September) and four qualitative transect sampling events (March, June, September, and December).

Mr. Szal moved and Mr. Bridges seconded to accept the program of study recommended by the Benthic Subcommittee; the motion passed unanimously.

V. 1988 Impingement and Overflight Monitoring

Mr. Anderson reported that the 1986 impingement rate at Pilgrim Station was the highest recorded since 1981 and the sixth highest overall. Atlantic herring (34%), rainbow smelt (27%) and Atlantic menhaden (11%) were the dominant species impinged. For January-June, 1987 the impingement rate was very low as both circulating water pumps were not operated from March-June.

Mr. Anderson recommended to the Committee that impingement monitoring continue in 1988 to keep a data base going because impingement is a definite source of impact at the plant. Modifications are planned for the intake structures in the near future, and data will be needed to assess their effectiveness. Dr. Deegan moved to continue impingement monitoring at the present sampling schedule of three times per week. Dr. Finn seconded the motion which was unanimously supported by Committee members.

As to overflight monitoring of fish in western Cape Cod Bay, Mr. Anderson recommended continuing this program on a weekly basis from March-November. A motion was made by Dr. Deegan and second by Dr. Finn to continue the program as outlined into 1988. The A-T Committee voted unanimously to continue the overflights as a warning indicator of approaching schools of fish to the immediate vicinity of Pilgrim Station.

VI. 1988 Entrainment Monitoring

Mr. Anderson recommended continuing entrainment monitoring at Pilgrim Station in 1988 adhering to the present program which consists of collecting triplicate samples in the discharge canal twice monthly in January, February, October, November, and December; weekly sampling is done March through September. A contingency sampling plan will also be retained in the event eggs and/or larvae of any dominant species prove to be "unusually abundant" in the plant's discharge samples.

A motion was made by Mr. Maietta and seconded by Mr. Bridges to continue entrainment monitoring at Pilgrim Station in 1988 adhering to the sampling regime of 1987. The motion received unanimous support from the Committee.

VII. Environmental Radiation Monitoring

Mr. Bruce Dionne, Senior Radiological Engineer for Boston Edison Company, was an invited guest at the meeting and spoke on their radiological environmental monitoring program at Pilgrim Station. He spoke specifically on monitoring marine life - lobster, shellfish, finfish, and Irish moss (red algae). The Division of Marine Fisheries collects the samples, Yankee Atomic Environmental Laboratory does the radiological analysis, and Boston Edison Company interprets the data and prepares any written reports.

effluent water at Pilgrim Station is a pathway through which reactor radia[illegible]n is released into the environment. Liquid releases at the plant are batch releases into the waste-water discharge. Radioactive isotopes, such as cesium-137 and cobalt-60, are produced directly as major fission products in the reactor and are long-lived. Cesium-137 has a half-life of 30.2 years and is initially strongly radioactive when produced.

There was a large build-up of blue mussels in the discharge canal this year, and with the plant in an outage there was no heat and a significantly reduced flow of water through the discharge canal. This concerned Boston Edison in that with a reduction in the volume of water discharged, dilution of waste releases is diminished and mussels in the canal would likely concentrate radioactive isotopes. It is known that fission products present in discharge water even in small amounts can be concentrated in biota by preferential uptake by finfish and shellfish which, in turn, can be eaten by man. With this in mind, samples of mussels were collected from the discharge canal and a reference site this past June. Composite samples were analyzed with the following results. The concentration of cobalt-60 in control mussels was 100 picocuries/kg of mussels (background). The concentrations found in mussels within the discharge canal were: at the headwall or outlet pipe - 2,000 picocuries/kg, halfway down the canal - 600 picocuries/kg, and at the mouth of the canal - 300 picocuries/kg. Also found at two to three times the typical concentrations were cesium-137 and magnesium-54.

Mr. Dionne calculated that the dose that would be found in a human ingesting 14 pounds of these mussels in a year would be only 0.2 millirems/year (whole body dose) or 0.4 millirems/year in the G.I. tract. To put this in perspective, the International Council on Radiation Protection recommends a dose limit of 500 millirems/year whole body exposure for any member of the public. This places the radiation level obtained by eating mussels from Pilgrim's discharge canal clearly well below the recommended limit.

Boston Edison Company, nevertheless, considered several alternatives to rid the discharge canal of these contaminated mussels. After much consideration, they believed the most cost-effective way was to leave the mussels in the canal and let them depurate via the large volumes of circulating water when the plant resumes operation. In addition, they believed that many of the mussels would detach next summer because of elevated temperatures and be carried out of the canal. In the mean time, large numbers of mussels began dying in the effluent canal, possibly due to crowding and to siltation produced by work done at the plant.

Mr. Dionne told the Committee that Boston Edison Company plans to prepare a brochure for the public on health hazards from radiation exposure. They also plan to refine their annual technical report on radiation monitoring at the plant by adding more explanative text and graphics.

VIII. Other Business

There was none.

IX. Adjournment

Meeting adjourned at 2:45 p.m.

Pilgrim Administrative-Technical Committee Meeting

September 29, 1987

Attendants

Name	Agency
Gerald Szal, Chairman	Mass. DEQE/DWPC
Robert Lawton (Acting) Recording Secretary)	Mass. DMF
Robert Anderson	BECo
Michael Bilger	U.S. EPA, Lexington
Linda Deegan	UMass, Amherst
John Finn	UMass, Amherst
W. Leigh Bridges	Mass. DMF
Bruce Dionne	BECo (non-voting)
Robert Maietta	Mass. DEQE/DWPC

MEMORANDUM

TO: Members of the Administrative-Technical Committee, Pilgrim Power Plant Investigations

FROM: Robert Lawton, (Acting) Recording Secretary, Massachusetts Division of Marine Fisheries

SUBJECT: Addendum to the 67th meeting minutes of the Administrative-Technical Committee

DATE: September 30, 1987

Corrections to the 67th meeting minutes are as follows:

Page 1, Section II, 3rd paragraph, 3rd line: Change "was no current discharged by the plant as both circulating water pumps were generally off." to "was limited current discharged by the plant as one of the two circulating water pumps was generally off.

Page 2, Section III, 2nd paragraph, 4th line: Change ". . . menhaden or pollock were sighted and only one aggregation of baitfish was . . ." to ". . . menhaden or polock were sighted in the Station vicinity and only one aggregation of baitfish was . . ."

Page 2, Section IV, 1st paragraph, 3rd line: Change ". . . current . . ." to " . . . temperature increase or current . . ."

Page 3, Section VI, 2nd paragraph, 1st line: Change "Mike said that the summary report of entrainment . . ." to "Mike said that the long-term progress and recommendations' summary report of entrainment . . ."

Page 5, the affiliation of Derek McDonald should read MBC and not MBI.

RPL/cm

BOSTON EDISON
Executive Offices
800 Boylston Street
Boston, Massachusetts 02199

BECo 88- 028
April 30, 1988

Ralph G. Bird
Senior Vice President — Nuclear

Mass. Division of Water Pollution Control
Permit Section - 7th Floor
One Winter Street
Boston, MA 02108

License DPR-35
Docket 50-293

NPDES PERMIT MARINE ECOLOGY MONITORING REPORT

Dear Sir:

In accordance with Part I, Paragraph A.7.b & c. and Attachment I, Paragraph I.G, of the Pilgrim Nuclear Power Station NPDES Permit No. MA0003557 (Federal) and No. 359 (State), Semi-Annual Marine Ecology Report No. 31 is submitted. This report covers the period from January through December 1987.

R. G. Bird

Attachment: Semi-Annual Marine Ecology Report No. 31

RDA/amm/1292

cc: Mass. Division of Water Pollution Control
Lakeville Hospital
Lakeville, MA 02346

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