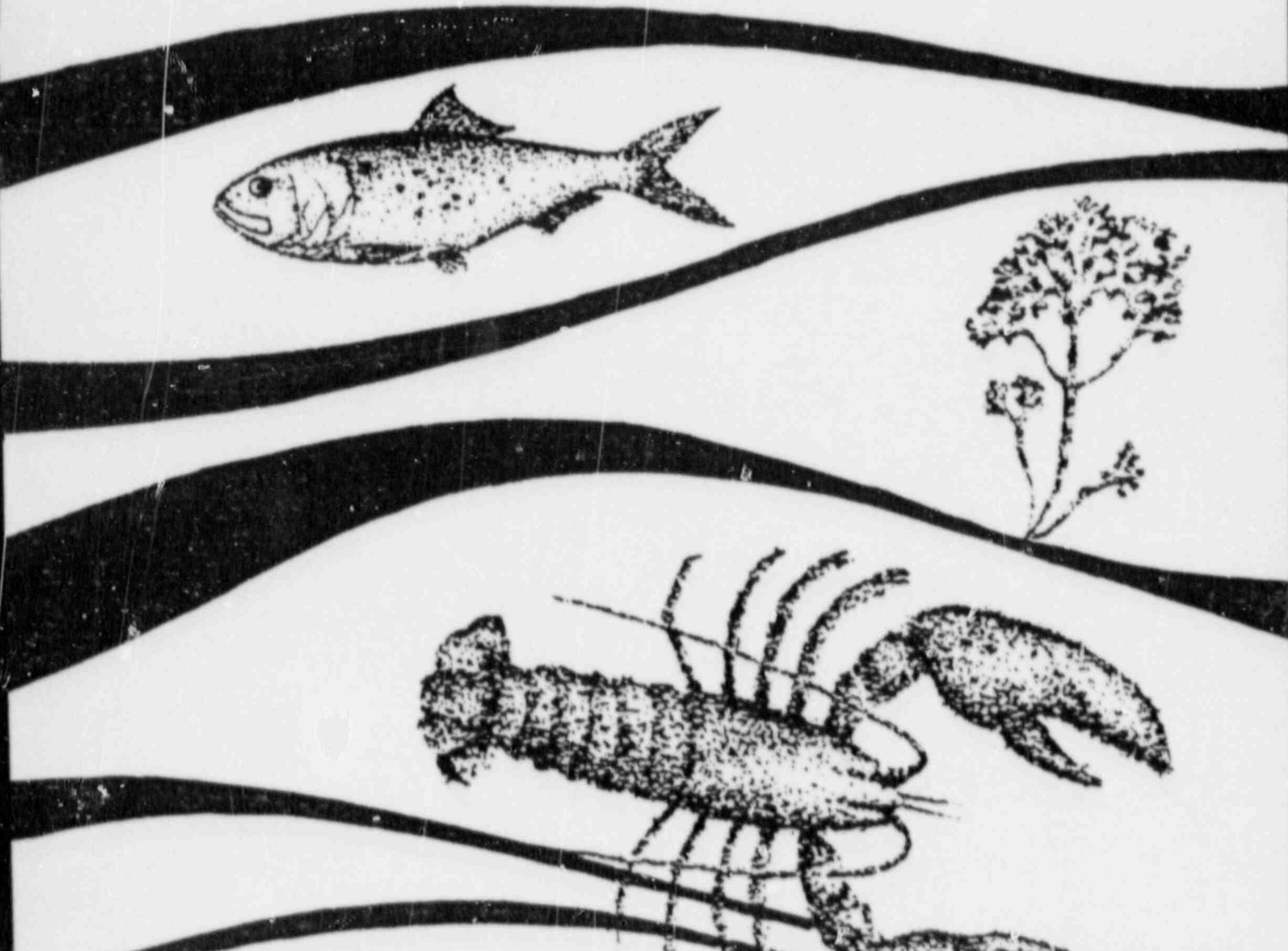
marine ecology studies

Related to Operation of Pilgrim Station

SEMI-ANNUAL REPORT NUMBER 32
JANUARY 1988 - JUNE 1988



BOSTON EDISON COMPANY
NUCLEAR ENGINEERING DEPARTMENT
LICENSING DIVISION

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BOSTON EDISON
800 Boylston St. Boston, MA 02199

MARINE ECOLOGY STUDIES

RELATED TO OPERATION OF PILGRIM STATION

SEMI-ANNUAL REPORT NO. 32

REPORT PERIOD: JANUARY 1988 THROUGH JUNE 1988

DATE OF ISSUE: OCTOBER 31, 1988

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SUMMARY

Highlights of the environmental surveillance and monitoring program results obtained over this reporting period (January - June 1988) are presented below (Note: PNPS was in an outage from January - June 1988 with virtually no thermal discharge present during this time frame, representing a control situation for data collection. For portions of the period, particularly in April and May, no circulating seawater pumps were operating).

Marine Fisheries Monitoring:

1. Pelagic fish mean catch from January - June 1988 at the gill net station (315 fishes/set) decreased 14% from 1987 when 365.2 fishes/ set were taken. Atlantic herring (52%), pollock (26.5%) and cunner (8%) made up 86% of the total catch. Striped bass and bluefish were sampled in much lower numbers than during operational years, possibly due to a lack of an attracting thermal effluent.

2. Shrimp trawl catch from January - June 1988 recorded fifteen benthic fish species with winter flounder (41.7%), little skate (30.1%), windowpane (14.7%) and yellowtail flounder (4.8%) composing 91% of the total. Mean catch-per-unit-effort (CPUE) for all species was lowest at the Intake Station (10.9) and 12.7 for all stations pooled in 1988 (three times less than in 1987). CPUE from January - June 1988 for commercially important winter flounder was lowest at the

Intake Station. The smallest winter flounder recorded were sampled in the intake embayment.

3. Adult lobster mean monthly catch rate per pot haul in May - June 1988 was 0.35 lobsters (0.29 in 1987). This is comparable to the mean spring catch rate near Pilgrim Station over the last 18 years. The surveillance area (thermal plume) catch rate was 0.37 while the reference area (control) was 0.19; the same trend as 1986 and 1987 (outage years), but opposite 1985 when there was a thermal discharge.

4. In May - June 1988 fish observational dive surveys six species were observed in the discharge area. Cunner (81%) were the most numerous species seen. No fish showed abnormal behavior and no gas bubble disease symptoms were observed on routine observational dives. Most fish were in greatest concentrations in the path of the PNPS discharge, being observed most often at station D_1. Blue mussel proliferation and algal growth in the discharge canal, and outside of it, were dense because of the PNPS outage which commenced in early April 1986.

5. Sand lance spp. accounted for 73.7% of the June 1988 haul seine (shore zone) fish catch; Atlantic tomcod 9.7%, winter flounder 6.8%, with a total of ten species collected. Diversity was greatest at Long Point. CPUE was highest in the PNPS intake embayment where sand lance spp. were dominant.

6. The June 1988 shorefront sportfish survey at Pilgrim Station recorded 90 angler-trips, mostly on weekends. The PNPS outage, which resulted in no thermal discharge to attract sportfish species, reflected low catches of only two species, winter flounder and cunner.

7. The research lobster study commenced in June 1988 and recorded 0.25 adult lobsters (0.12 in 1987) per pot as a catch rate in 545 pot-hauls. The catch rate for adult lobsters was similar in surveillance and reference areas.

Impingement Monitoring:

1. The mean January - June 1988 impingement collection rate was 0.30 fish/hr. The rate ranged from 0.04 fish/hr (June) to 1.13 fish/hr (March) with Atlantic silverside comprising 50.9% of the catch, followed by winter flounder 8.8%, Atlantic tomcod 7.0%, and rainbow smelt 7.0%.

2. In March 1988, when the fish impingement rate was 1.13, Atlantic silverside accounted for 80.0% of the fishes collected. Fish impingement rate was 1½ times higher than in 1987, but still relatively low because Pilgrim Station had much less circulating water pump capacity than normal.

3. The mean January - June 1988 invertebrate collection rate was 2.43/hr with polychaetes accounting for 31.5% and sand shrimp 30.9% of the catch. One American lobster was caught.

4. Initial impinged fish survival at the end of the Pilgrim Station intake sluiceway was 35.7% for static washes and 53.3% for continuous washes.

<u>Benthic Monitoring</u>:

1. Three new species of fauna were added to the list of sampled biota as a result of analysis of the March 1988 samples, bringing the total number of species to 469.

2. Species richness between the PNPS discharge and the Manomet Point/Rocky Point stations was notably different in March 1988, with the latter stations ranking highest.

3. Greatest faunal densities in March 1988 occurred at Manomet Point. Faunal densities were also lower at the Effluent than at Rocky Point. A significant difference was found for both Manomet Point and Rocky Point when compared to the Effluent. Changes in rank were not found among stations for density without mussels (<u>Mytilus edulis</u>).

4. There was some difference between pairs of stations for dominance patterns, with 6 of the 15 dominant species at each station not being shared. Species diversity was lowest at the Effluent Station and highest at Rocky Point.

5. No additional algal species were encountered in the study area during March 1988. Algal community overlap was high (>80%) among all three station pairs, but community overlap values showed that the Effluent station was lower than the reference stations when compared to each other.

6. Total algal biomass was lower at Rocky Point than at the Manomet Point and Effluent stations. Mean Chondrus biomass was much lower at the Effluent station than the other stations, and Phyllophora spp. biomass was highest at Manomet Point and lowest at Rocky Point station.

7. March and June 1988 mappings of the near-shore acute impact zones were performed. A small decrease in the total near-field impact zone (stunted growth) is evident when comparing March and June 1988 results probably because of the continuing PNPS outage during this period and, more specifically, the minimal circulating seawater pumping capacity from March - June 1988.

Entrainment Monitoring:

1. A total of 34 species of fish eggs and/or larvae were found in the January - June 1988 entrainment collections.

2. Egg collections for January - April 1988 (winter-early spring spawning) were dominated by American plaice, fourbeard rockling and

winter flounder. May and June (late spring - summer spawning) egg samples were most representative of Atlantic mackerel and labrids.

3. Larval collections for January - April 1988 were dominated by rock gunnel, sculpin, seasnail and sand lance. For May and June larvae, seasnail, winter flounder and mackerel dominated.

4. Nc lobster larvae were collected in the entrainment samples for January - June 1988.

5. In two cases high densities of sculpin larvae almost required contingency sampling to be initiated. However, in both instances concentrations of the larvae quickly returned to average levels.

INTRODUCTION

A. Scope and Objective

This is the thirty-second 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 Western Cape Cod Bay ecosystem with particular emphasis on the Rocky Point area. This is the twentieth 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 an Administrative-Technical Committee which was chaired by a member of the Mass. Division of Water Pollution Control in 1988 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 Station Administrative-Technical Committee meetings held during this reporting period are included in Section IV.

B. Marine Biota Studies

1. Marine Fisheries Monitoring

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 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 which provide more 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 weekly during June - November at 5 stations (Figure 1).

Monitoring is conducted of local lobster stock catch statistics for areas in the proximity of Pilgrim Station (Figure 4). Catch statistics are collected approximately biweekly 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 1987, an experimental, lobster pot trawl monitoring effort was initiated to eliminate any biases associated with the collection of lobster stock catch statistics for determining PNPS effects. Ten 5-pot lobster trawls were fished in the thermal plume and control areas around PNPS (Figure 3).

Results of the marine fisheries monitoring during the reporting period are presented in Section IIIA.

2. <u>Benthic Monitoring</u>

The benthic monitioring 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 is conducted four times a year (March, June, September and December). Results of the benthic surveys reported during this period are discussed in Section IIIB.

3. Plankton Monitoring

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. Information generated through these studies has been utilized to make periodic modifications in the sampling program to more efficiently address the question of the effect of entrainment. These modifications have been developed by the contractor, and reviewed and approved by the Pilgrim A-T Committee on the basis of the program results. Plankton monitoring in 1988 emphasized consideration of ichthyoplankton entrainment. Results of the ichthyoplankton entrainment monitoring for this reporting period are discussed in Section IIIC.

4. <u>Impingement Monitoring</u>

The Pilgrim 1 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 1 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 impingement monitoring and survival program for this reporting period are discussed in Section IIID.

C. <u>Fish Surveillance Studies</u>

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, biweekly 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.

Annual summary reports for these efforts for 1988 will be presented in Semi-Annual Report No. 33.

D. Station Operation History

The daily average, reactor thermal power levels from January through June 1988 are shown in Figure 6. As can be seen, PNPS was in an outage during this reporting period.

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.

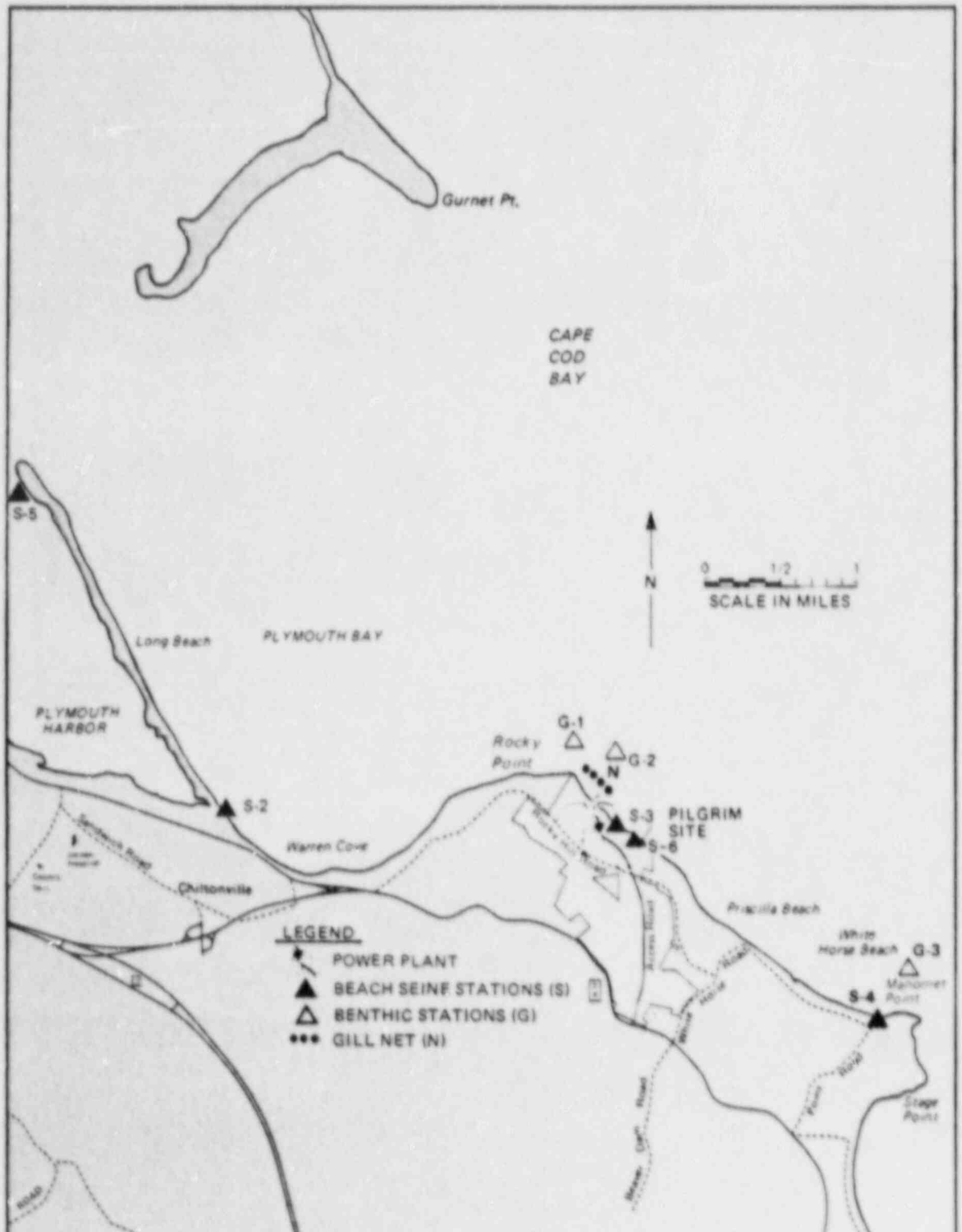


Figure 1. Location of Beach Seine and Gill Net Sampling Stations for Marine Fisheries Studies, and Benthic Studies Sampling Stations

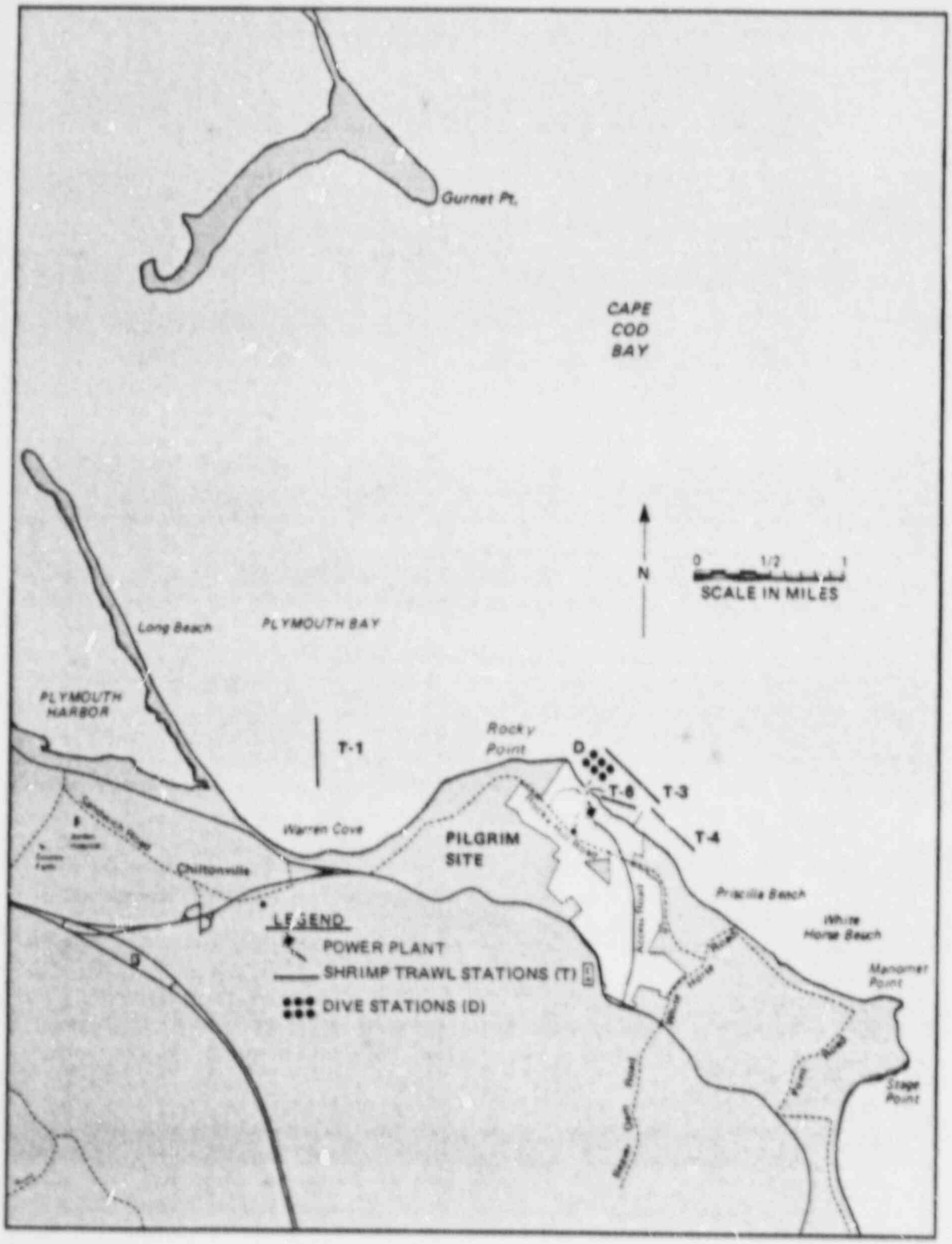


Figure 2. Location of Shrimp Trawl and Dive Sampling Stations for Marine Fisheries Studies

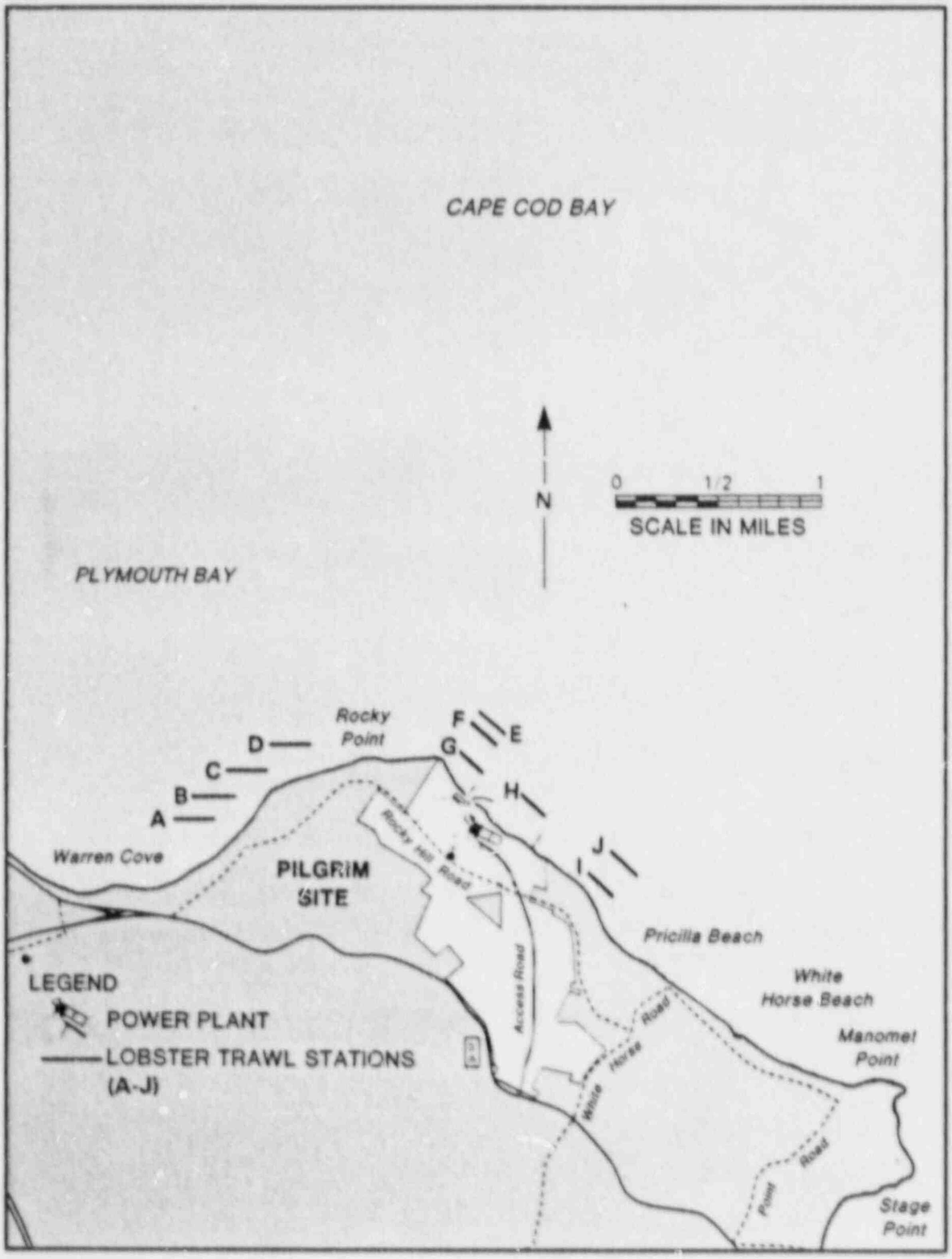


Figure 3. Location of experimental lobster gear (5-pot trawls) for Marine Fisheries Studies.

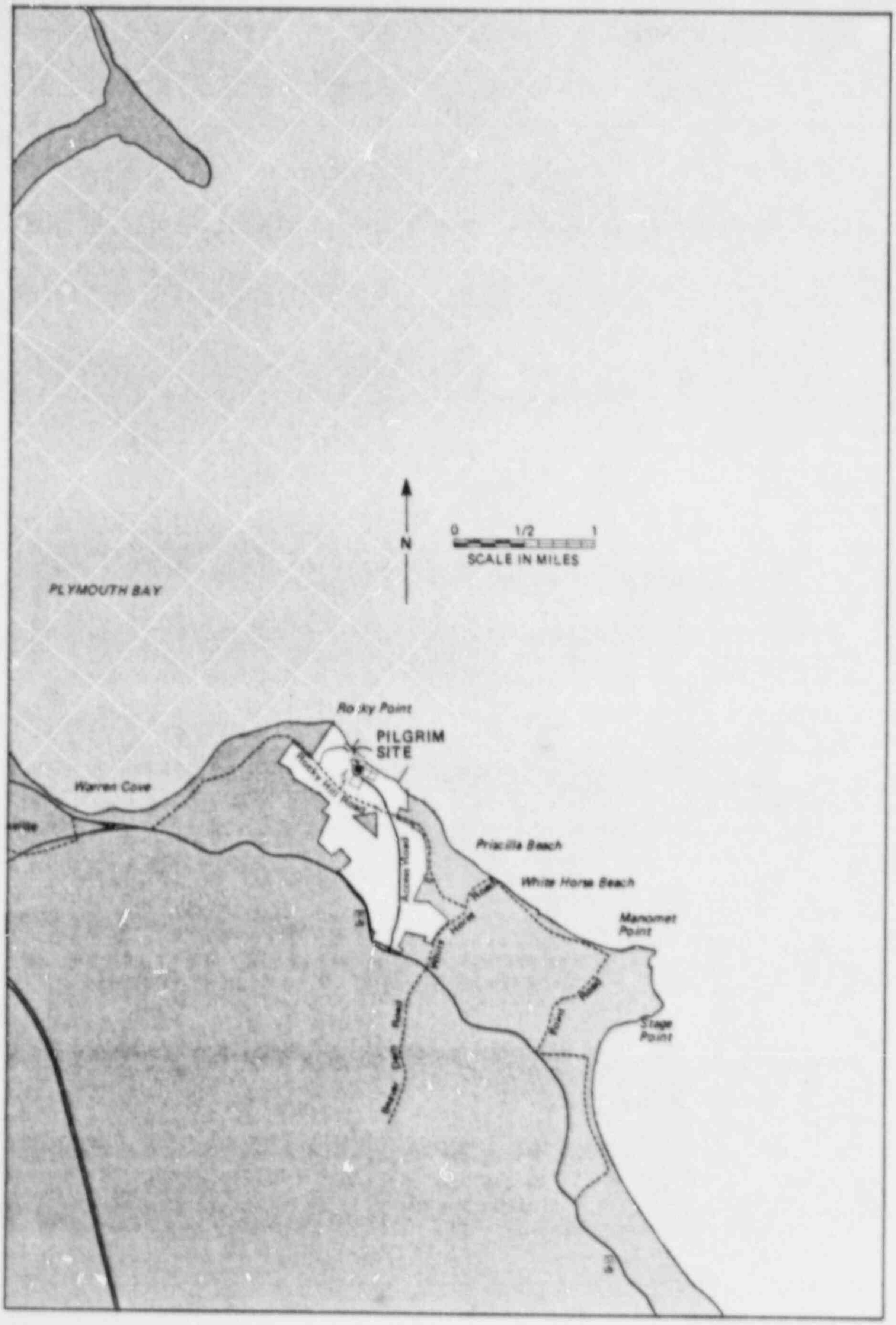


Figure 4 Lobster Pot Sampling Grid for Marine Fisheries Studies.

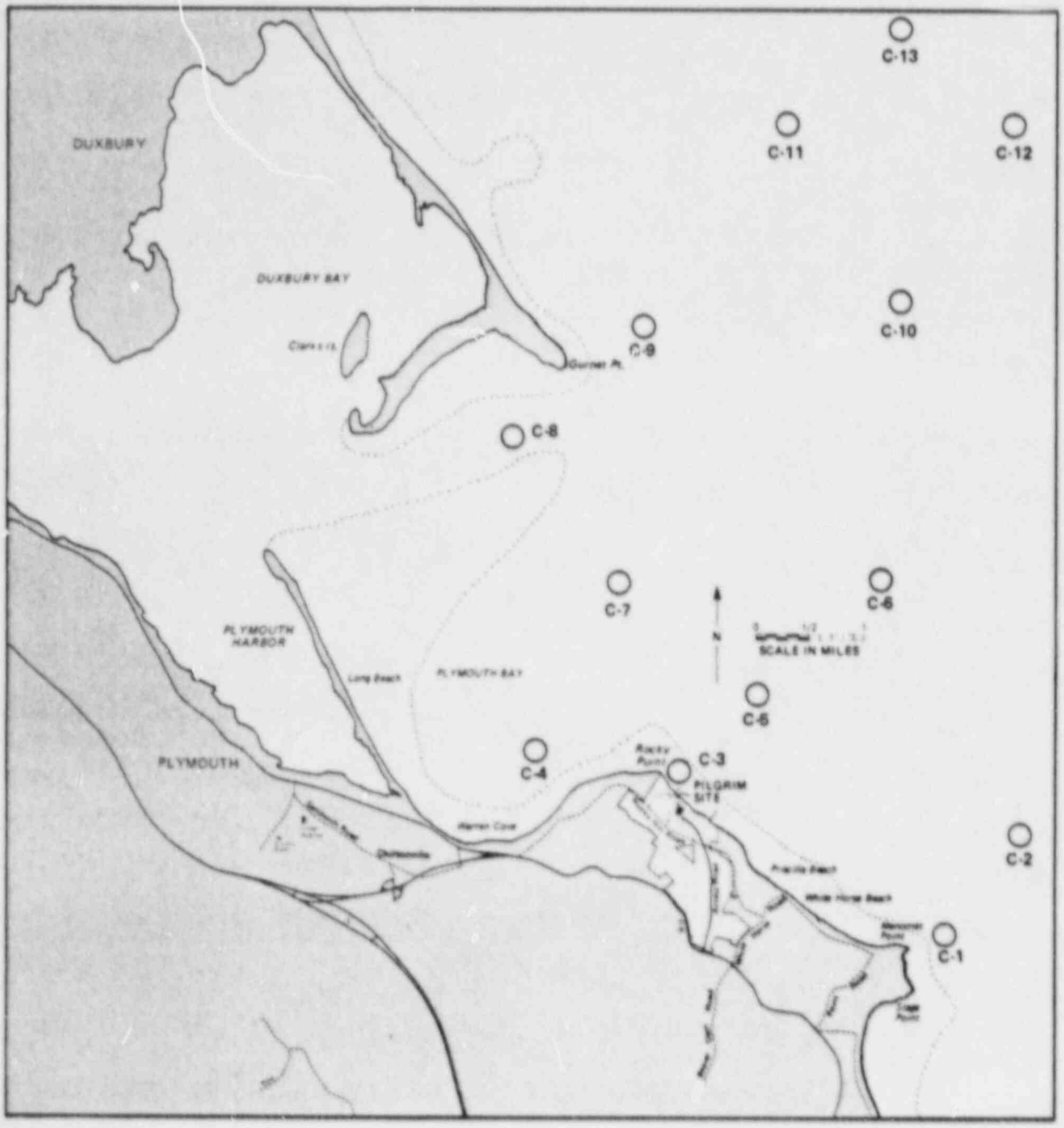


Figure 5 Location of Entrainment Contingency Plan Sampling Stations, C.

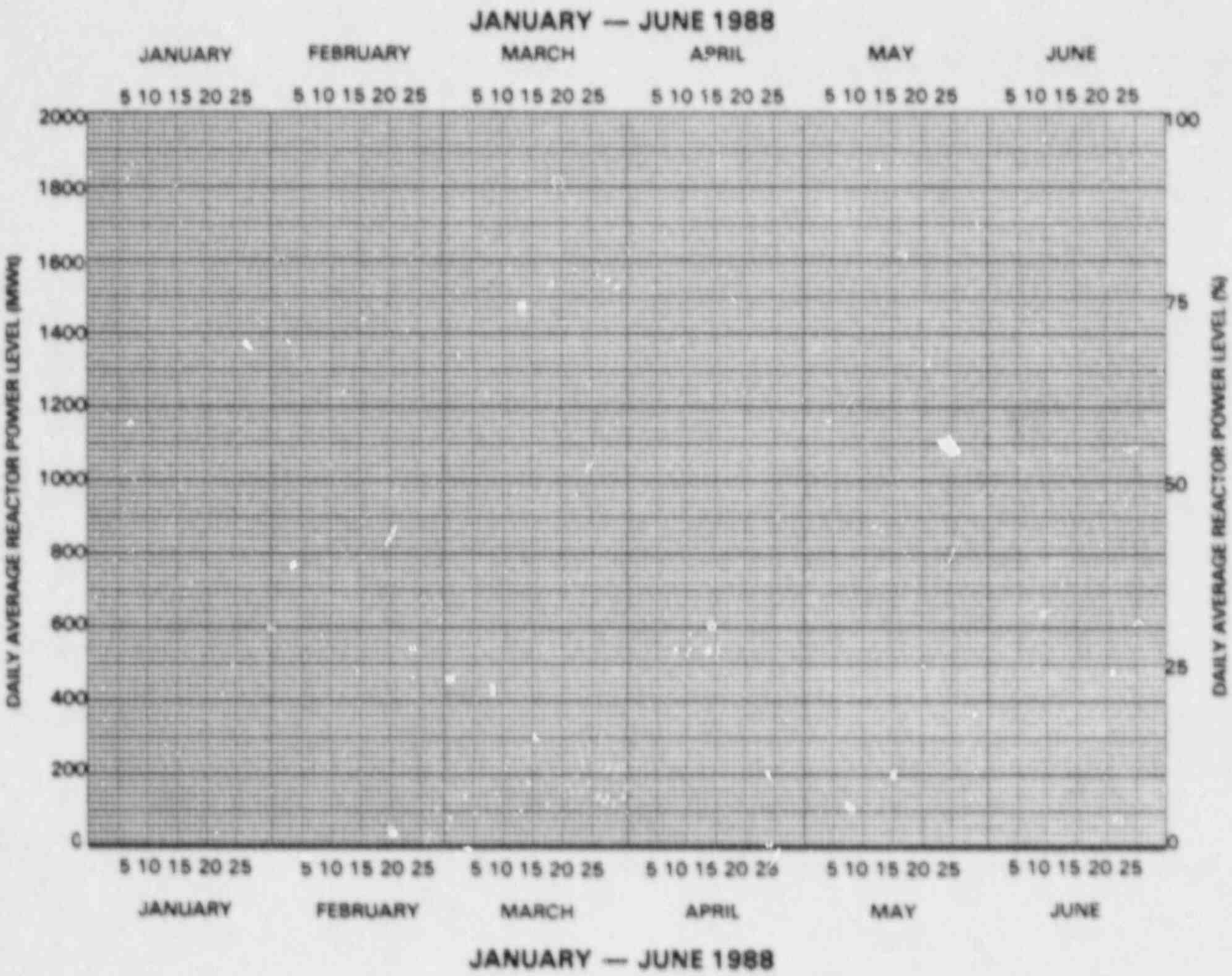
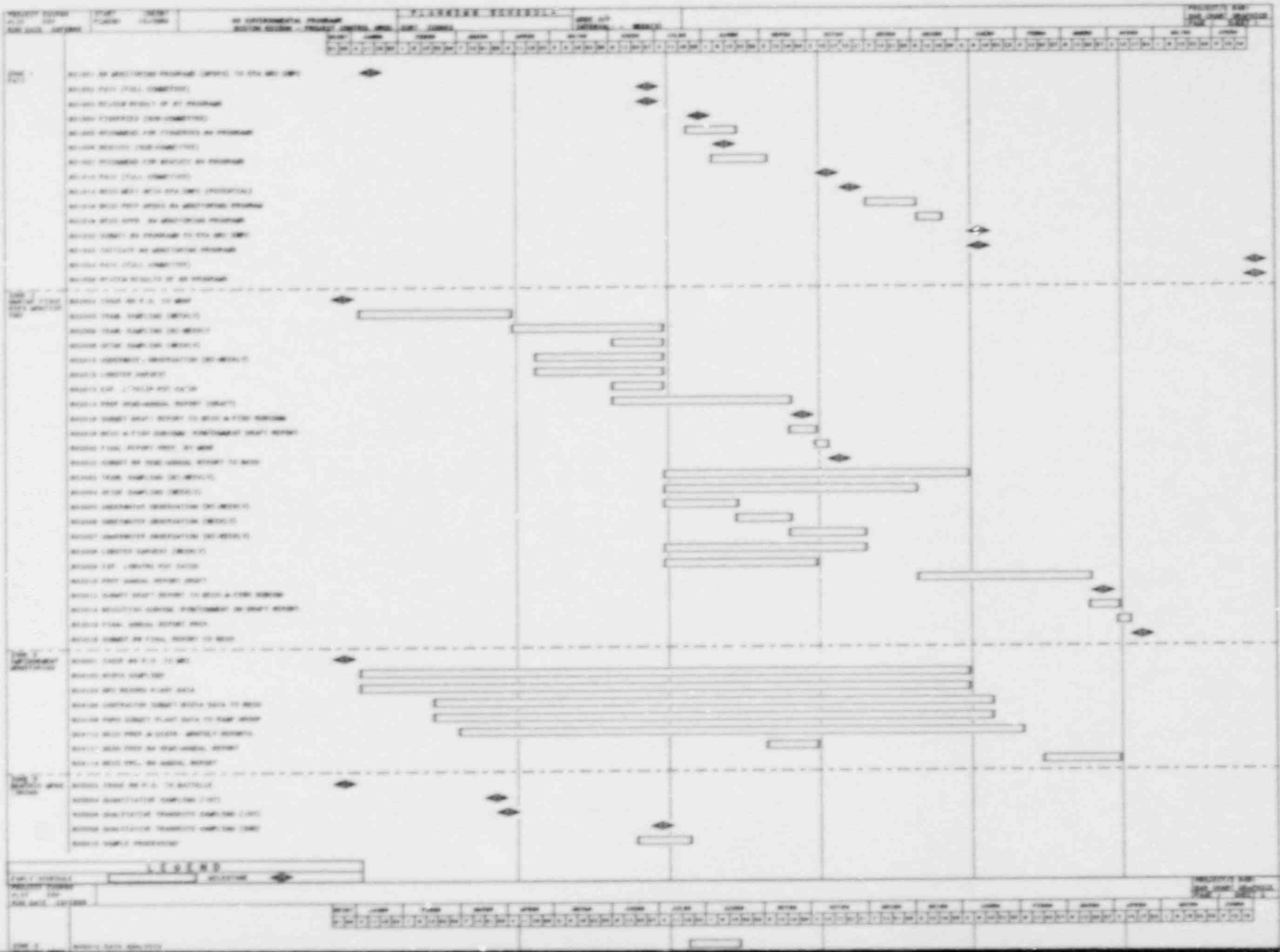
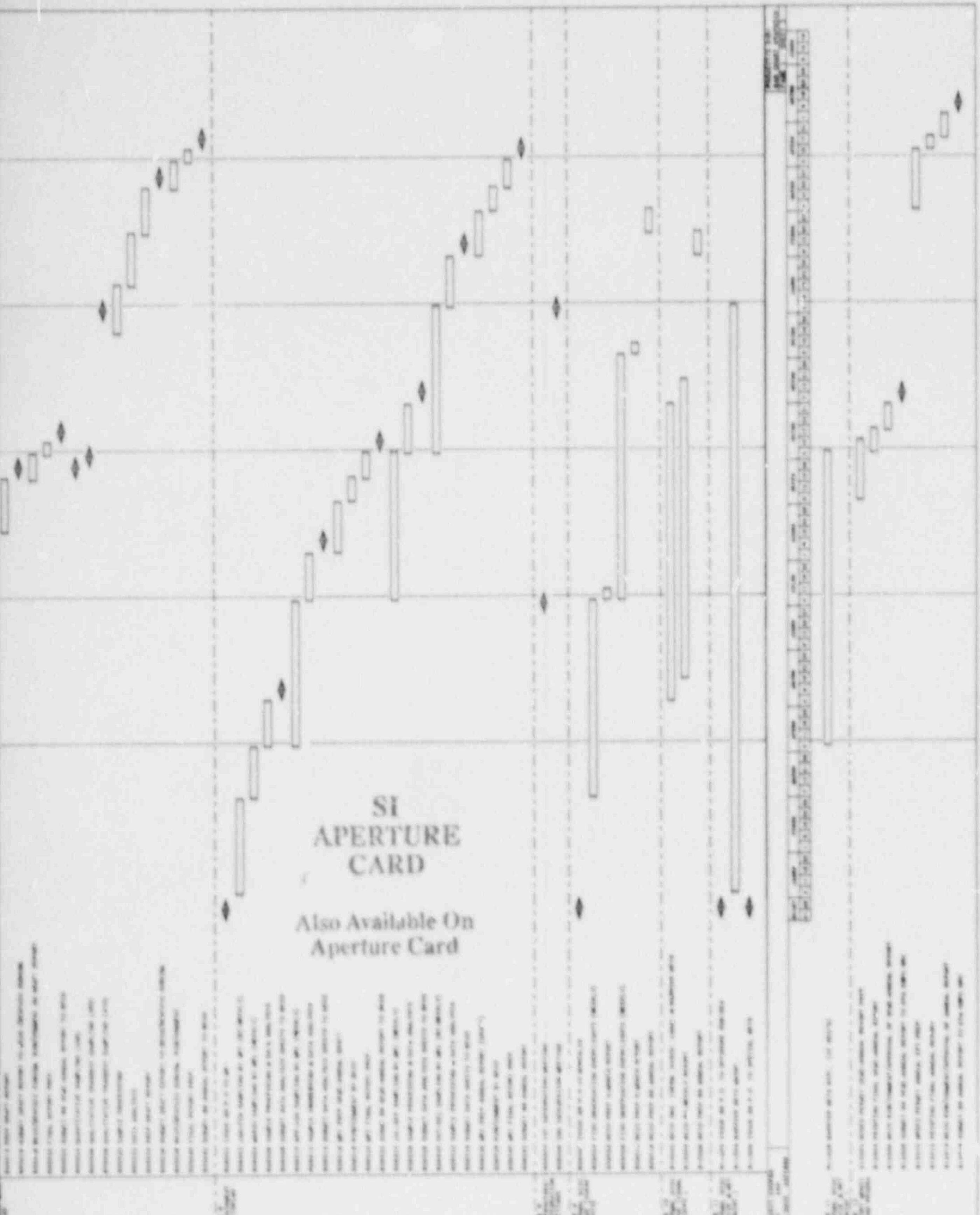


Figure 6. Daily Average Reactor Thermal Power Level (MW_t and %) from January-June 1988 for Pilgrim Nuclear Power Station.

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





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

Project Report No. 45 (January-June, 1988)

By

Vincent J. Malkoski, Brian C. Kelly, Robert P. Lawton,
Mando Borgatti, Kevin P. Creighton, and Theresa L. Ritchot

August 30, 1988
Massachusetts Department of Fisheries,
Wildlife, and Environmental Law Enforcement
Division of Marine Fisheries
100 Cambridge Street
Boston, Massachusetts 02202

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I. EXECUTIVE SUMMARY

Commercial Lobster Pot-Catch Fishery

From May-June (spring) of 1988, data were obtained from the trap catch of one commercial lobsterman who fished in the vicinity of Pilgrim Nuclear Power Station. Sample size included a total of 633 pots hauled and 888 lobster captured. The percent of legal-sized (CL $\geq$ 81.76mm) lobster in the total catch was 25%. Legal catch rate for the overall inshore area averaged 0.35 legals per pot-haul, which is higher than last year's spring rate of 0.29.

Controlled Research Lobster Fishing

We completed eleven sampling trips in June, with data obtained from 545 pot-hauls. Of the 1202 lobster captured in the study, 8% were of legal size. Legal catch rate averaged 0.25 lobster per pot-haul overall and 0.23 for the discharge area.

Nearshore Benthic Finfish

A bottom trawl survey of groundfish in the Pilgrim area was conducted January-June, 1988. A total of 545 finfish representing 15 species was collected during 43 trawl tows. Overall catch per unit effort for all stations and species pooled was 12.7 fish/tow, as compared to last year's mean of 36.7 fish/tow. Numerically dominant species in the catch were winter flounder, little skate, and windowpane. Winter flounder and windowpane were most abundant in Warren Cove and little skate was most abundant off White Horse/Priscilla Beach.

Pelagic and Benthi-pelagic Fishes

The 1988 gill net catch was dominated by three species of fish: Atlantic herring (52%), pollock (26.5%), and cunner (8%). Atlantic cod, Atlantic mackerel, and tautog each contributed approximately 2% to the total catch. Sixteen other species were captured in the gill net, but in sum they comprised less than 7% of the total.

Shorezone Fishes

Ten species of finfish, totaling 308 individuals, were captured in 16 standard haul seine sets in June. Sand lance, Atlantic tomcod, and winter flounder comprised over 90% of the total catch. Diversity (number of species sampled) was highest at Long Point. Catch per set (relative abundance) was highest in the Pilgrim Intake embayment. Both of these sampling sites are sheltered shorelines.

Underwater Finfish Observations

Biweekly observational dives were performed in May and June, 1988 at six stations in and around the Pilgrim Station discharge canal. Six species of finfish - cunner, pollock, rock gunnel, tautog, lumpfish and sea raven - were sighted. Cunner and pollock together comprised nearly 87% of the total observed. In the continued absence of a thermal effluent (the current outage began in April, 1986), algae including Irish moss, and blue mussels have flourished in the discharge canal.

Sportfishing

The Shorefront recreational area at Pilgrim Station was delayed in opening from April 1 to April 20 this year. Few anglers appeared to fish there in April and May. During June, fewer than 100 angler-trips were made to the Shorefront; most of these were on weekends. Fishing was primarily for groundfish;

only eight fish were reportedly caught (six cunner and two winter flounder). Overall, fishing effort and catch were lower than last spring. Clearly, the extended plant outage has negatively impacted sport fishing at Pilgrim Shorefront.

II. INTRODUCTION

Monitoring by the Massachusetts Division of Marine Fisheries is ongoing to assess environmental change induced by the operation of Pilgrim Nuclear Power Station. Ecological investigations of fisheries resources in the surrounding waters of Western Cape Cod Bay for 1988 are funded by Boston Edison Company under Purchase Order No. 65216. Sampling data collected from reference and surveillance stations during January-June, 1988 are summarized and discussed in relation to past findings. It is noted, however, that the plant has not operated since early April of 1986, negating waste heat discharge; current flow has been greatly reduced as one or both circulating sea water pumps have been off. Measurements, counts, percentages, and indices of abundance are used in this progress report to identify trends and/or relationships in the data both spatially and temporally.

III. RESULTS AND DISCUSSION

1. COMMERCIAL LOBSTER POT CATCH FISHERY

Seasonal monitoring of the commercial lobster fishery around Pilgrim Station was continued in 1988. We began monitoring the catch of a cooperating lobsterman in early May and continued through June with a total of 888 lobster sampled from 633 pot-hauls. Figure 1 depicts the distribution of pots sampled by quadrat.

The sampled catch included 224 legal ($\geq$ 81.76 mm carapace length - CL) lobster for a mean catch rate for the study area of 0.35 legals per pot-haul over the two months. This is a slight increase over last year's value of 0.29 but is on par with the

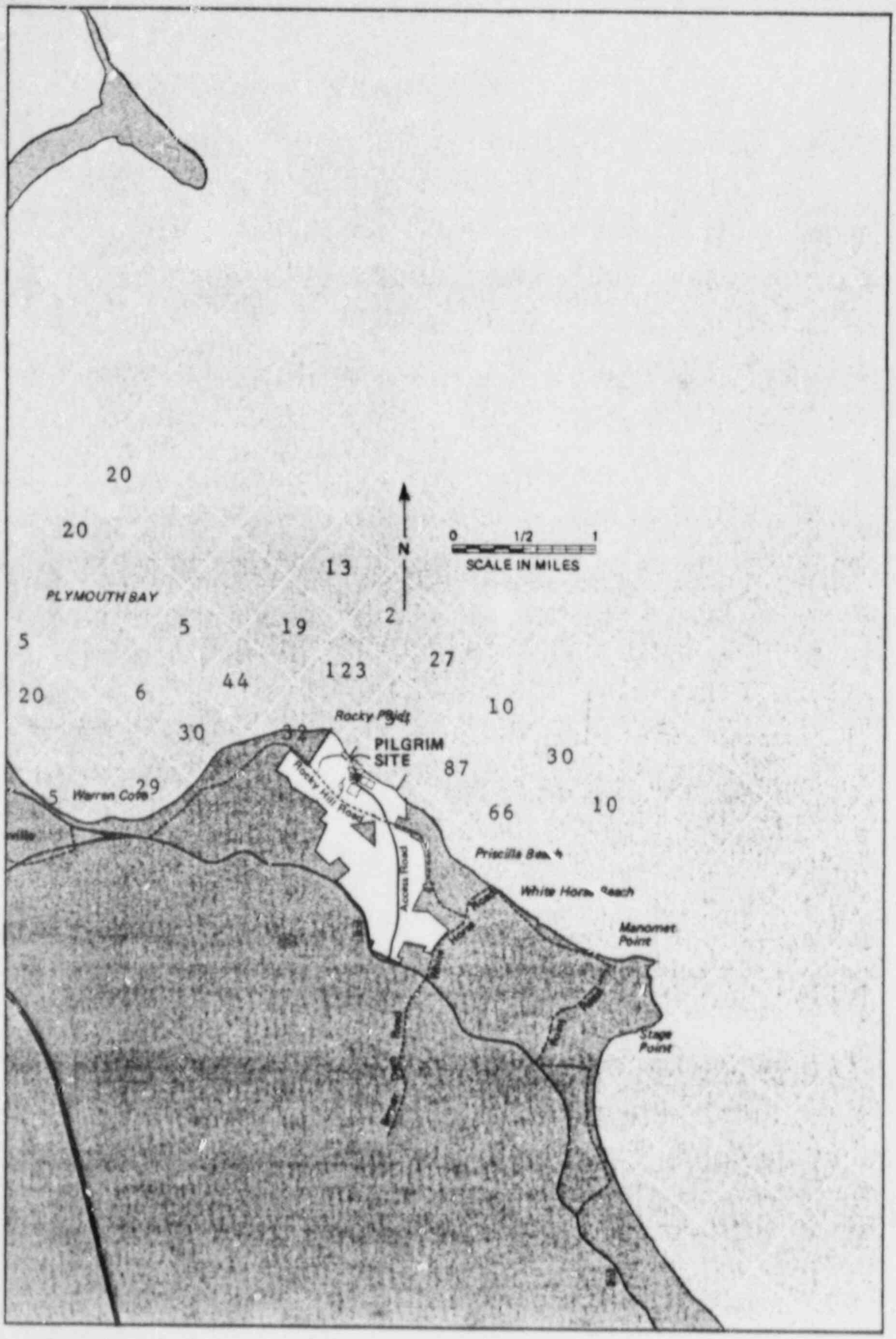

Figure 1 Lobster Pot Sampling Grid for Marine Fisheries Studies.

mean value of 0.36 legals per pot-haul obtained during the past 18 years of monitoring (Lawton et al. 1985, 1987). The increase over the 1987 value is probably the result of warmer Cape Cod Bay water temperatures in the spring of 1988 affecting the molt, and parallels findings noted in other Massachusetts waters (Bruce Estrella, personal communication)[1].

The mean legal catch rate for reference quadrats (E-13 & 14, F-13) of 0.19 (6 legal lobster per 26 pot-hauls) is equivalent to the 1987 rate of 0.19 for the same period. Spring catch rates for the surveillance quadrats (H-11 & 12, I-11 & 12) were somewhat similar in 1987 and 1988 (0.33 and 0.37, respectively).

2. CONTROLLED RESEARCH LOBSTER FISHING

During June 1988, we began controlled research lobster trap fishing in the environs of Pilgrim Nuclear Power Station (Figure 2). Eleven sampling days were completed during which 1202 lobster were sampled from 545 trap hauls. Incidence of null pots, i.e., traps in which no lobster were found, was 22%. The lobster sampled were predominantly (89%) sublegal in size (< 81.76 mm CL). A total of 135 lobster was legal-sized ($\geq$ 81.76 mm CL), with a ratio of sublegal to legal of 7.9:1. The overall mean number of lobster of all sizes caught per trap-haul for the study area was 2.2. Mean study area catch rates of legal and sublegal lobster were 0.25 and 1.96 lobster/trap-haul, respectively.

A comparison of total catch rates at the three sampling

---

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

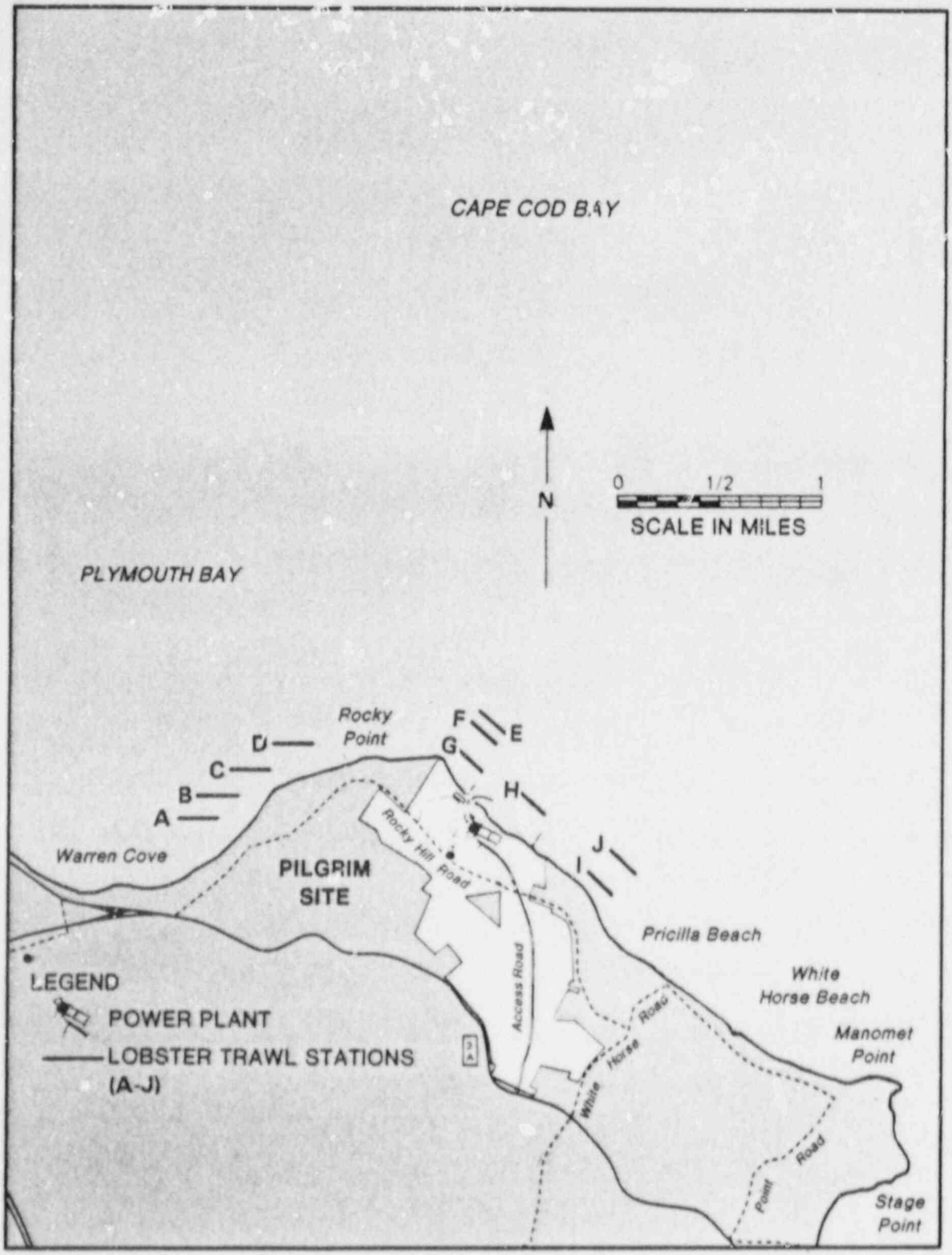

Figure 2. Location of experimental lobster gear (5-pot trawls) for Marine Fisheries Studies.

locations (Figure 3) revealed a difference between Rocky Point and the other two sites (Discharge and Priscilla/White Horse Beach), with a higher rate of capture at Rocky Point. A similar pattern was noted for sublegal catch rates. It is, however, difficult to determine the significance of differences due to the limited amount of data.

In 1986 and 1987, we tagged a portion of the sampled catch in order to determine the rate of recapture in our pots; recaptures could then be discounted and an unbiased estimate of catch obtained. As a result of two years of tagging data, we feel that catch rate need not be adjusted because of the low recapture rate and have thus discontinued tagging in 1988. It is interesting to note, however, that several sublegal lobster tagged in 1987 were recaptured in 1988. One of the returns was taken from the west side of Stellwagen Bank, a distance of 23 nautical miles from the area of tagging (Warren Cove).

3. NEARSHORE BENTHIC FINFISH

Our nearshore bottom trawl survey for 1988 commenced in mid-January and continued through June. Station locations (Figure 4) included Warren Cove, off White Horse/Priscilla Beach, in the area of the Discharge, and in the Intake embayment at Pilgrim Station. Sampling was conducted monthly during January through April and biweekly in May and June. Catches for tows greater than or equal to 10 minutes, but less than the standard 15 minute duration, were multiplied by an expansion factor (15 minutes/actual tow minutes) to standardize sampling effort. Any tow of less than 10 minute duration was rejected *a priori*.

A total of 545 finfish comprising 15 species was collected

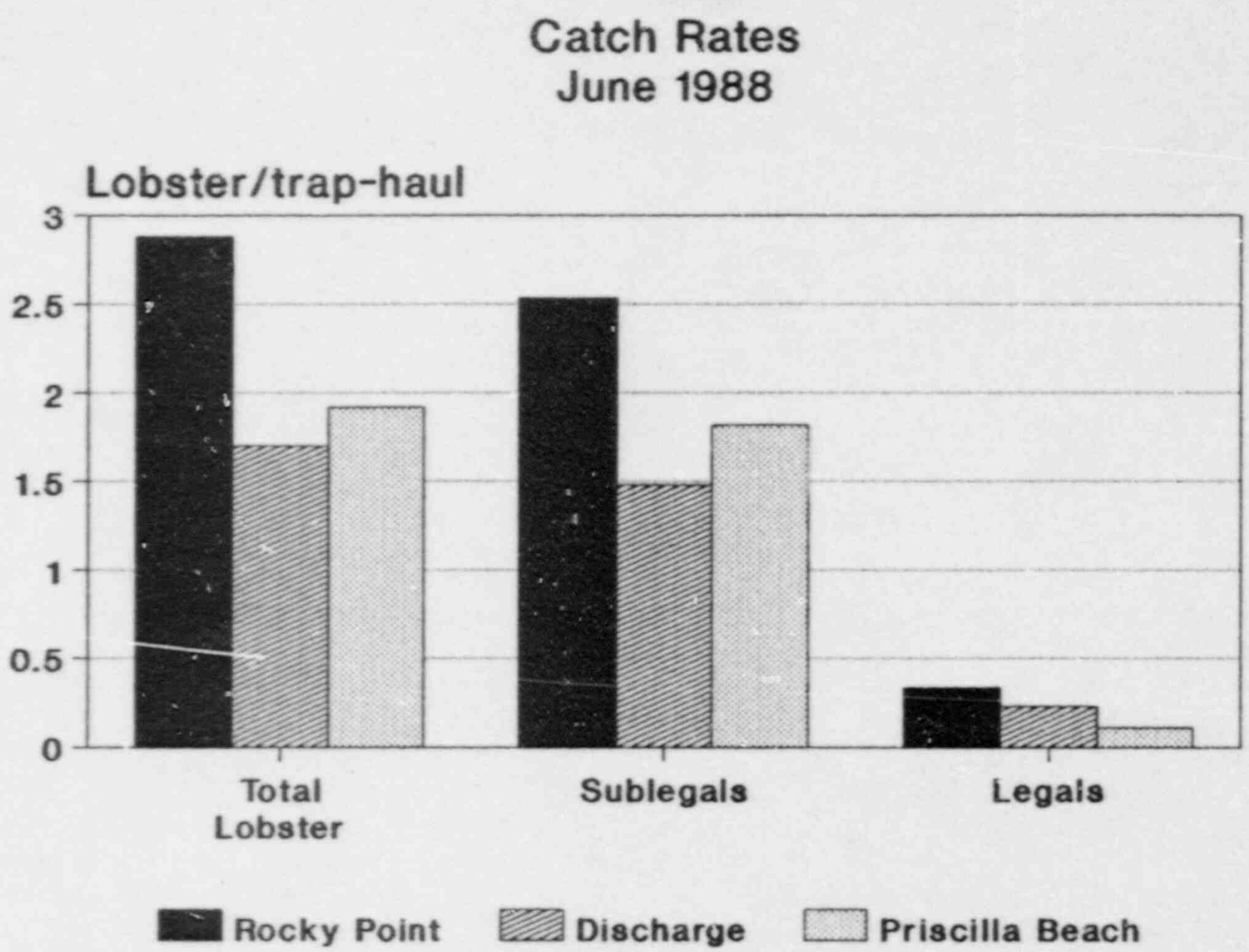

Figure 3. Catch rates of total, legal, and sublegal lobster in the research lobster traps fished in the area around Pilgrim Station, January - June, 1988.

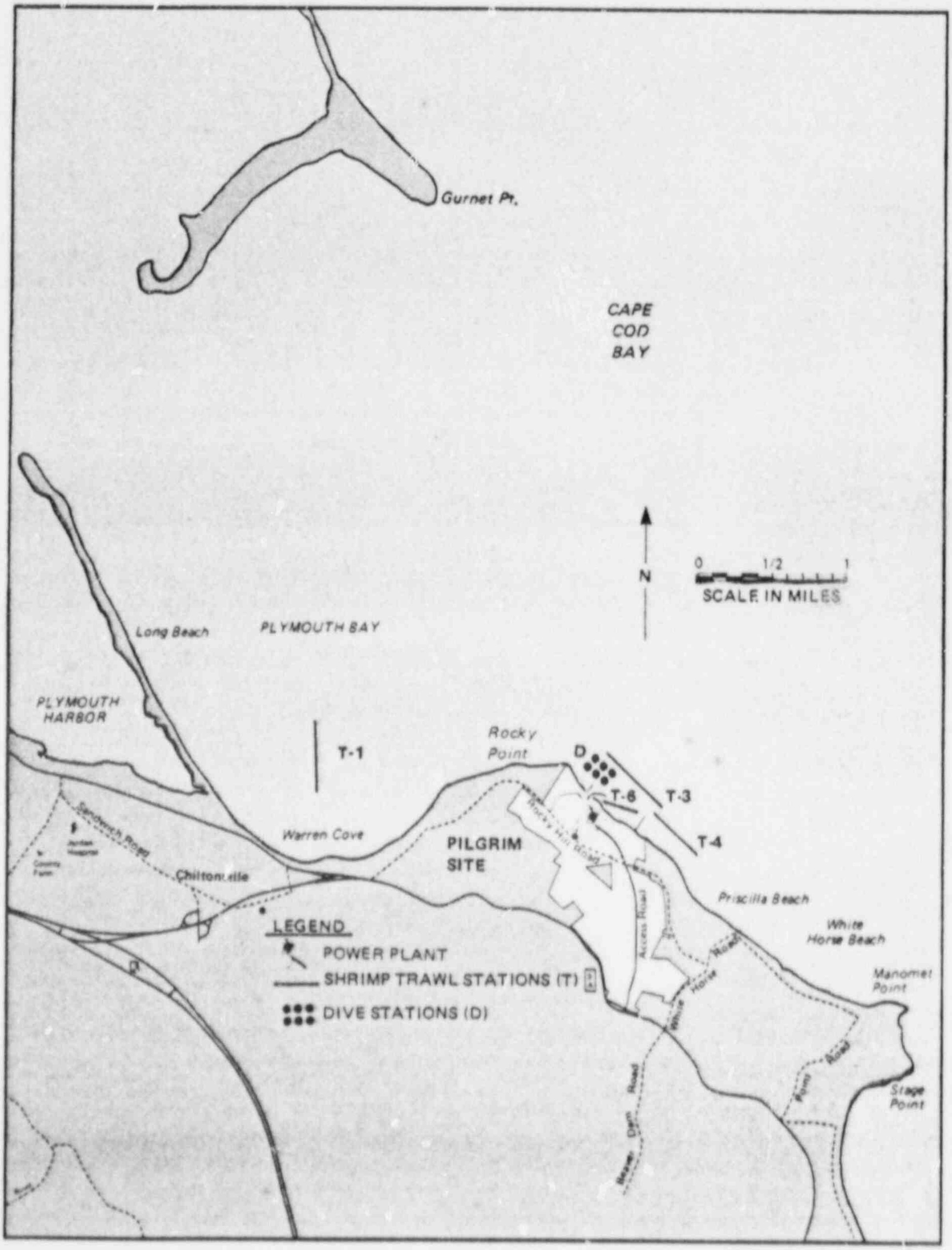

Figure 4. Location of Shrimp Trawl and Dive Sampling Stations for Marine Fisheries Studies.

during 43 tows in the study area (Table 1). Twenty species and 1,470 finfish were collected in 40 tows for the same period in 1987. In 1988, 3 of the stations had collections that were equally diverse with 10 demersal fish species sampled; at Warren Cove, 8 species were captured.

CPUE (mean catch per standard 15 minute tow) for all stations and species pooled was 12.7 fish/tow, as compared to last year's mean of 36.7 fish/tow. CPUE for all species pooled ranged from 14.3 at the White Horse site to 10.9 in the Intake. For the same sampling period in 1987, CPUE was greatest in the Discharge area (39.5) and lowest in Warren Cove (32.3). Four species : winter flounder (*Pseudopleuronectes americanus*), little skate (*Raja erinacea*) windowpane (*Scophthalmus aquosus*), and yellowtail flounder (*Limanda ferruginea*) comprised 91% of the total catch through the first half of 1988.

Winter flounder was numerically dominant (42%) in trawl samples. Relative abundance was highest in Warren Cove at 7.4 fish/tow and lowest in the Intake embayment at 2.4 (Table 2). The overall winter flounder abundance index (catch/tow) was 50% lower than last year.

Little skate ranked second comprising 30% of the trawl catch. Spatially, CPUE ranged from 4.9 off White Horse/Priscilla Beach to 1.8 in Warren Cove (Table 2). For the same sampling period in 1987, the catch rate between sites was more variable, again being lowest in Warren Cove (2.2) and highest off White Horse (10.2). The overall little skate abundance index declined threefold from 1987.

Table 1. Expanded trawl catch[1] and percent composition of finfish captured by nearshore trawling in the vicinity of Pilgrim Station, January-June, 1988.

Species	Warren Cove	Pilgrim Discharge	Priscilla Beach	Pilgrim Intake	Totals	% Catch
Winter flounder	88.5	45.7	75.9	17.1	227.2	41.7
Little skate	21.5	50.9	63.3	28.5	164.2	30.1
Windowpane	26.8	19.9	20.5	13.1	80.3	14.7
Yellowtail flounder	1.0	8.5	13.2	3.8	26.4	4.8
Atlantic cod	1.0	7.5	1.0	2.0	11.5	2.1
White hake	0.0	1.4	7.0	0.0	8.4	1.5
Ocean pout	3.0	1.4	1.0	2.5	7.9	1.4
Other spp.[2]	2.0	4.5	4.1	8.9	19.5	3.6
Pooled Species						
Number of species	8	10	10	10	15	
Number of tows	12	11	13	7	43	
Total # fish	143.8	139.7	186.1	76.0	545.4	
Catch/tow	12.0	12.7	14.3	10.9	12.7	
Percent catch	26.4	25.6	34.1	13.9		

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

[2]Represent combined totals from 8 species of low catch.

Table 2. Expanded trawl catch data (total length and catch per unit effort) for dominant demersal community finfish occurring in the vicinity of Pilgrim Station, January-June, 1988.

	Winter flounder	Little skate	Windowpane
STATION 1			
Mean catch/tow	7.4	1.8	2.2
Mean size (cm)	30.5	40.7	24.0
Size range (cm)	14-44	25-55	16-33
STATION 3			
Mean catch/tow	4.2	4.6	1.8
Mean size (cm)	29.8	33.5	22.5
Size range (cm)	11-41	17-52	15-30
STATION 4			
Mean catch/tow	5.8	4.9	1.6
Mean size (cm)	30.9	33.6	23.3
Size range (cm)	11-46	20-52	13-28
STATION 6			
Mean catch/tow	2.4	4.1	1.9
Mean size (cm)	28.4	32.1	23.7
Size range (cm)	9-38	23-47	15-33

Windowpane ranked third at 15% of the total. Relative abundance was greatest in Warren Cove (2.2) and lowest off White Horse/Priscilla Beach (1.6). The total windowpane abundance index also declined three-fold from last year.

Preliminary observations based on trawl catches from Cape Cod Bay during the 1988 spring Massachusetts Division of Marine Fisheries Resource Assessment bottom trawl survey contrast with our findings by indicating a noticeable increase in the winter flounder abundance index (catch/tow) and unchanged abundance levels for little skate and windowpane relative to last spring (Arnold Howe, personal communication)[1]. The pronounced decline this year in the catches of the three dominant demersal species from the Pilgrim area cannot be readily reconciled with data from Cape Cod Bay proper. This discrepancy may be partly attributed to inherent trawl catch variability or may be a very localized phenomenon. The average January-June bottom water temperature from the Pilgrim area in 1988 (8.3 C) is unchanged relative to the same time period in 1987, remaining warmer than the 7-year average of 7.7 C (1982-88).

Comprising 5% of the trawl catch, yellowtail flounder was fourth in the dominance hierarchy. Catch per tow of this species was highest off White Horse/Priscilla Beach and in the Discharge. Atlantic cod ranked fifth in catch abundance (2%). The highest CPUE for cod occurred at the Discharge station.

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[1]A. Howe, Senior Marine Fisheries Biologist, Resource Assessment Project, Massachusetts Division of Marine Fisheries, Sandwich, MA.

4. PELAGIC AND BENTHI-PELAGIC FISHES

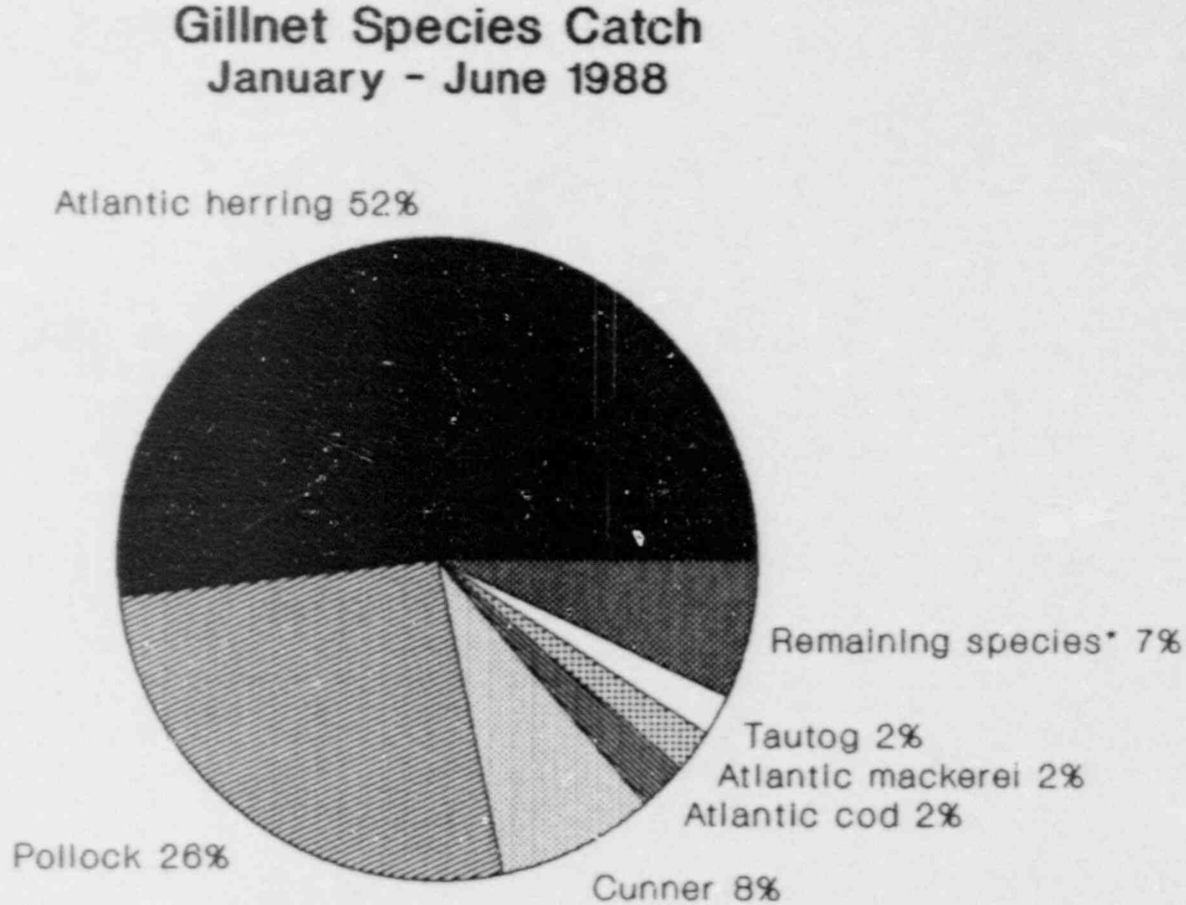
A total of 2,204 fish, comprising 22 species (Figure 5) was netted in 7 overnight sets made in the vicinity of Pilgrim Station (Figure 6) during the period January through June, 1988. Atlantic herring (*Clupea harengus harengus*), pollock (*Pollachius virens*), and cunner (*Tautogolabrus adspersus*) comprised 86.5% of the total catch.

Overall catch per overnight set (catch per unit effort or CPUE) for pooled species was 315 fish per set. This catch rate is somewhat less than that for the first half of 1987 (356) but is substantially higher than for 1986, when CPUE was 98.

Atlantic herring was numerically predominant, comprising 52% of the total catch. This migratory fish has regularly been found in abundance in project gill net collections. Pollock ranked second in abundance making up 26.5% of the total, while cunner was third at nearly 8% of the catch.

It should be noted, however, that although Atlantic herring ranked first in total gill net catch for the period of January-June, the largest number (1,146 or 99.7% of the species total) was taken during a single set in February. As such, this reflects their seasonality and known schooling behavior (Bigelow and Schroeder 1953). Pollock and cunner were more consistent in occurrence, ranking first and second, respectively, in four of the seven gill net sets.

Atlantic cod (*Gadus morhua*), Atlantic mackerel (*Scomber scombrus*) and tautog (*Tautoga onitis*) each comprised roughly 2% of the catch (Figure 5). The remaining 16 species did not occur in abundance with their sum comprising less than 7% of the total.



*Remaining spp. not found in abundance

Figure 5. Gill-net catch data (7 panels of 3.8-15.2 cm mesh) from the vicinity of Pilgrim Station, January - June, 1988.

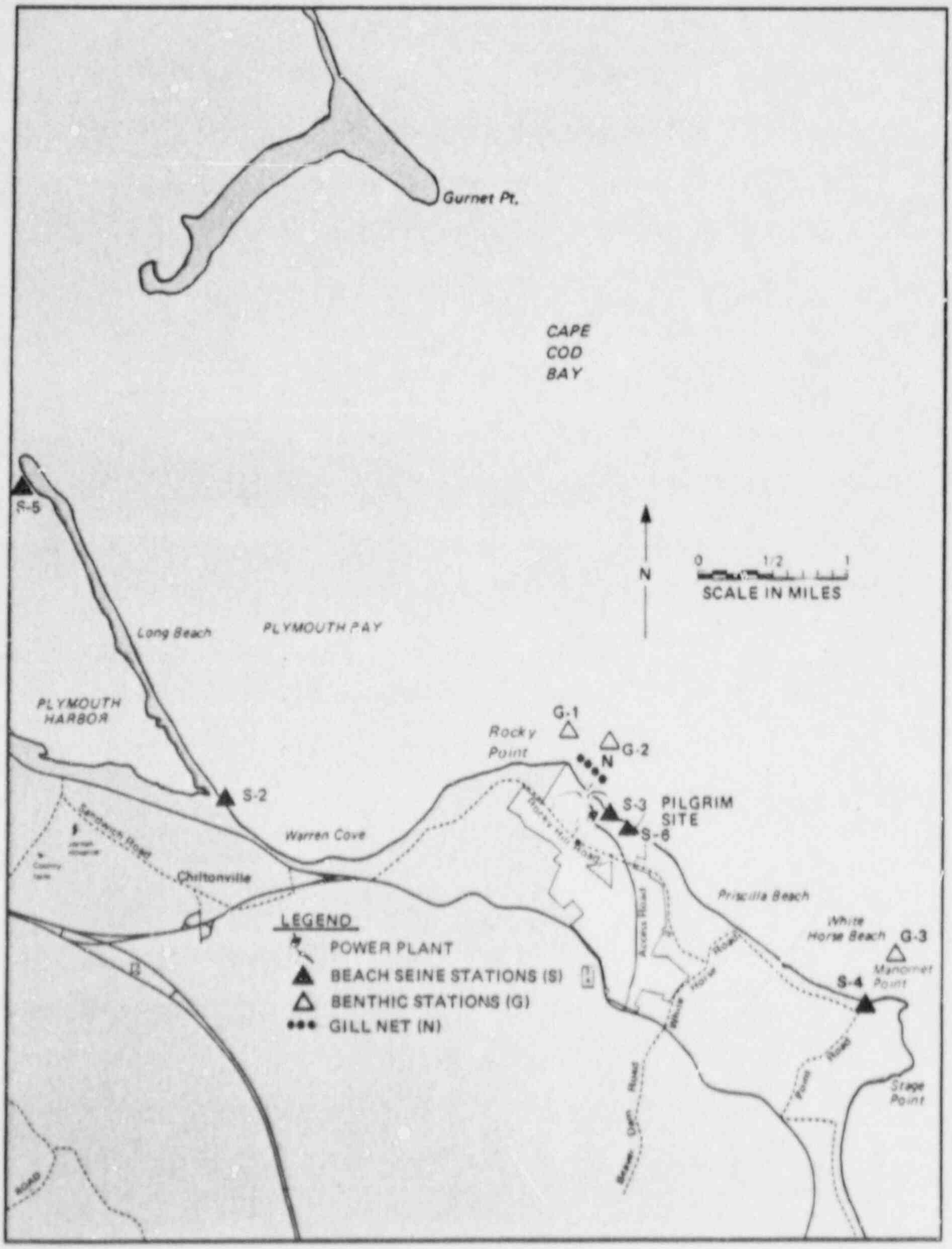


Figure 6. Location of Beach Seine and Gill Net Sampling Stations for Marine Fisheries Studies, and Benthic Studies Sampling Stations.

5. SHOREZONE FISHES

Four stations were sampled by haul seining (Figure 6), with a total of 308 finfish representing 10 species captured. Sixteen sets of the 45.7 m haul seines were completed at ± 2 hours of low tide during 2 sampling days in the month of June (Table 3). For the same time period and equivalent sampling effort last year, we captured 2,186 finfish representing 12 species. However, of the 1987 total catch, over 1,900 individuals (89%) were sand lance (*Ammodytes spp.*) taken at the Intake station, or over 1,700 more sand lance than were captured this year. Water temperature (surface) and salinity at the time of sampling in 1988 ranged overall from 11.0 to 18.0 C and 30.0 to 34.0 ppt, respectively. Temperatures were higher at Long Point (Station S-5) than at the other three sampling locations.

Three taxa - sand lance , Atlantic tomcod (*Microgadus tomcod*), and winter flounder (*Pseudopleuronectes americanus*) - comprised over 90% of the total seine catch. Although sand lance led the catches, accounting for 74% of the total, they were captured only in the Intake embayment. In fact, 80% of the total seine catch in June for all species pooled was obtained at this site. Atlantic tomcod ranked second in overall catch (10%), occurring nearly exclusively at Long Point. Winter flounder ranked third (7%), occurring at the Intake and Long Point stations.

Diversity, as measured by the total number of species captured at a sampling location, was highest in June at Long Point followed by Pilgrim Intake embayment. Catch per set (pooled

Table 3. Shore-zone fishes captured by haul seining at sampling stations in the environs of Pilgrim Station for June, 1988.

Species	Warren Cove	Pilgrim Intake[1]	Long Point	Manomet Point	Total Number	Percent of Total catch
Sand lance spp.*		227			227	73.7
Atlantic tomcod			29	1	30	9.7
Winter flounder		13	8		21	6.8
Northern pipefish			12		12	3.9
Windowpane		5	1		6	1.9
White hake	2		3		5	1.6
Grubby		1	2		3	1.0
Atlantic silverside	1		1		2	
Threespine stickleback			1		1	1.2
Atlantic herring		1			1	
Total # fish	3	247	57	1	308	
Number of sets	4	4	4	4	16	
Catch/set	0.8	61.8	14.2	0.3	19.3	
Total # species	2	5	8	1	10	
Percent of total catch	1.0	80.2	18.5	0.0	100.0	

* Not separated by species

[1] 45.7 m x 3.0 m seine; others sampled by 45.7 m x1.8 m seine.

species), as an index of overall relative abundance, was highest in the Intake and lowest at Manomet Point. It is problematic to comprehensively analyze species diversity and relative abundance trends based on one month's sampling.

In a continuing effort to more effectively sample shore-zone juvenile flatfish, we used a smaller double-leadline foot seine (6.1m) at five locations (Figure 6) at low tide (± 2 hours of ebb tide). We completed 20 sets on two sampling days in June catching four windowpane (*Scophthalmus aquosus*,) four winter flounder, and a few white hake (*Urophycis tenuis*) and Atlantic tomcod. Although foot seine catches were extremely low, we expect a substantial increase in catch as coastal waters warm this summer.

6. UNDERWATER FINFISH OBSERVATIONS

Biweekly observational SCUBA dives were made at six stations in and around the discharge canal in May and June, 1988. Six species of finfish (Figure 7) were noted, as well as blue mussels (*Mytilus edulis*), American lobster (*Homarus americanus*), starfish (*Asterias* spp.), and rock and jonah crabs (*Cancer irroratus* and *C. borealis*). We also observed numerous species of algae, including stands of kelp (*Laminaria* spp.) and Irish moss (*Chondrus crispus*).

The station outage that began in April 1986 continued through June 1988, resulting in a continuation of recolonization in the discharge area (Lawton et al. 1988). Enhanced algal growth (both biomass and number of species) was evident throughout the observational area, in particular the recolonization of the stunted and denuded zones by Irish moss.

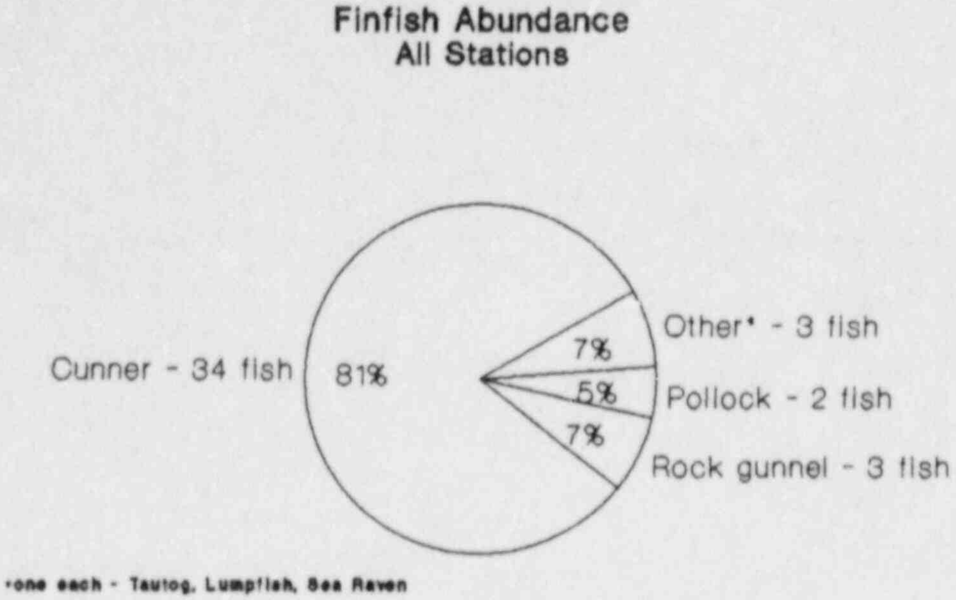


Figure 7. Finfish abundance as observed by divers in the area around the Pilgrim Station discharge canal, January-June, 1988.

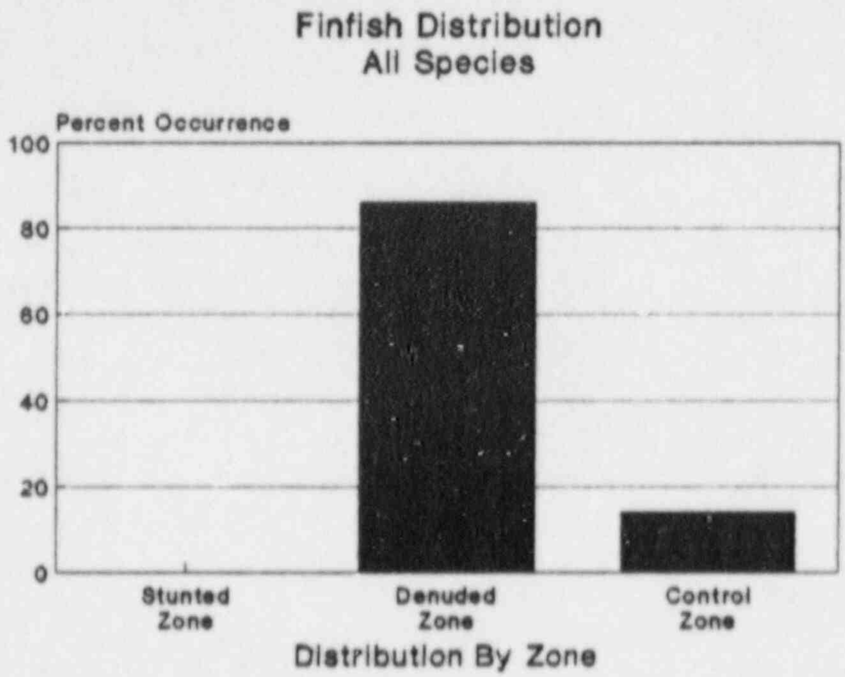


Figure 8. Finfish distribution as noted by divers in the area around the Pilgrim Station discharge canal, January-June, 1988.

Also in abundance was kelp, found attached to the many boulders in and around the discharge canal and on the large erratic at Station D_1.

The total number of finfish observed (42) was considerably lower than the number (204) for May and June of 1987. Local distribution (Figure 8) was also somewhat different in that no fish were observed in the stunted zone this spring. It should be noted, however, that due to the limited number of observations and the qualitative nature of the data it is difficult, if not impossible to attach statistical significance to differences in numbers between years.

Cunner (*Tautogolabrus adspersus*) comprised 81% of the total fish sightings (Figure 7), being found most often at Station D_1. Only one tautog (*Tautoga onitis*) was sighted by project divers. There appears to be a decrease in abundance of this species in recent years (Lawton et al. 1988). The remaining species: rock gunnel (*Pholis gunnellus*), lumpfish (*Cyclopterus lumpus*), pollock (*Pollachius virens*), and sea raven (*Hemitripterus americanus*) were sighted sporadically. As in the first half of 1987, no striped bass (*Morone saxatilis*) or bluefish (*Pomatomus saltatrix*) were observed by divers.

7. SPORTFISHING

Sportfish catch data from the Pilgrim Station Shorefront recreation area were obtained in June by BECo public relations' personnel at the water front. A questionnaire was employed to record the information on a daily basis. This cooperative effort with the Division of Marine Fisheries enables us to maintain a data base on recreational shore fishing in the Pilgrim area.

The opening of the Shorefront to the public in 1988 was delayed from April 1 to April 20. No quantitative catch data were obtained until June 11, however; at that time, BECo personnel were stationed at the Shorefront. Pilgrim Station has been in an extended outage since April 1986, which has negated waste heat removal and resulted in reduced discharge current flow throughout this period. During April and May, 1988, both circulating seawater pumps were essentially inoperative, and only a minimal flow of water issued from the discharge canal as one or two of the five service water pumps were operated. One circulating pump was operated during much of June. A lack of thermal current at Pilgrim Station has the effect of markedly decreasing the sportfish catches of gamefish at the Shorefront (Lawton et al. 1987).

Although no data were systematically collected in April and May, our observations in the area indicate that few anglers fished at the Shorefront. In fact, at times the Shorefront was closed to the public. In June about 90 angler-trips were recorded, with over 80% of these occurring on weekends. Most anglers bottom fished from the outer intake breakwater. Only eight fish: six cunner (*Tautogolabrus adspersus*) and two winter flounder (*Pseudopleuronectes americanus*) were landed. In June of last year, some 250 angler-trips were made to the Shorefront, and 38 fish were caught.

Overall, fishing effort and sportfish catch at Pilgrim Station were even lower this spring than last year. Clearly, the extended power station outage negatively impacts sportfishing at the Pilgrim Shorefront.

V. 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 John Dinga, Virginia Fay, Dan McKiernan, and Ann-Marie Schultz. We thank Chris Kyranos for allowing us to sample his lobster catches, and Raymond Dand and Robert Ellenberger for overseeing the collection of creel data at the Shorefront area. 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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SEMI-ANNUAL REPORT
Number 32

to

BOSTON EDISON COMPANY

on

BENTHIC ALGAL AND FAUNAL MONITORING AT THE PILGRIM NUCLEAR POWER STATION
January - June 1988

3 October 1988

BATTELLE
Ocean Sciences
397 Washington Street
Duxbury, Massachusetts 02332

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EXECUTIVE SUMMARY

This report presents the results of the benthic monitoring veys conducted at the Pilgrim Nuclear Power Station (PNPS) in ch and June 1988. Data discussed in this report were collected er two years of the outage at PNPS that began in April 1986. ing the period between January 1 and June 30, 1988, only one culating water pump was operating for a portion of each month, raging between 0.2 and 0.7 percent of the time per month.

QUANTITATIVE MONITORING

Quantitative samples of benthic fauna and algae were collected March 18 at three stations: Effluent, Manomet Point, and Rocky int. The Manomet Point and Rocky Point stations are reference ations that are beyond the influence of the PNPS effluent.

Faunal Analysis

The numbers of species and individuals found in the faunal mples taken at the Effluent station were lower than those found the samples from the other two stations. All three stations re dominated by the bivalve Mytilus edulis, which accounted for percent or greater of all individuals found at each station. versity, a measure of how the individuals in a sample are stributed among the species in the sample, was lowest at the fluent station. The pattern seen in these results is similar to at seen throughout the course of this study.

A similarity analysis showed that faunal samples taken at each the three stations were more similar to each other than to amples from the remaining stations. That is, each of the three tations had a unique identity in terms of the faunal community. s in past surveys, the Manomet Point and Rocky Point stations ere more similar to each other than to the Effluent station.

Algal Analysis

Total algal biomass was highest at Manomet Point and lowest at the Effluent station. Chondrus crispus (Irish moss) was equally abundant at Rocky Point and Manomet Point, where it represented 43 and 36 percent of the total biomass, respectively. Chondrus accounted for only 10 percent of the algal biomass at the Effluent station, representing a significant decrease from both the March and September 1987 values for that station. Phyllophora spp. accounted for 38 to 50 percent of the algal biomass at the three stations.

The highest biomass of epiphytic algae was found at Manomet Point and the lowest epiphytic biomass was found at the Effluent station. The warm-water indicator Gracilaria folifera was not seen in any of the March 1988 samples. The colonization index study indicated that, as in the past, Phyllophora spp. was more heavily colonized by algal epiphytes and invertebrates (such as bryozoans) than was Chondrus. Colonization was lowest at the Effluent station and approximately equal at Manomet Point and Rocky Point.

QUALITATIVE TRANSECT SURVEYS

Qualitative data were collected on March 16 and June 25, 1988. Divers followed a transect along the discharge canal centerline and noted the relative areas of stunted or sparse growth of Chondrus crispus. One small area near a large boulder that serves as a fixed reference point was devoid of algae; however, sparse growth of Chondrus was seen throughout the area that has historically been described as being denuded of this species. In June, there were no areas without Chondrus. The transition between areas of sparse and normal growth was not clear and no definitive boundaries could be drawn. These results indicate a dramatic recovery within the zone of acute impact in response to the power outage at PNPS.

INTRODUCTION

This report presents the results of the most recent survey of the benthic algal and faunal communities near the Pilgrim Nuclear Power Station (PNPS). PNPS is located on the northwest shore of Cape Cod Bay, 5 miles southeast of Plymouth Harbor, Massachusetts. The surveys are part of a long-term monitoring effort by Boston Edison Company (BECO) to assess the impact on the inshore benthic community of the thermal effluent and current from the 655 megawatt nuclear-powered electric generating station. The quantitative algal and faunal data discussed in this report were derived from field samples collected on March 18, 1988. Qualitative transect data were collected on March 16 and June 15, 1988.

Sampling periods and procedures followed in this program were established by the Pilgrim Administrative Technical Committee (PATC). These procedures were adopted by BECO and modified in 1981 (BECO, 1982). A detailed description of the field, laboratory, and analytical methods can be found in Semi-Annual Report No. 29 (BECO, 1987a) and are discussed only briefly in this volume.

Data discussed in this report were collected after two years of the outage at PNPS that began in April 1986. During the period between January 1 and June 30, 1988, only one circulating water pump was operating for a portion of each month, averaging between 0.2 and 0.7 percent of the time per month.

Battelle's Project Manager for the PNPS algal and faunal investigations during the first part of this report period was Ms. Tracy Stenner. Dr. James A. Blake assumed responsibility for the program in May. Field logistics and collections were supervised by Mr. John Williams. Algae were identified by Ms. Brenda Cavicchi. Fauna were identified by Ms. Nancy Alff Padell and Mr. Russell Winchell. Additional personnel participating in this project included Dr. James Blake, Mr. Thomas Angell, Ms. Ellen Baptiste, Dr. Nancy Maciolek, Mr. Steven Mellenthien, Mr. Phillip Nimeskern, Mr. R. Eugene Ruff, and Mr. Robert Williams.

METHODS

Five replicate 0.1089-m^2 benthic samples were collected with SCUBA at each of three sites: Effluent, Manomet Point, and Rocky Point (Figure 1). The Manomet Point and Rocky Point stations are beyond the influence of the effluent and were selected as reference sites. Quantitative samples were preserved in the field and returned to the laboratory, where faunal and algal fractions were separated and analyzed. Details of these procedures can be found in Semi-Annual Report No. 29 (BECO, 1987a).

Qualitative transect data were collected by divers using a fixed line stretched offshore along the discharge canal centerline and a moveable line placed perpendicular to the centerline. The divers noted the boundaries of denuded areas or areas of stunted Irish moss, Chondrus crispus.

All data generated for samples analyzed during this report period were audited by Battelle's Quality Assurance Unit. Statistical analyses of data were performed on Battelle's VAX 11/750 computer using software that had been used previously to analyze PNPS benthic data.

RESULTS

FAUNAL STUDIES

Systematics

Three species were newly recorded from the samples collected in March 1988. These species were a polychaete, Scalibregma inflatum; an isopod, Chiridotea sp.; and a mollusc, Acmaeidae sp. 1. These additions bring the total number of invertebrate species recorded from the study area to 469.

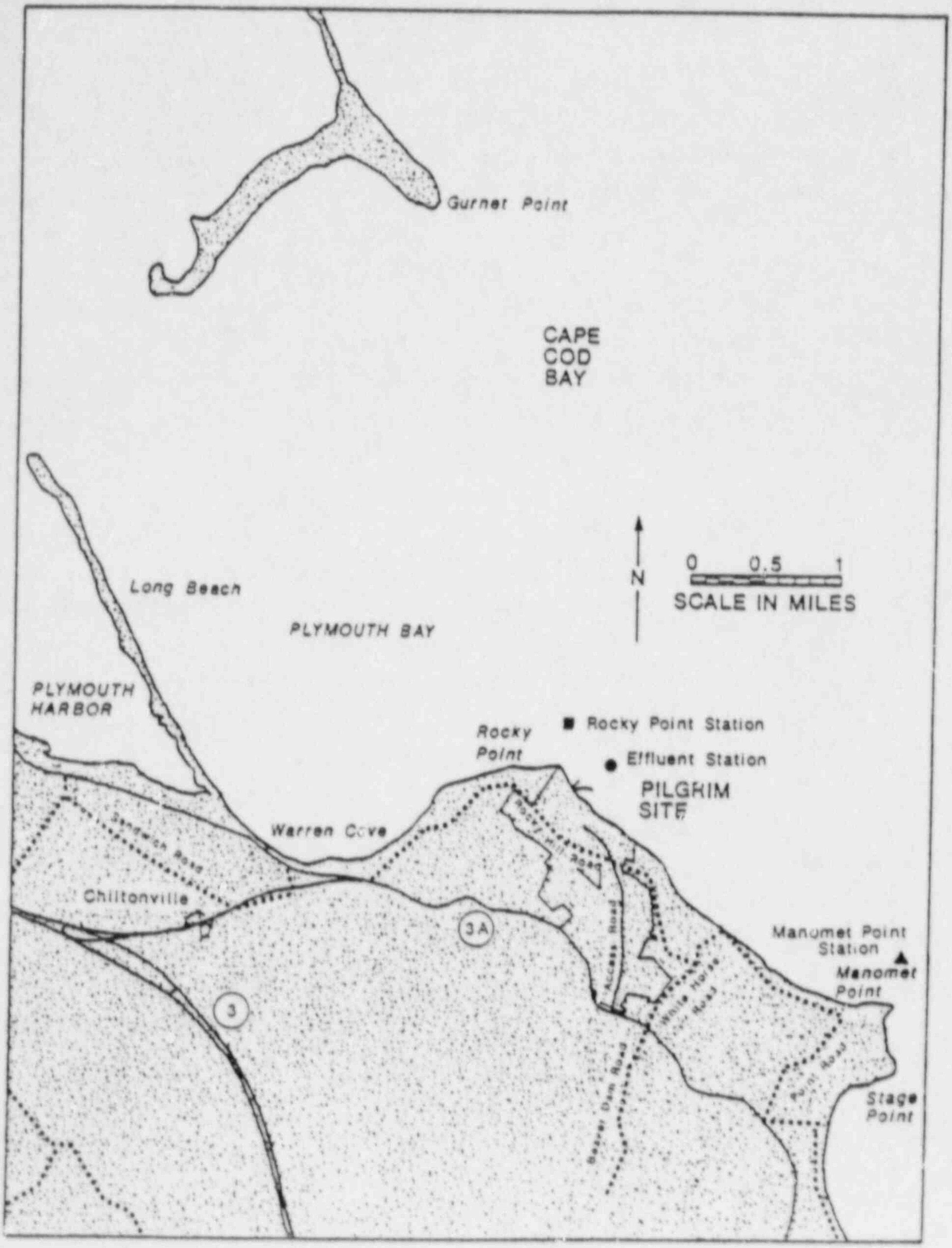

FIGURE 1. LOCATION OF ROCKY POINT, EFFLUENT, AND MANOMET POINT SUBTIDAL (10 FT. MLW) STATIONS.

Species Richness

Species richness values for all three stations in March 1988 are presented in Table 1. The Effluent station continued to have the lowest total number of species of the three stations; however, the 47 species found at the Effluent station represented an increase of 6 over the number found in September 1987 (41 species) and an increase of 11 over the 36 species found in March 1987. At Manomet Point and Rocky Point, the total number of species in March 1988 was nearly identical to the number found in September 1987 (61 vs. 62 and 62 vs. 60 species at Manomet and Rocky Point, respectively). March 1988 values at both stations were higher by 13 and 20 species, respectively, than values in March 1987.

In order to assess rare species that might be present at the stations but were not found because of the small total area sampled at each station (0.5445 m^2), a jackknifed estimate was calculated (Heltshe and Forrester, 1983). The estimated species richness was lowest at the Effluent station, intermediate at Rocky Point, and highest at Manomet Point, consistent with the pattern seen in previous years. At all three stations, values were higher in March 1988 than in March or September 1987.

The variance of the estimated species richness (var $\hat{s}$) is a measure of the spatial distribution of species that occurred in only one replicate sample (i.e., unique species). High values for this parameter indicate that all unique species at the station are concentrated in a small space, whereas low values indicate that these species are evenly distributed over the space the community inhabits. A high variance value was found only at the Effluent station (Table 1).

Faunal Density

Benthic macrofaunal densities were calculated including all specimens found in the samples, even if they were not identified to species (i.e., juveniles and indeterminants were retained). Density was also examined both with and without the bivalve

TABLE 1. FAUNAL SPECIES RICHNESS IN MARCH 1988.

Station/ Replicate No.	Number of Species	Jackknife Estimate Species Richness ($\hat{S}$) (±95 % CI)	Var ($\hat{S}$)
Effluent			
1	25		
2	28		
3	21		
4	26		
5	25		
$\bar{S}$	25.0		
Total	47	61.4 ± 11.96	18.56
Manomet Point			
1	41		
2	43		
3	34		
4	39		
5	40		
$\bar{S}$	39.4		
Total	61	73.8 ± 4.15	2.24
Rocky Point			
1	43		
2	37		
3	43		
4	48		
5	42		
$\bar{S}$	42.6		
Total	62	71.6 ± 5.66	4.16

$\bar{S}$ = Mean number of species per replicate.
Total = Total number of species recorded from station.
CI = Confidence interval.
Var ($\hat{S}$) = Variance of the jackknifed estimate of species richness.

Mytilus edulis, which occurred in very high densities in all replicates (Table 2). With *Mytilus* included, mean density at the Effluent station was less than half that recorded at either Manomet Point or Rocky Point. Densities at the latter two stations were comparable to each other, but were slightly lower at Rocky Point, where mean densities were 87 percent of those found at Manomet Point. Mean values at all three stations were between 2.2 and 4.9 times higher in March 1988 than in March or September 1987. (Values at the Effluent station were 2.2 and 2.4 times higher, values at Manomet Point were 3.0 and 3.2 times higher, and values at Rocky Point were 4.9 and 3.9 times higher in March 1988 than in March and September 1987, respectively.)

When *M. edulis* was excluded, the mean density at the Effluent station was still only 40 to 58 percent of that found at the other two stations; however, mean densities at Manomet Point and Rocky Point differed substantially, with mean density at Rocky Point being only 70 percent of that recorded at Manomet Point. Even with *M. edulis* excluded, however, mean densities at both Manomet Point and Rocky Point were higher than values recorded in either March or September 1987.

A one-way analysis of variance (ANOVA), followed by the Student-Newman-Keuls range test, indicated that mean densities at the Effluent station were significantly lower ($p < 0.05$) than mean densities at Manomet Point or Rocky Point. Mean densities at Manomet Point and Rocky Point were not statistically different at the $p = 0.05$ level. The results of this analysis were the same with *Mytilus edulis* included or excluded.

Species Dominance

The 15 numerically dominant species at each station are presented in Table 3. The majority of dominant taxa at the three stations were arthropods, as is typical of rocky subtidal habitats. However, the bivalve *Mytilus edulis* ranked first and accounted for 58 percent or greater of the fauna at each of the three stations (60.8 percent at Effluent, 57.9 percent at Manomet

TABLE 2. FAUNAL DENSITY WITH AND WITHOUT *MYTILUS EDULIS* INCLUDED, MARCH 1988.

Station/ Replicate No.	Number of Individuals (*Mytilus* included)	Number of Individuals (*Mytilus* excluded)
Effluent		
1	8648	3656
2	8392	3172
3	8784	4360
4	2080	1472
5	9680	4940
$\bar{X}$	7517 ± 3078	3520 ± 1328
m^2	69,025	32,323
Manomet Point		
1	21,880	10,892
2	17,480	8712
3	11,612	5688
4	12,488	7276
5	27,732	10,916
$\bar{X}$	18,238 ± 6726	8697 ± 2281
m^2	167,478	79,860
Rocky Point		
1	23,048	10,428
2	19,364	4860
3	9064	4344
4	16,656	6076
5	11,624	4580
$\bar{X}$	15,951 ± 5672	6058 ± 2533
m^2	146,476	55,625

$\bar{X}$ = Mean density per replicate.

m^2 = Density per square meter.

TABLE 3. RANK ORDER OF ABUNDANCE FOR THE 15 DOMINANT SPECIES IN SAMPLES COLLECTED IN MARCH 1988. AN * MARKS THE DOMINANTS SHARED BY ALL THREE STATIONS. A - MARKS DOMINANTS SHARED ONLY BY EFFLUENT AND MONOMET POINT.

Station/Species	Mean Number per Replicate	Percent of Total
Effluent		
*Mytilus edulis (Bivalve)	3996.8	60.83
Calliopius laeviusculus (Amphipod)	1007.2	15.33
*Pontogeneia inermis (Amphipod)	490.4	7.46
*Lacuna vincta (Gastropod)	346.4	5.27
*Ischyrocerus anguipes (Amphipod)	336.8	5.13
*Jassa falcata (Amphipod)	88.8	1.35
*Dexamine thea (Amphipod)	44.8	0.68
Idotea phosphorea (Isopod)	43.2	0.66
*Proboloides holmesi (Amphipod)	36.8	0.56
Cancer irroratus (Decapod)	28.0	0.43
*Corophium bonelli (Amphipod)	20.8	0.32
-Caprella penantis (Caprellid)	17.6	0.27
Anomia simplex (Bivalve)	15.2	0.23
Pagurus sp. 1 (Decapod)	13.6	0.21
*Corophium acutum (Amphipod)	11.2	0.17
Total of 15 species	6497.6	98.90
Remaining Fauna — 32 species	72.8	1.10
Total Fauna — 47 species	6570.4	100.00
Manomet Point		
*Mytilus edulis (Bivalve)	9541.6	57.90
*Jassa falcata (Amphipod)	1352.8	8.21
*Ischyrocerus anguipes (Amphipod)	1285.6	7.80
*Pontogeneia inermis (Amphipod)	903.2	5.48
*Lacuna vincta (Gastropod)	851.2	5.17
*Dexamine thea (Amphipod)	460.0	2.79
*Corophium bonelli (Amphipod)	401.6	2.44
*Corophium acutum (Amphipod)	356.8	2.17
*Proboloides holmesi (Amphipod)	217.6	1.32
Pleusymtes glaber (Amphipod)	168.8	1.02
Onoba aculea (Gastropod)	153.6	0.93
Margarites helicinus (Gastropod)	120.8	0.73
-Caprella penantis (Caprellid)	90.4	0.55
Corophium insidiosum (Amphipod)	65.6	0.40
Amphithoe rubricata (Amphipod)	53.6	0.33
Total of 15 species	16,023.2	97.24
Remaining Fauna — 46 species	456.8	2.76
Total Fauna — 61 species	16,480.0	100.00
Rocky Point		
*Mytilus edulis (Bivalve)	9893.6	67.25
*Ischyrocerus anguipes (Amphipod)	1226.4	8.34
*Jassa falcata (Amphipod)	903.2	6.14
*Lacuna vincta (Gastropod)	632.8	4.30
*Pontogeneia inermis (Amphipod)	192.0	1.31
*Dexamine thea (Amphipod)	176.0	1.20
Margarites helicinus (Gastropod)	175.2	1.19
*Corophium bonelli (Amphipod)	172.8	1.17
Nicolea zostericola (Polychaete)	150.4	1.02
Onoba aculea (Gastropod)	144.8	0.98
*Proboloides holmesi (Amphipod)	120.8	0.82
Pleusymtes glaber (Amphipod)	111.2	0.76
*Corophium acutum (Amphipod)	107.2	0.73
Alvania pseudoareolata (Gastropod)	84.0	0.57
Metopella angusta (Amphipod)	74.4	0.51
Total of 15 species	14,164.8	96.29
Remaining Fauna — 47 species	547.2	3.71
Total Fauna — 62 species	14,712.0	100.00

Point, and 67.2 percent at Rocky Point). This dominance is in sharp contrast to results from March 1987, when M. edulis accounted for 3.2 percent, 4.5 percent, and 1.7 percent at the Effluent, Manomet Point, and Rocky Point stations, respectively. In September 1987, M. edulis accounted for 0.7 percent, 4.5 percent, and less than 2 percent, respectively, at the same three stations.

The remaining top dominants at the Effluent station included 8 amphipods, 1 caprellid, 2 crabs, 2 molluscs, and 1 isopod. Of the top 15 species, only 5 did not occur among the top 15 dominant species at Manomet Point and 6 did not occur among the top dominants at Rocky Point. Idotea phosphorea was the only isopod to occur among the top dominant species at any of the three stations. The species that were shared dominants often held a similar or higher rank at Manomet Point or Rocky Point, meaning that they occur in higher numbers at those two stations than at the Effluent station.

At Manomet Point, the dominant species that ranked 2nd through 15th included 10 amphipods, 3 gastropods, and 1 caprellid. Of these species, 3 did not occur among the top 15 dominants at Rocky Point, and 5 did not occur among the top dominants at the Effluent.

At Rocky Point, species ranked 2nd through 15th included 9 amphipods, 4 gastropods, and 1 polychaete. Nicolea zostericola, which ranked ninth, was the only polychaete among the top dominants at any of the three stations. Of the top 15 species at Rocky Point, 3 did not occur among the dominants at Manomet Point and 6 did not occur among the top dominants at Effluent.

Species Diversity

Species diversity is a measure of the number of species present (species richness) in combination with the relative abundance (evenness) of each species in the sample. In general, low evenness values indicate that the community sampled is dominated by one or a few species. Shannon-Wiener diversity (H') and evenness (J) values were calculated after all juvenile or indeterminant specimens were excluded from the data set. Including such individuals would provide a falsely high diversity value. For consistency with past reports, and because the Shannon-Wiener index is disproportionately influenced by a single, overwhelmingly dominant species, H' and J were calculated both with and without Mytilus edulis (Tables 4 and 5).

When M. edulis was included, the lowest diversity was seen at the Effluent station (H' = 2.06), followed closely by Rocky Point (2.16). Manomet Point had the highest diversity (2.52). Values at all stations were lower than the diversity recorded in either March or September 1987. Evenness values (J) were also severely depressed from the 1987 values, reflecting the high contribution of M. edulis to the total density.

When M. edulis was removed from the data, evenness values were higher (Table 5). The lowest diversity was still found at the Effluent station; however, H' was higher in March 1988 than in March 1987 (2.78 vs. 2.33, respectively). With M. edulis excluded, the highest diversity was seen at Rocky Point (H' = 3.82), and again this value was higher in March 1988 than in March 1987, when H' was 3.53. Similarly, diversity at Manomet Point was higher in March 1988 than in 1987 (3.65 vs. 2.74).

Another measure of diversity, Hurlbert's (1971) rarefaction method, was also used to compare the three stations. Results of this analysis are presented in Table 6 and Figure 2. These results confirm the pattern seen with the Shannon-Wiener index: diversity was lowest at the Effluent station and highest at the Rocky Point station in March 1988.

Measures of Similarity

Similarity analysis followed by use of a clustering method is a multivariate tecnnique used to assess the overall comparability among samples and stations. It has been used here to address the following questions:

TABLE 4. DIVERSITY AND EVENNESS VALUES FOR EACH REPLICATE AND STATION SAMPLED IN MARCH 1988. MYTILUS EDULIS WAS INCLUDED IN THIS ANALYSIS.

Replicate	Manomet Point		Rocky Point		Effluent	
	H'	J'	H'	J'	H'	J'
1	2.46	0.46	2.29	0.42	1.75	0.38
2	2.61	0.48	1.31	0.25	1.85	0.38
3	2.55	0.50	2.63	0.48	1.91	0.43
4	2.82	0.53	2.09	0.37	2.89	0.61
5	1.99	0.37	2.13	0.40	2.09	0.45
Station	2.52	0.42	2.16	0.36	2.06	0.37

TABLE 5. DIVERSITY AND EVENNESS VALUES FOR EACH REPLICATE AND STATION SAMPLED IN MARCH 1988. MYTILUS EDULIS WAS EXCLUDED FROM THIS ANALYSIS.

Replicate	Manomet Point		Rocky Point		Effluent	
	H'	J'	H'	J'	H'	J'
1	3.23	0.61	3.15	0.58	2.19	0.48
2	3.48	0.64	3.32	0.64	3.37	0.71
3	3.50	0.69	3.86	0.72	2.19	0.51
4	3.58	0.68	4.12	0.74	2.95	0.63
5	3.44	0.65	3.42	0.64	2.66	0.58
Station	3.65	0.62	3.82	0.64	2.78	0.50

H' = Shannon-Wiener Diversity.
J' = Evenness.

TABLE 6. EXPECTED NUMBER OF SPECIES FOR POOLED STATION DATA USING RAREFIED SAMPLE SIZES OF 50, 400, 750, 2500, AND 5000 INDIVIDUALS. *MYTILUS EDULIS* WAS INCLUDED IN THIS ANALYSIS.

Station	Species Per 50 Individuals	Species Per 400 Individuals	Species Per 750 Individuals	Species Per 2500 Individuals	Species Per 5000 Individuals
Effluent	7.5	16.6	20.9	31.1	37.8
Manomet Point	10.4	22.5	27.3	38.1	45.0
Rocky Point	9.7	25.3	31.1	42.8	48.9

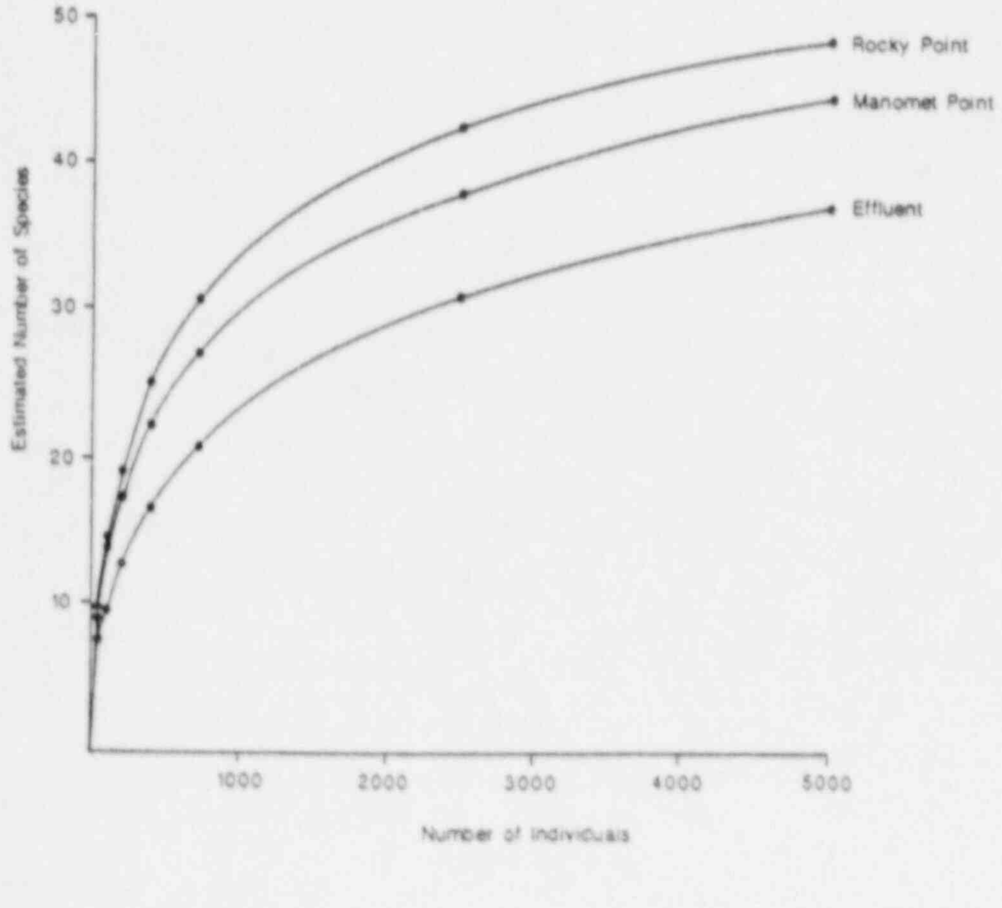

FIGURE 2. RAREFACTION CURVES FOR MARCH 1988 SAMPLES.

- How similar is the benthic community at the Effluent station to the communities at the reference stations at Manomet Point and Rocky Point?

- If there are differences among stations, which species are responsible for those differences?

To address these questions, the similarity analysis was done using two different similarity measures: Bray-Curtis and the Normalized Expected Species Shared (NESS).

Analysis of Replicates

The results of the cluster analysis based on log-transformed data and the Bray-Curtis similarity measure (with group average sorting and β set at -0.25) are shown in Figure 3. Three major groups or clusters can be identified. Group 1 includes the five replicate samples from the Effluent station. These five samples cluster at 72 percent similarity. Groups 2 and 3 represent Manomet Point and Rocky Point, respectively. These two groups join each other at 76 percent similarity, but as a unit are similar to Group 1 (the Effluent station) only at 56 percent.

A somewhat different pattern was seen with the NESS similarity measure (Figure 4). Because NESS is less influenced by highly dominant species in the samples and is more sensitive to the less abundant species, the effect of the dominant Mytilus edulis is less apparent in these results. There are two major groups in Figure 4. One group includes all samples from the Effluent station; four replicates are similar at 88 percent or greater. Replicate 4 joins the other replicates to form a station group at 77 percent similarity. The second major group includes all of the replicates from Manomet Point and Rocky Point. Within this group, all of the samples from Manomet Point form a small subgroup, which is joined at various levels of similarity by the replicates from Rocky Point. The group comprised of Manomet Point and Rocky Point

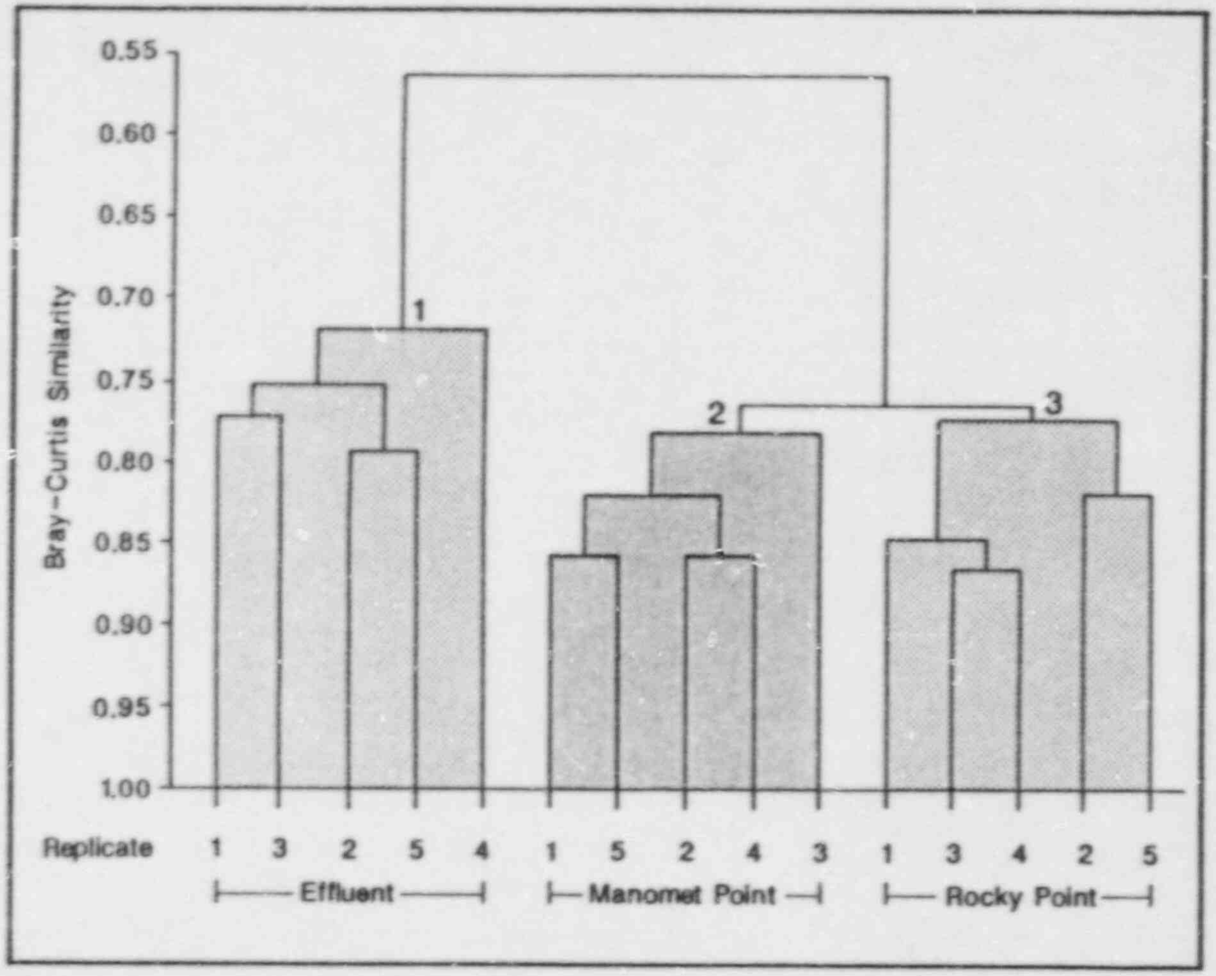

FIGURE 3. DENDROGRAM BASED ON THE BRAY-CURTIS SIMILARITY ANALYSIS OF THE MARCH 1988 SAMPLES.

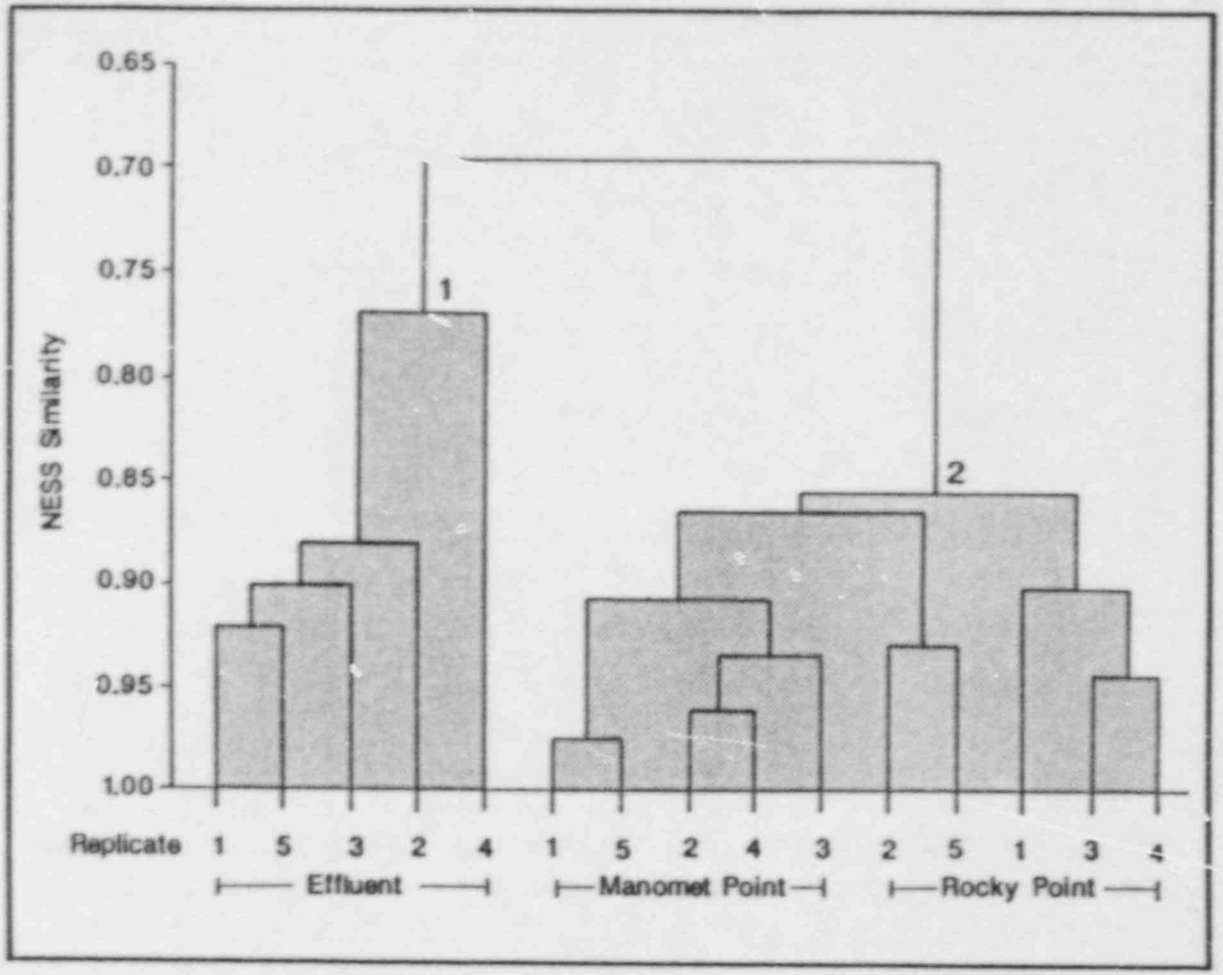

FIGURE 4. DENDROGRAM BASED ON THE NESS SIMILARITY ANALYSIS OF THE MARCH 1988 SAMPLES.

samples is similar to the group comprised of Effluent station samples at 69 percent similarity.

Nodal Analysis

For the nodal analysis, the top 50 species were clustered, and species groupings were identified. Replicates from each station were clustered and groups were chosen. These analyses were performed on log-transformed data; the Bray-Curtis similarity measure with group average sorting and β set at -0.25 was used. The two analyses were then combined in a matrix in order to interpret the patterns observed for species and for samples. Two parameters, constancy and fidelity, were calculated for each intersection of the matrix. Constancy is a measure of how often a species occurs in a particular sample group out of all possible number of occurrences (in all samples combined). Fidelity is a measure of whether a species occurs only in a particular sample group or in many.

The analysis by species resulted in the groups listed in Table 7. When the log-transformed data were used for the analysis by sample, the five replicates from each station clustered together, resulting in three sample groups, each corresponding to one of the three stations. Abbreviated versions of each dendrogram are shown in Figure 5 (constancy) and Figure 6 (fidelity).

Constancy. Species group 1 showed very high constancy at all three stations (Figure 5). This is not surprising because this group included many of the top dominants at each station. Eight of the 17 species in group 1 were top dominants at all three stations, and the remainder were top dominants at one or two stations. Similarly, species groups 2 and 5 included dominants found at Rocky Point, and these groups also showed very high constancy at that station, but low constancy at the Manomet Point and Effluent stations.

Species group 2 had high constancy at Manomet Point, but less than at Rocky Point. Species group 3, consisting of three

TABLE 7. SPECIES GROUPS IDENTIFIED BY INVERSE CLUSTER ANALYSIS OF MARCH 1988 DATA.

Group 1

- Idotea phosphorea
- Corophium acutum
- Corophium bonelli
- Dexamine thea
- Proboloides holmesi
- Caprella penantis
- Pleusymtes glaber
- Onoba aculea
- Margarites helicina
- Caprella nr. septemtrionalis
- Mitrella lunata
- Ischyrocerus anguipes
- Lacuna vincta
- Pontogeneia inermis
- Jassa falcata
- Mytilus edulis
- Calliopius laevisculus

Group 2

- Metopella angusta
- Nicolea zostericola
- Anomia simplex
- Corophium insidiosum
- Ophiopholis aculeata
- Nereis pelagica
- Hiatella arctica
- Mya arenaria
- Strongylocentrotus droebachiensis
- Amphipholis squamata
- Harmothoe imbricata

Group 3

- Amphithoe rubicata
- Eualus pusiolus
- Onchidoris aspera

Group 4

- Caprella linearis
- Caulleriella bioculata
- Hiatella striata
- Cirratulus cirratus
- Crepidula fornicata
- Lumbrineris fragilis
- Ischnochiton ruber
- Capitella capitata
- Phyllodoce maculata
- Naineris quadricuspis
- Fabricia sabella

Group 5

- Alvania pseudoareolata

Group 6

- Cerastoderma pinnulatum

Group 7

- Cancer irroratus
- Pagurus sp. 1
- Sabellaria vulgaris
- Pagurus acadianus
- Dodecaceria sp. A

Group 8

- Nephtys caeca

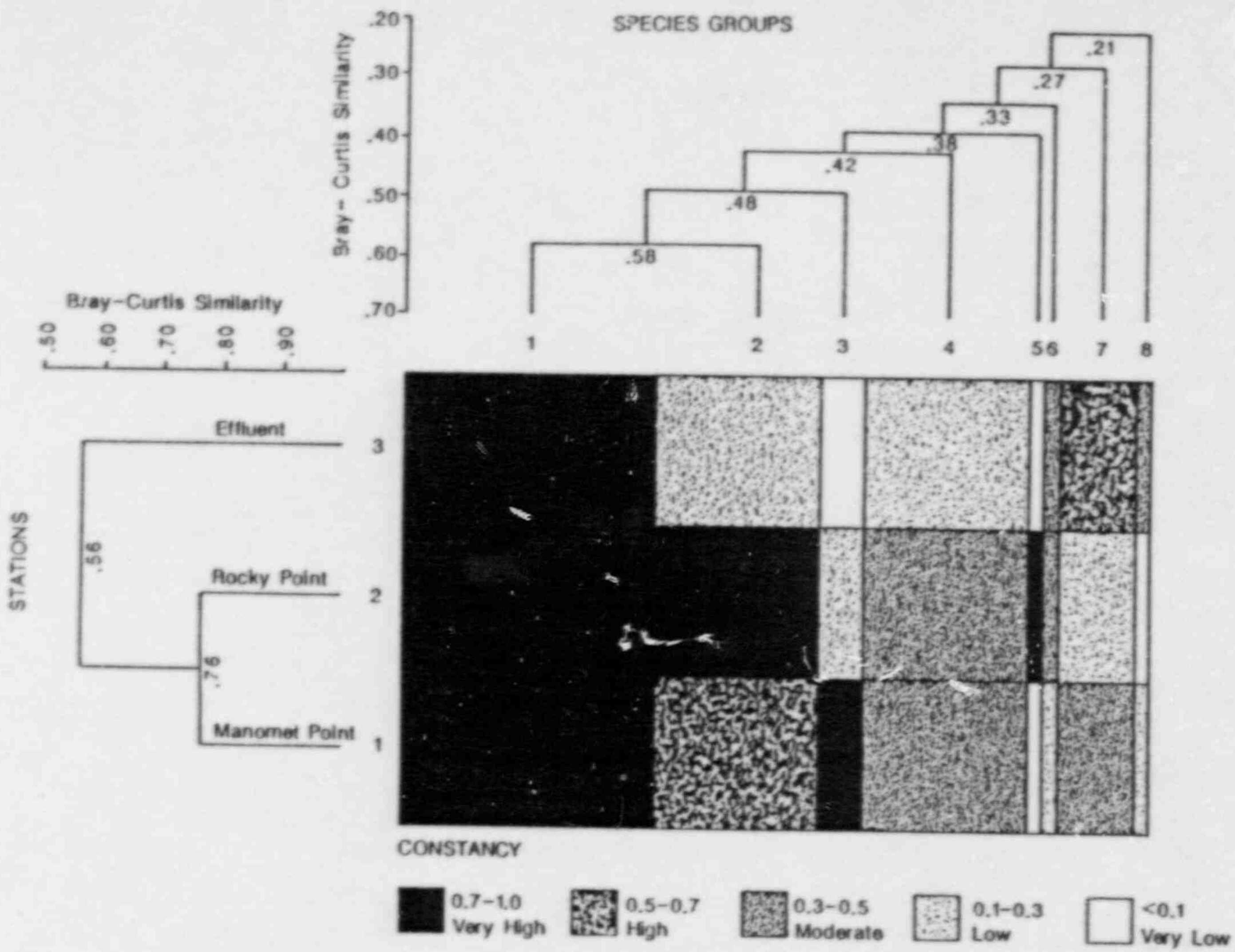

FIGURE 5. CONSTANCY DIAGRAM FOR SPECIES GROUPS AND SITE GROUPS IN MARCH 1988. CLUSTERING IS BASED ON BRAY-CURTIS SIMILARITY AND GROUP AVERAGE SORTING.

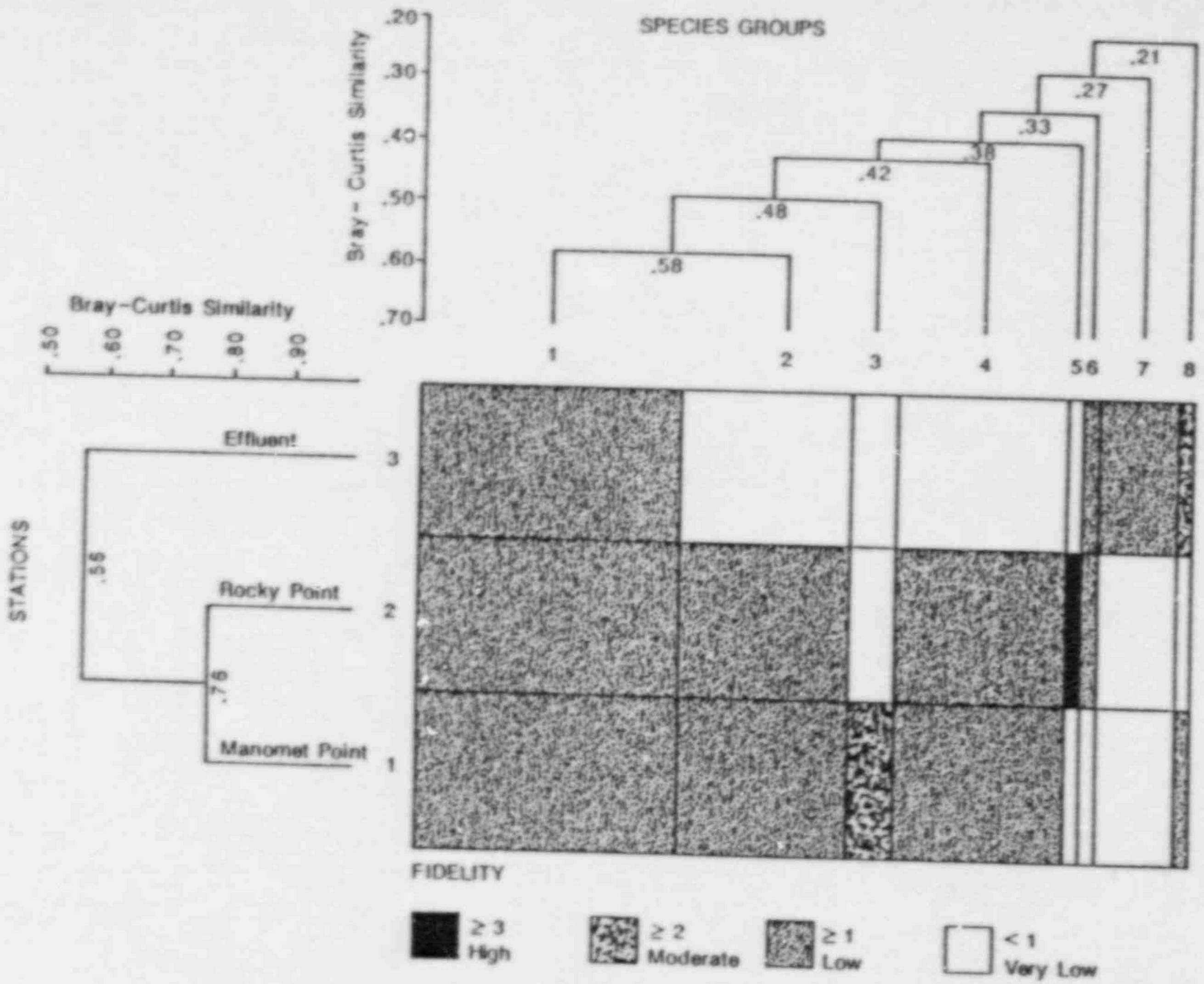

FIGURE 6. FIDELITY DIAGRAM FOR SPECIES GROUPS AND SITE GROUPS IN MARCH 1988. CLUSTERING IS BASED ON BRAY-CURTIS SIMILARITY AND GROUP AVERAGE SORTING.

species, showed very high constancy at Manomet Point, and low or very low constancy at the Effluent and Rocky Point stations.

Species group 7, which included three crabs and two polychaetes, showed high constancy at the Effluent station. All other species groups had moderate to low constancy values at each station.

Fidelity. Only one species (group 5, Alvania psuedoareolata) showed high fidelity to any station (Rocky Point), indicating that this species was found mostly at Rocky Point and not at the other two stations. Species groups 3 and 8 showed moderate fidelity at Manomet Point and Effluent, respectively. All other species groups had low or very low fidelity at any station, indicating that few species were restricted to a particular station.

ALGAL STUDIES

Systematics

No new species were added to the list of 37 species given in Semi-Annual Report No. 31 (BECO, 1988).

Algal Community Description

The rocks and cobble found at the Manomet Point, Rocky Point, and Effluent stations were heavily colonized by red macroalgae. As indicated by biomass, Chondrus crispus was most abundant at Rocky Point; Phyllophora spp. was most abundant at Manomet Point. The highest biomass of benthic species other than Chondrus and Phyllophora (the category "remaining benthic species") occurred at the Effluent station. The highest biomass of epiphytic algae was found at Manomet Point, and the lowest epiphytic biomass was found at the Effluent station. The primary hosts for epiphytes were Chondrus and Phyllophora, but other benthic species, such as Polyides rotundus and Ahnfeltia plicata, were also hosts. Red algae such as Spermothamnion repens, Polysiphonia spp., Phycodrys rubens, Cystoclonium purpureum, Ceramium rubrum, and Rhodomela confervoides were the most commonly observed epiphytes. The warm-water indicator Gracilaria foliifera was not seen in any sample collected in March 1988.

Algal Community Overlap

Community overlap was calculated for the March 1988 data using Jaccard's Coefficient of Community (Greig-Smith, 1964) to measure the similarity in algal species composition among the three stations. This coefficient evaluates similarity based on presence/absence of species and does not take into account the abundances of the species recorded. Presence/absence of the 37 species given in the last Semi-Annual Report (No. 31) (BECO, 1988) were used for the calculations.

Results of the community overlap comparisons are presented in matrix form in Figure 7. Overlap among replicates at Manomet Point ranged from 76.0 to 95.2 percent; from 72.0 to 95.2 percent at Rocky Point, and 69.6 to 94.7 percent at the Effluent station. Overlap between station pairs was highest between the two reference stations (88.9 percent), but was also very high for Rocky Point-Effluent (85.2 percent) and Manomet Point-Effluent (81.5 percent). The last two values are higher than the percent overlap between the two reference stations in either March or September 1987.

Algal Biomass

Chondrus crispus

Biomass of Chondrus crispus at each station in March 1988 is presented in Table 8. Mean biomass of this species was essentially the same at Manomet Point and Rocky Point (132.5 and 133.9 g/m^2, respectively), but was much lower at the Effluent station (27.3 g/m^2). Chondrus accounted for only 10 percent of the algal biomass at the Effluent station, and 36 and 43 percent

	1	2	3	4	5
1		19	18	20	18
2	86.4		20	20	19
3	81.8	95.2		19	18
4	83.3	80.0	76.0		20
5	81.8	86.4	81.8	83.3	

Number of Species Shared

Percent Overlap
MANOMET POINT STATION

	1	2	3	4	5
1		19	18	19	18
2	76.0		19	20	21
3	78.3	79.2		20	20
4	82.6	83.3	95.2		20
5	72.0	87.5	90.9	87.0	

Number of Species Shared

Percent Overlap
ROCKY POINT STATION

	1	2	3	4	5
1		18	18	16	17
2	94.7		18	17	17
3	90.0	85.7		18	18
4	69.6	73.9	78.3		18
5	81.0	77.3	81.8	78.3	

Number of Species Shared

Percent Overlap
EFFLUENT STATION

OVERLAP BETWEEN STATIONS

Station Pair	Number of Species Shared	Community Overlap
Manomet Point-Rocky Pt.	24	88.9
Manomet Point-Effluent	22	81.5
Rocky Point-Effluent	23	85.2

FIGURE 7. 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 (10 FT. MLW) MARCH 1988.

TABLE 8. DRY WEIGHT BIOMASS VALUES (g/m^2) FOR CHONDRUS CRISPUS, PHYLLOPHORA SPP., EPIPHYTES, THE REMAINING BENTHIC SPECIES, AND TOTAL ALGAL BIOMASS FOR MANOMET POINT, ROCKY POINT, AND EFFLUENT SUBTIDAL (10 FT. MLW) STATIONS FOR MARCH 1988.

Station/Replicate	*Chondrus crispus*		*Phyllophora* spp.		Remaining Benthic Species		Epiphytic Species (Total)		Total Algal Biomass
	Biomass	Percent	Biomass	Percent	Biomass	Percent	Biomass	Percent	
Manomet Point									
1	115.39	34	148.90	44	4.68	1	72.43	21	341.40
2	155.97	40	158.81	41	2.39	0.6	70.40	18	387.57
3	213.62	49	181.21	41	1.84	0.4	42.05	10	438.72
4	39.66	12	158.08	49	63.98	20	62.51	19	324.23
5	137.79	38	168.18	46	0.92	0.3	55.35	15	362.24
$\bar{x}$	132.49	36	163.04	44	14.76	4	60.55	16	370.84
Rocky Point									
1	44.80	14	188.65	60	0.46	0.1	79.32	25	313.23
2	100.25	42	101.44	43	9.27	4	27.18	11	238.14
3	225.6[illegible]	55	125.35	32	1.74	0.4	50.30	12	407.03
4	199.21	64	62.61	20	1.10	0.4	47.28	15	310.20
5	99.69	34	116.[illegible]	40	62.15	21	16.34	6	294.58
$\bar{x}$	133.92	43	119.69	38	14.94	5	44.08	14	312.63
Effluent									
1	6.06	2	130.45	45	134.40	46	22.12	8	293.03
2	102.82	32	177.72	55	12.76	4	29.19	9	322.49
3	27.82	10	117.50	41	125.77	44	1[illegible].85	5	283.94
4	0	0	88.68	42	112.91	53	10.92	5	212.51
5	0	0	151.01	69	46.25	20	[illegible]4.61	11	219.87
$\bar{x}$	27.34	10	133.07	50	86.02	32	19.94	7	266.37

$\bar{x}$ = Mean biomass.

at Manomet Point and Rocky Point, respectively. Replicate values varied widely at each station, with the greatest range seen at the Effluent station (0 to 102.8 g/m^2).

These values represent a significant decrease in Chondrus biomass at the Effluent station: biomass in both March and September 1987 was about 6 times higher than the biomass in March 1988. Biomass was about the same at Manomet Point in March 1987 and March 1988 (124.8 and 132.5 g/m^2, respectively), and was higher in those months than in September 1987 (94.8 g/m^2). At Rocky Point, biomass in March 1988 was intermediate between that recorded in March 1987 (32.9 g/m^2) and September 1987 (174.0 g/m^2).

Phyllophora spp.

Biomass of Phyllophora spp. at each station in March 1988 is presented in Table 8. This species accounted for 50 percent of the algal biomass at the Effluent station, and 38 percent at Rocky Point, and 44 percent at Manomet Point. Mean biomass values were highest at Manomet Point (163.0 g/m^2), intermediate at the Effluent station (133.1 g/m^2) and lowest at Rocky Point (119.7 g/m^2).

These biomass values were lower than those recorded in September 1987 at the Effluent and Rocky Point stations, but were essentially the same as at Manomet Point. There is no pattern in relation to biomass recorded in March 1987: the March 1988 values were higher at Rocky Point, lower at Manomet Point, and essentially the same at the Effluent station compared to March 1987.

Replicate values were very consistent at Manomet Point and only slightly less so at the Effluent station. The greatest variability among replicates was at Rocky Point.

Remaining Benthic Species

The category designated "remaining benthic species" includes all algal species except Chondrus crispus, Phyllophora spp., and algal epiphytes. Biomass values for each replicate and mean values for each station are given in Table 8. This category was most important at the Effluent station, where it accounted for 32 percent of the total algal biomass; at Manomet Point and Rocky Point, it accounted for only 4 to 5 percent of the total. At the Effluent station, mean biomass was 86.0 g/m^2, more than 5 times the biomass at the other two stations.

At the Effluent station these values were higher than those recorded in March and September 1987, but at Manomet Point and Rocky Point values are lower than earlier results. Mean biomass at Rocky Point (14.9 g/m^2) was similar to biomass recorded in March 1987 (23.8 g/m^2), but was an order of magnitude lower than was recorded in September 1987 (156.2 g/m^2). Mean biomass at Manomet Point (14.8 g/m^2) was intermediate between biomass recorded in March 1987 (3.2 g/m^2) and September 1987 (20.1 g/m^2) at that station.

Epiphytic Species

Biomass values of epiphytic algae are given in Table 8. As for most of the previous sampling times, Phyllophora spp. had a higher degree of colonization by epiphytes than Chondrus crispus. Mean biomass of epiphytes was lowest at the Effluent station and highest at Manomet Point, although the biomass of Phyllophora was similar at both stations. All March 1988 values were intermediate between biomass recorded in March and September 1987.

Total Algal Biomass

Total algal biomass for each replicate and station is given in Table 8. The Effluent station had the lowest total biomass and Manomet Point had the highest. Total biomass at the Effluent station was lower than that recorded in March or September 1987. Total biomass at Manomet Point and Rocky Point was intermediate between March and September 1987 values.

Chondrus/Phyllophora Colonization Index Study

Colonization index values for Chondrus crispus and Phyllophora spp. are given in Table 9. These values are a qualitative measure of the amount of algal epiphytes and invertebrate species (such as bryozoans) that are present on the host species. Details of the procedure to determine these values are given in Semi-Annual Report No. 30 (BECO, 1987b).

The March 1988 data indicate that, as in past sampling periods, Phyllophora spp. was more heavily colonized than was Chondrus. This is probably due to the denser frond development of Phyllophora spp. compared with Chondrus. Colonization was lowest at the Effluent station and approximately equal at Manomet Point and Rocky Point.

QUALITATIVE TRANSECT SURVEY

The qualitative transect surveys of acute nearfield impact zones were started in January 1980 and have been conducted quarterly since 1982. Diver surveys were made in March and June 1988, bringing the total number of surveys to 30.

The denuded zone has been defined as the area devoid of Irish moss (Chondrus crispus) and the stunted zone has been defined as the area with Chondrus of decreased size and density compared with conditions considered normal for this species. By December 1987, after 1.5 years of the power outage at PNPS, it was difficult to define these zones (BECO, 1988). The border between the stunted and the denuded zones could no longer be clearly defined because there was recolonization by Chondrus resulting in

TABLE 9. COLONIZATION INDEX VALUES FOR CHONDRUS CRISPUS AND PHYLLOPHORA SPP. FOR THE MANOMET POINT, ROCKY POINT, AND EFFLUENT SUBTIDAL (10 FT. MLW) STATIONS FOR MARCH 1988.

	Manomet Point	Rocky Point	Effluent
Chondrus crispus			
Algal Colonization	12	12	3
Faunal Colonization	11	9	6
Total	23	21	9
Phyllophora spp.			
Algal Colonization	20	18	16
Faunal Colonization	19	19	14
Total	39	37	30

patchy, thin growth in the formerly denuded zone. Because the recolonization was not complete, zones were still indicated in Semi-Annual Report No. 31 (BECO, 1988), but the size (square meters) of the zones was not calculated after June 1987.

March 1988

The results of the divers' observations immediately offshore from PNPS on March 16, 1988 are illustrated in Figure 8A. A large boulder that is nearly exposed at mean low water and that is used as a landmark by both the Battelle and Division of Marine Fisheries dive teams is plotted in the figure. The boulder serves as a visual fix for the proper placement of the transect line and ensures consistency over the series of observations.

Chondrus crispus was observed throughout the area that has historically been described as being denuded of this species. Transitions from denuded areas to areas of stunted or normal Chondrus growth were not clear and no reliable areal measurements could be made. The solid line indicating clear boundaries has been drawn in Figure 8A as a dotted line to indicate the poor definition of this zone. One small area to the north of the large boulder was the only area that could be described as being denuded of algae. Laminaria sp. was observed out to 50 m and Fucus sp. was observed between 40 and 70 m along the transect line (Figure 8A).

June 1988

The results of the divers' observations on June 15, 1988 are plotted in Figure 8B. No denuded or stunted zones could be defined along the 80-m transect line. The small denuded area near the boulder was colonized by a sparse growth of algae. Although growth was sparse in some areas, Chondrus, Laminaria, and Fucus were present throughout the entire area. Rocks that had been bare of algal growth were sparsely covered with Chondrus. Fucus and

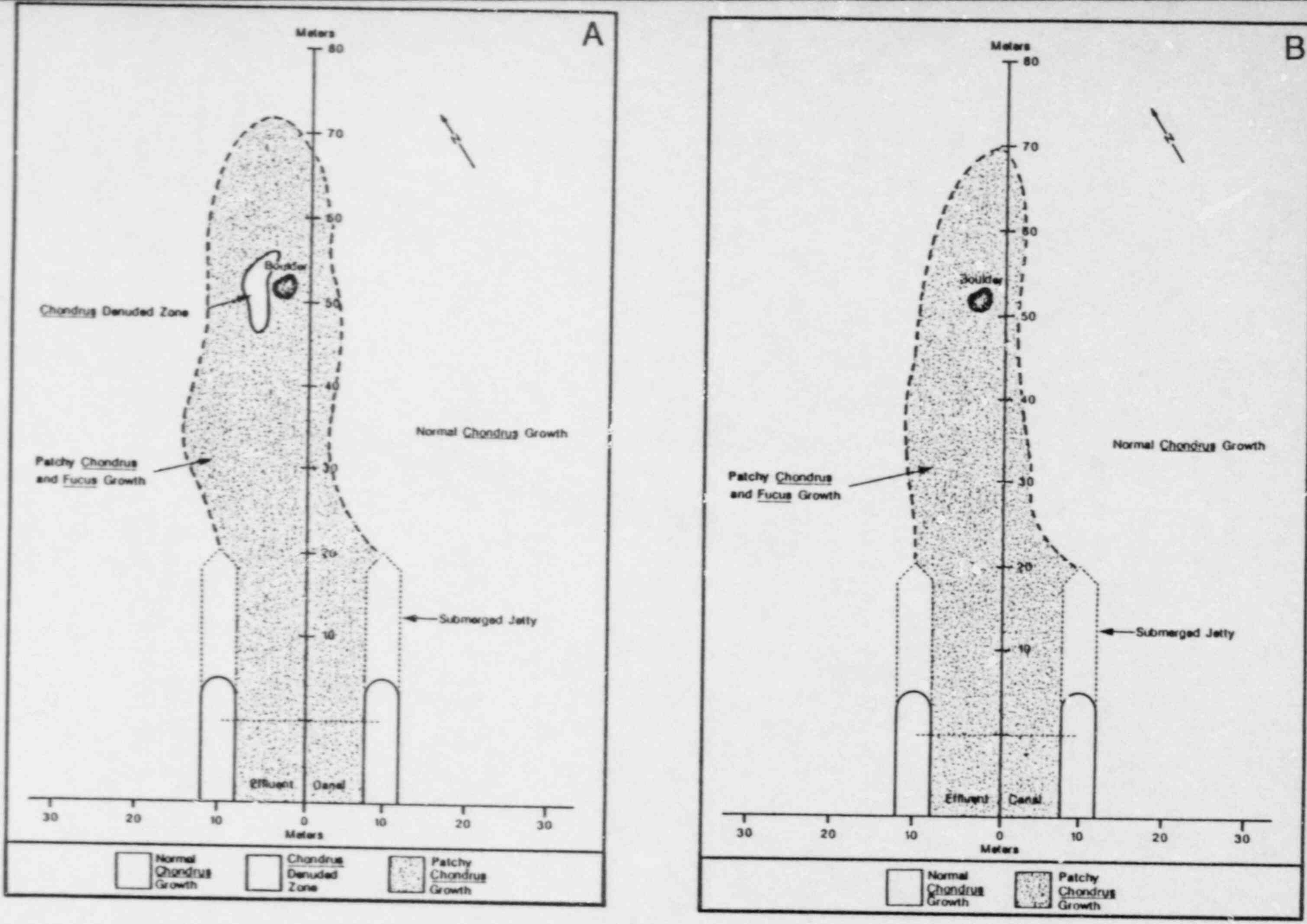

FIGURE 8. CONFIGURATION OF DENUDED AND STUNTED CHONDRUS ZONES. A. MARCH 16, 1988. B. JUNE 15, 1988.

the coralline alga Corallina were also present on some of the rocks about 40 m along the transect line.

DISCUSSION

The impact of the thermal effluent on algal and faunal communities near PNPS appears to have been reversed during the two years of power outage at PNPS. Fluctuations in the PNPS operations have resulted in various departures from the typical relationships between the Effluent and reference stations sampled as part of this study. These responses were summarized in Semi-Annual Report No. 31 (BECO, 1988) and will not be repeated in detail here. In general, impacts on the benthic communities during "normal" operations have primarily affected the less dominant components of the Effluent station communities. In addition, a distinct zone of acute impact that fluctuates in lateral and offshore extent in response to variations in PNPS output developed in the area immediately adjacent to the discharge canal.

The most significant result during the current report period is the decline in the acute impact zone, which had been denuded of the Irish moss Chondrus crispus, or contained only stunted specimens of the alga. In March 1988, boundaries of denuded or stunted growth zones were no longer clearly defined, and by June 1988 there were no areas that could be characterized as denuded. Patchy Chondrus growth was seen throughout the historically denuded area, and both Laminaria spp. and Fucus spp. were also seen. No warm-water indicator species such as Gracilaria spp. were seen in March or June 1988, nor have they been recorded since September 1986. These results indicate a dramatic recovery within the zone of acute impact in response to the power outage at PNPS.

Other measures of the algal and faunal communities, however, indicate that the Effluent station continues to differ from the two reference stations. All three stations were dominated by the bivalve Mytilus edulis, but faunal density and diversity were significantly lower at the Effluent station than at Manomet Point or Rocky Point, whether M. edulis was included or not. When Mytilus was included, diversities were lower in March 1988 than in March 1987, especially at Rocky Point, but when Mytilus was excluded, diversity was higher in March 1988 than in March 1987 at all stations.

Similarity between the Effluent station and the two reference stations, based on the Bray-Curtis analysis of log-transformed data, was 56 percent. This value is lower than has recently been obtained for periods when the plant was not operating, and may reflect the one Effluent station replicate that had unusually low densities. In 1987, similarity between the Effluent station and the reference stations has exceeded 70 percent (BECO, 1988).

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Ichthyoplankton Entrainment Monitoring at Pilgrim Nuclear Power Station January - June 1988

Submitted to

Boston Edison Company

Boston, Massachusetts

by

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Falmouth, Massachusetts

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SECTION I

SUMMARY

Ichthyoplankton entrainment samples were collected from the Pilgrim Nuclear Power Station (PNPS) discharge canal in triplicate twice per month in January and February, weekly from March through June. Although PNPS was out of service for an extended period, one of two circulating seawater pumps was in operation on each sampling occasion.

Through the first six months of 1988, 34 species of fish were identified in the ichthyoplankton samples; 16 were represented by eggs, 28 by larvae. The winter-early spring spawning period (January-April) was dominated primarily by American plaice, fourbeard rockling, and winter flounder eggs as well as sculpin, rock gunnel, seasnail, and sand lance larvae. May and June collections reflected the late spring-summer spawning species dominated numerically by Atlantic mackerel and labrid eggs as well as seasnail, winter flounder, and mackerel larvae.

Comparison of January-June 1988 egg and larval densities with those observed over the 1975-1987 period suggested that Atlantic cod eggs were relatively uncommon from January through March and during May. On the other hand, windowpane eggs in May and mackerel eggs in June exceeded previous high densities for those respective months. Among the larvae in 1988 three species were found to be notably abundant: rock gunnel in March, seasnails in April, and sculpin in February and March; in each of these cases respective 1988 monthly mean densities exceeded all previous [illegible] values for the same month.

Larval sculpin densities on February 25 and March 16, 1988 were unusually high as defined by the contingency sampling program. In both cases the unusual densities appeared to be short-lived.

No lobster larvae were collected through June.

SECTION II

INTRODUCTION

This progress report briefly summarizes results of ichthyoplankton entrainment sampling conducted at the Pilgrim Nuclear Power Station (PNPS) from January through June 1988 by Marine Research, Inc. (MRI) for Boston Edison Company (BECo) under Purchase Order No. 65221. A more detailed annual report covering all 1988 data will be prepared following the July-December collection periods.

SECTION III

METHODS

Entrainment sampling at PNPS for January-June 1988 consisted of collecting triplicate samples twice monthly in January and February followed by weekly sets of triplicates from March through June. Sampling utilized rigging mounted approximately 30 meters from the discharge canal headwall as in past years (Figure 1). All collections were made with a 0.333-mm mesh, 60-cm diameter plankton net fitted with a General Oceanics Model 2030R digital flowmeter. Although PNPS was out of service throughout the period, one of two circulating seawater pumps was in operation during each collection period.

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

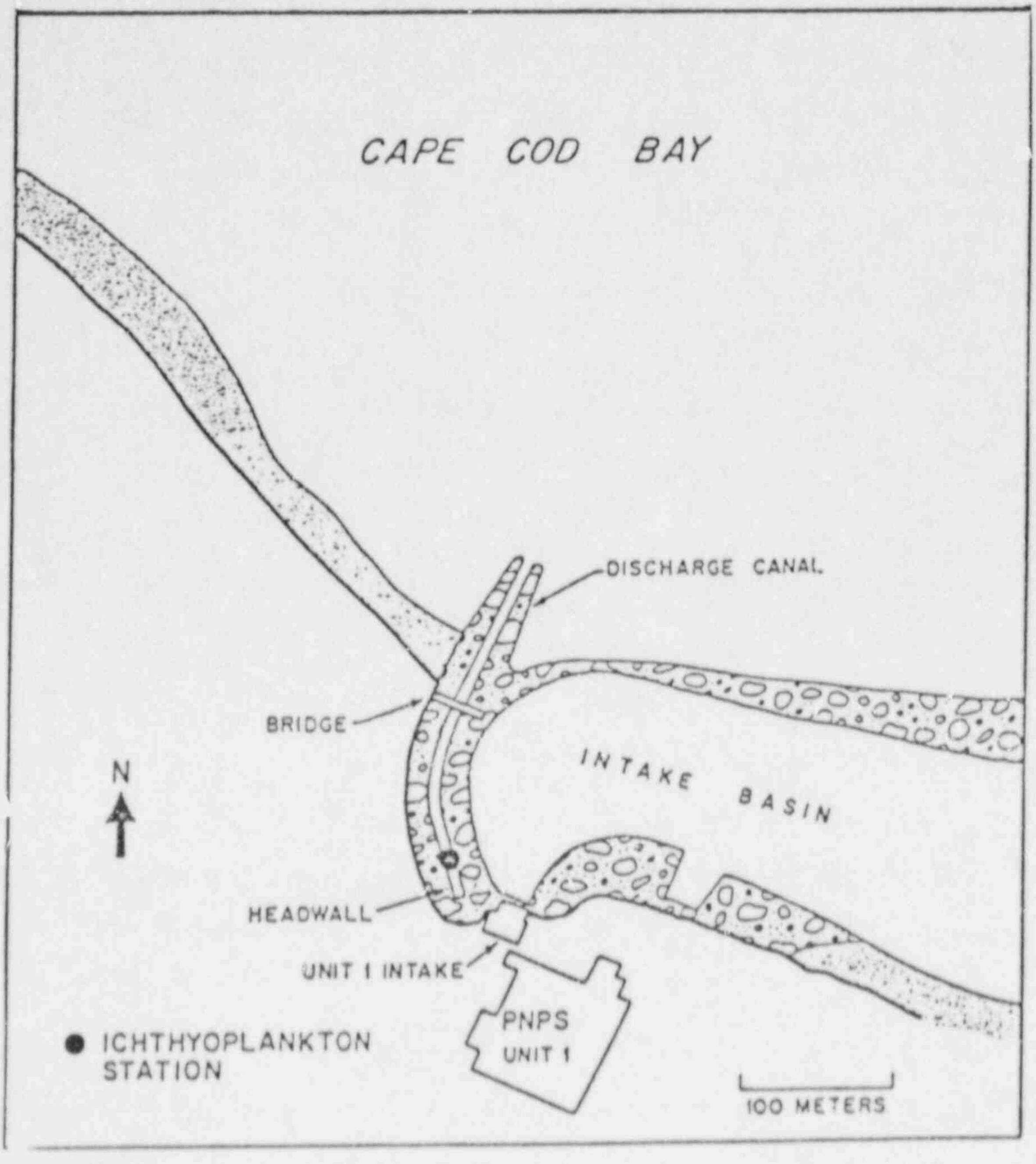

Figure 1. Entrainment sampling station in PNPS discharge canal.

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 state III haddock eggs and haddock larvae collected at PNPS. The gadidae-*Glyptocephalus* grouping was not considered necessary in January and February because it is unlikely that witch flounder spawn during these months (Fahay 1983) and haddock spawning is not likely to occur 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 two 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 1977). 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 bay anchovy (Anchoa mitchilli) and striped anchovy (Anchoa hepsetus) are easily distinguishable, but their larvae are not. Eggs of these fishes were therefore 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 northerly 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). 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, 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 development 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 (7.1-8.2 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 Motoda (1959; see also Van Guelpen et al. 1982). Samples collected from May through October were examined completely for larval lobsters (Homarus americanus).

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. "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 1987.

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 the Boston Edison Senior Marine Fisheries Biologist.

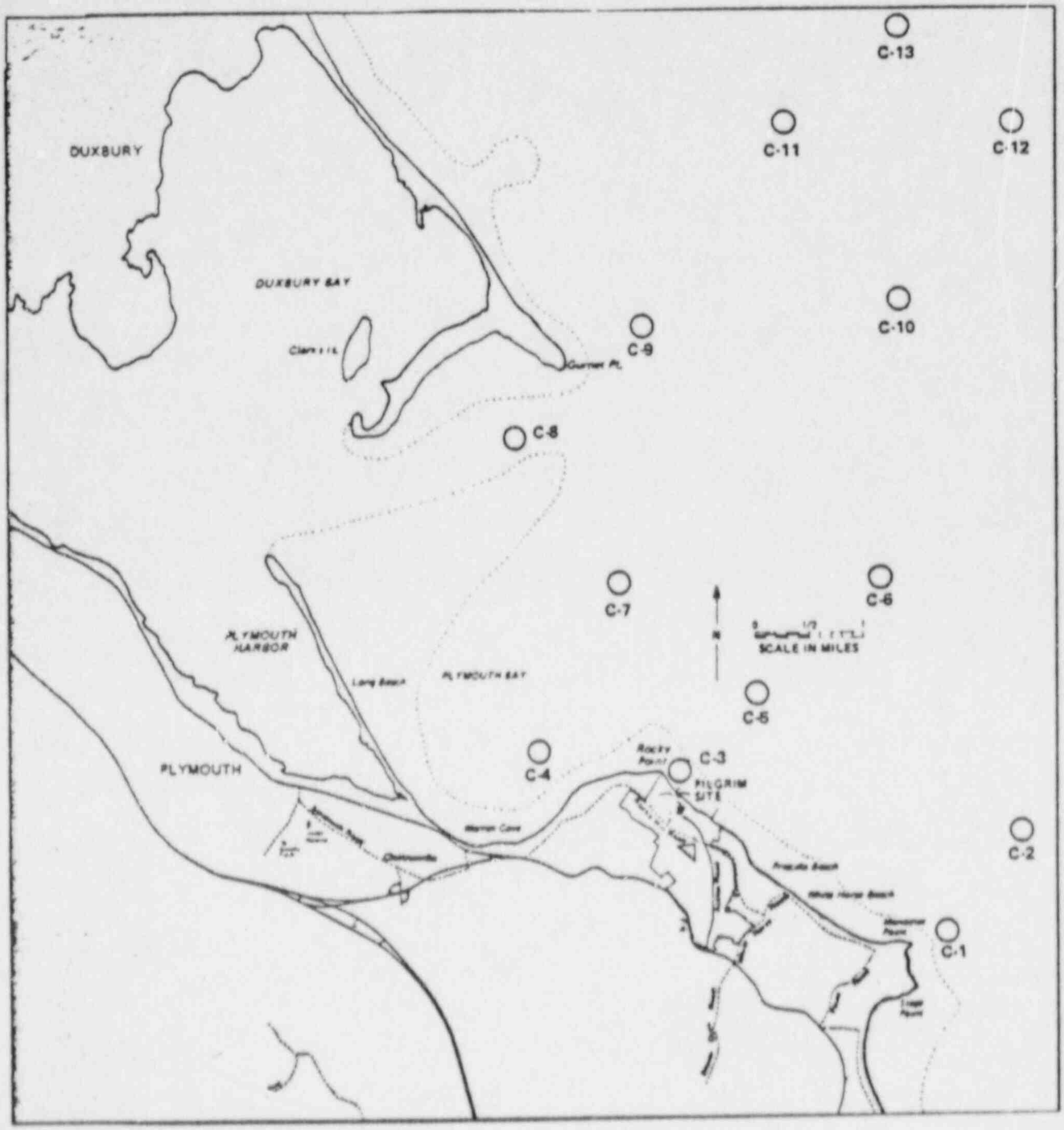

Figure 2. Location of entrainment contingency plan sampling stations, C-1 through C-13.

SECTION IV

RESULTS

Population densities per 100 m^3 of water for each species listed by date, station, and replicate are presented for the January-June period of 1988 in Appendix A (available upon request). The occurrence of eggs and larvae of each species by month appears in Table 1.

Ichthyoplankton entrained during January through April generally represent winter-early spring spawning fishes. The number of species found in the discharge collections was four in January, ten in February, 16 in March, and 17 in April. Samples contained relatively few eggs since species contributing the greatest numbers to entrainment during this period spawn demersal, adhesive eggs which are not normally subject to entrainment. Only two eggs were found during January and February combined, one an unidentified demersal, the other an American plaice (Hippoglossoides platessoides). March samples contained a greater variety of eggs (5 species) with winter flounder being numerically dominant. They accounted for 92% of the month's total with a mean density of 9 eggs per 100 m^3 of water. Fourbeard rockling, Atlantic cod, American plaice, and yellowtail flounder, all with mean monthly densities less than 1 per 100 m^3, completed the March egg catch. April collections contained six species of eggs with plaice and rockling being most numerous; monthly mean densities per 100 m^3 of 3.7 and 3.3 accounted for 26 and 24% of the total, respectively. Atlantic cod, haddock, yellowtail, and winter flounder completed the catch. Since winter flounder eggs are demersal and adhesive, their densities in the PNPS discharge canal cannot be considered

Table 1. Species of fish eggs (E) and larvae (L) obtained in ichthyoplankton collections from the Pilgrim Nuclear Power Station discharge canal, January-June 1988.

Species		Jan	Feb	Mar	Apr	May	Jun
American eel	*Anguilla rostrata*				L	L	
Atlantic menhaden	*Brevoortia tyrannus*						E/L
Atlantic herring	*Clupea harengus harengus*			L	L	L	
Rainbow smelt	*Osmerus mordax*				L	L	
Goosefish	*Lophius americanus*					E	
Fourbeard rockling	*Enchelyopus cimbrius*			E	E/L	E/L	E/L
Atlantic cod	*Gadus morhua*		L	E/L	E	E	E/L
Haddock	*Melanogrammus aeglefinus*				E		
Silver hake	*Merluccius bilinearis*						E
Atlantic tomcod	*Microgadus tomcod*		L	L	L	L	
Pollock	*Pollachius virens*	L	L	L			
Hake	*Urophycis* spp.						E
Northern pipefish	*Syngnathus fuscus*						L
Silversides	*Menidia* spp.						L
Wrasses	Labridae					E	E
Tautog	*Tautoga onitis*						L
Cunner	*Tautogolabrus adspersus*						L
Snakeblenny	*Lumpenus lumpretaeformis*			L			
Radiated shanny	*Ulvaria subbifurcata*				L	L	L
Rock gunnel	*Pholis gunnellus*	L	L	L	L	L	
Sand lance	*Ammodytes* sp.		L	L	L	L	

Table 1 (continued).

Species		Jan	Feb	Mar	Apr	May	Jun
Atlantic mackerel	*Scomber scombrus*					E	E/L
Butterfish	*Peprilus triacanthus*						E
Searobins	*Prionotus* spp.						E
Grubby	*Myoxocephalus aenaeus*	L	L	L	L	L	
Longhorn sculpin	*M. octodecemspinosus*	L	L	L			
Shorthorn sculpin	*M. scorpius*		L	L	L		
Lumpfish	*Cyclopterus lumpus*						L
Seasnail	*Liparis atlanticus*			L	L	L	L
Gulf snailfish	*L. coheni*		L	L	L		
Windowpane	*Scophthalmus aquosus*					E	E/L
Witch flounder	*Glyptocephalus cynoglossus*					E	E/L
American plaice	*Hippoglossoides platessoides*		E	E/L	E/L	E/L	E/L
Yellowtail flounder	*Limanda ferruginea*			E	E	E/L	E
Winter flounder	*Pseudopleuronectes americanus*			E	E/L	L	L

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 or perhaps fish.

Larval collections during the winter-early spring period contained increasing numbers of species with each successive month - 4 in January, 9 in February, 13 in March, and 14 in April. Numerical dominants included sculpin (Myoxocephalus spp.), rock gunnel (Pholis gunnellus), seasnails (Liparis spp.), and sand lance. Sculpin densities averaged 0.4 in January (37% of the total larval catch), 41 in February (82% of total), 115 in March (48%), and 43 per 100 m^3 in April (43%), with the grubby (M. aenaeus) being most abundant overall among the three species. For rock gunnel densities per 100 m^3 of water were 0.5 in January (50% of total), 8 in February (16%), 118 in March (50%), and 4 in April (5%). Larval seasnails were uncommon until April when a monthly mean of 17 larvae per 100 m^3 was recorded representing 25% of the larval catch; the majority of these (99.4%) were L. atlanticus. Larval sand lance did not appear in the January collections, averaged 0.4 per 100 m^3 in the February collections (1% of the catch), 2 per 100 m^3 in March (1%), and 11 in April (16%).

May and June collections (along with July) consist of late spring-summer spawning species. Overall 19 species were represented in May and 18 were represented in June, with 9 and 13 species being represented by eggs in those two respective months. Numerically dominant eggs included Atlantic mackerel (Scomber scombrus) and the labrids. Mackerel accounted for 87% of the eggs taken in May and 61% of those taken in June; monthly densities amounted to

1724 and 2220 per 100 m³ respectively. Combined, labrid-Limanda and labrid eggs accounted for an additional 6% of the eggs in May and 35% of the eggs in June.

Larval collections contained 13 species in May, 15 in June, with seasnails (only L. atlanticus were found during this period), winter flounder, and Atlantic mackerel being the numerical dominants. Seasnails represented 42% of the larvae in May with a monthly mean density of 28 per 100 m³ of water and 35% of the larvae in June with a monthly mean of 7 per 100 m³. Winter flounder added 35% in May, 3% in June; monthly mean densities were 24 and 1 per 100 m³, respectively. Larval mackerel were not found until June at which time a monthly mean density of 6 per 100 m³ accounted for 29% of the total larval catch.

Appendix B lists mean monthly densities for each of the numerical dominants collected over the January-June period dating back to 1975. A general review of the data through the first six months of 1988 suggests that month by month egg densities were within the range of monthly mean densities observed over the past 13 years with three exceptions:
1) Atlantic cod eggs were relatively uncommon from January through March and during May. None were found in January for the third time and none were found in February for the first time. March and May mean monthly densities were both the lowest yet observed over the 1975-1988 period.
2) Paralichthys-Scophthalmus eggs, which the larval collections suggested were primarily windowpane, were relatively abundant in May. The 1988 mean monthly density of 74 per 100 m³ exceeded the previous May high (1980) by a factor of 2.2. 3) Mackerel eggs were also abundant in June 1988 exceeding June 1986, the previous high, by a factor of 8.0.

Similar results were obtained among the larvae comparing 1988 with the previous 13 years, again with three notable exceptions: 1) Rock gunnel were relatively abundant in March, the 1988 monthly mean of 118 per 100 m³ of water just exceeding March 1984 (109 per 100 m³), the previous March high value. 2) Larval seasnails were more abundant in April 1988 (17.4 per 100 m³) than in previous Aprils, just barely surpassing 1977 (16.9 per 100 m³), the previous high. 3) Larval sculpin were numerous in February 1988 due mainly to the shorthorn sculpin (Myoxocephalus scorpius) and in March due mainly to the grubby. Shorthorn sculpin were absent from most previous February collections being found in only three years since 1979; in 1988 a mean density of 33 per 100 m³ was obtained for the month, 5.3 times the previous February high observed in 1985. In March of 1988, with a monthly mean of 103 per 100 m³, grubby exceeded the previous March peak (1980) by a factor of 1.7.

Larval sculpin densities on February 25, 1988 (79 per 100 m³; 81% = M. scorpius) and March 16, 1988 (308 per 100 m³; 95% = M. aenaeus) were unusually high as defined under the contingency sampling program. In both cases, subsequent sampling on March 1 and March 21 suggested that the relatively high densities were of short duration as values returned to levels below the unusual level within those time frames. No additional, unscheduled sampling was conducted in response to the high densities because no excess heat or chlorine were introduced due to the extended plant outage, and both circulating seawater pumps were frequently off between sampling periods.

No lobster larvae were found through June 1988.

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-June 1988.

*Available upon request.

APPENDIX B. Mean monthly densities and range per 100 m³ of water for the dominant species of fish eggs and larvae entrained at PNPS. January-June 1975-1988.

Some standardization of data sets was required to adjust for changes in the sampling program which have occurred over the years:

1. Only 0.333-mm mesh net data were used in those cases (1975) when field sampling was carried out using both 0.333 and 0.505 mesh nets.
2. When, as in 1976 and 1977, 24-hour sampling series were conducted, the samples taken nearest the time of daylight low tide were selected for comparison since this conforms to the routine specification for the time of entrainment sampling used in all subsequent years.
3. For the same reason only daylight low tide data were used when, in 1975, samples were also taken at high tide and/or at night.
4. Cod and pollock egg densities were summed to make up the category "gadidae" since these eggs were not distinguished prior to 1976. In January and February when witch flounder do not spawn, all three egg stages are included in this category. During the remaining months, early-stage eggs are included with the gadidae-Glyptocephalus group.
5. Beginning in April when the Enchelyopus-Urophycis-Peprilus grouping became necessary, the listing for Enchelyopus cimbrius includes only late-stage eggs, the two early stages being included with the grouped eggs.
6. Since the Brosme-Scomber grouping was not considered necessary after 1983, grouped eggs were added to S. scombrus eggs in the table for 1975-1983 (B. brosme eggs having always been rare).

7. Sculpin larvae were identified to species beginning in 1979 following Khan (1971)*. They are shown by species beginning with that year as well as added together (Myoxocephalus spp.) for comparison with prior years.

8. Similar results are shown for seasnail larvae which were not speciated prior to 1981.

9. Although samples were in fact taken once in April 1976 and once in March and August 1977, comparisons with other years when sampling was weekly are not valid and consequently do not appear in the table. Data collected in 1974 was not included because samples were not collected at low tide in all cases.

10. When extra sampling series were required under the contingency sampling regime, results were included in calculating monthly mean densities.

Table format: $\frac{\text{Mean}}{\text{Range}}$

*Khan, N.Y. 1971. Comparative morphology and ecology of the pelagic larvae of nine cottidae (Pisces) on the northwest Atlantic and St. Lawrence drainage. Ph.D. thesis, University of Ottawa. 234p.

EGGS — January	1975	1976	1977	1978	1979	1980	1981	1982	1983
Brevoortia tyrannus	0	NO SAMPLING	NO SAMPLING	0	0	0	0	0	0
Gadidae-*Glyptocephalus*	-			-	-	-	-	-	-
Gadidae*	0.5 / 0-1			(0.2) / 0-0.7	(2.2) / 0-5	(2.9) / 0.3-6	(3.4) / 1-9	(0.5) / 0-1	0
Gadus morhua	-			0.2 / 0-0.7	2.1 / 0-5	2.9 / 0.3-6	3.4 / 1-9	0.5 / 0-1	0
Pollachius virens	-			0	0.1 / 0-0.4	0	0	0	0
Enchelyopus-*Urophycis*-*Peprilus*	-			-	-	-	-	-	-
*Enchelyopus cimbrius***	0.1 / 0-0.6			0	0	0	0	0	0
Urophycis spp.	0			0	0	0	0	0	0
Labridae-*Limanda*	0			0	0	0	0	0	0
Labridae	0			0	0	0	0	0	0
Scomber scombrus	0			0	0	0	0	0	0
Prionotus spp.	0			0	0	0	0	0	0
Paralichthys-*Scophthalmus*	0			0	0	0	0	0	0
Hippoglossoides platessoides	0			0	0	0	0.1 / 0-0.4	0	0
Total	0.6 / 0-1			0.2 / 0-0.7	2.7 / 0-5	2.9 / 0.3-6	3.5 / 1-9	0.5 / 0-1	0

*Represents *G. morhua* and *P. virens* eggs in all stages.

**Represents all three egg stages, January through April.

EGGS January	1984	1985	1986	1987	1988
Brevoortia tyrannus	0	0	0	0	0
Gadidae-*Glyptocephalus*	-	-	-	-	-
Gadidae*	(0.4) 0-2	0	(0.6) 0.6-2	(0.1) 0-1	0
Gadus morhua	0.4 0-2	0	0.6 0.6-2	0.1 0-1	0
Pollachius virens	0	0	0	0	0
Enchelyopus-*Urophycis*-*Peprilus*	-	-	-	-	-
*Enchelyopus cimbrius***	0	0	0	0	0
Urophycis spp.	0	0	0	0	0
Labridae-*Limanda*	0	0	0	0	0
Labridae	0	0	0	0	0
Scomber scombrus	0	0	0	0	0
Prionotus spp.	0	0	0	0	0
Paralichthys-*Scophthalmus*	0	0	0	0	0
Hippoglossoides platessoides	0	0	0	0	0
Total	0.4 0-2	0	0.6 0.6-2	0.2 0-1	0.1 0-1

*Represents *G. morhua* and *P. virens* eggs in all stages.

**Represents all three egg stages, January through April.

February EGGS	1975	1976	1977	1978	1979	1980	1981	1982	1983
Brevoortia tyrannus	0			0	0	0	0	0	0
Gadidae-*Glyptocephalus*	-			-	-	-	-	-	-
Gadidae*	0.9 / 0-3			(2.4) / 0-5	(1.6) / 0-3	(1.6) / 0.4-3	(1.1) / 0-2	(0.1) / 0-0.6	(0.3) / 0-1
Gadus morhua	-			1.4 / 0-4	1.6 / 0-3	1.6 / 0.4-3	1.1 / 0-2	0.1 / 0-0.6	0.3 / 0-1
Pollachius virens	-			0.9 / 0-5	0	0	0	0	0
Enchelyopus-*Urophycis*-*Peprilus*	-	NO SAMPLING	NO SAMPLING	-	-	-	-	-	-
*Enchelyopus cimbrius***	0			0	0	0	0	0	0
Urophycis spp.	0			0	0	0	0	0	0
Labridae-*Limanda*	0			0	0	0	0	0	0
Labridae	0			0	0	0	0	0	0
Scomber scombrus	0			0	0	0	0	0	0
Prionotus spp.	0			0	0	0	0	0	0
Paralichthys-*Scophthalmus*	0			0	0	0	0	0	0
Hippoglossoides platessoides	0			0.1 / 0-0.8	0.1 / 0-0.5	0.2 / 0-0.6	0	0	0.4 / 0-1
Total	1.0 / 0-3			2.5 / 0-5	1.6 / 0-3	1.8 / 0.8-3	3.5 / 0-13	0.1 / 0-0.6	0.6 / 0.5-2

*Represents *G. morhua* and *P. virens* eggs in all stages.

**Represents all three egg stages, January through April.

EGGS — February	1984	1985	1986	1987	1988
Brevoortia tyrannus	0	0	0	0	0
Gadidae-Glyptocephalus	-	-	-	-	-
Gadidae*	(1.5) / 0-3	(0.6) / 0-3	(0.4) / 0-1	(0.1) / 0-1	0
Gadus morhua	1.5 / 0-3	0.6 / 0-3	0.4 / 0-1	0.1 / 0-1	0
Pollachius virens	0	0	0	0	0
Enchelyopus-Urophycis-Peprilus	-	-	-	-	-
Enchelyopus cimbrius**	0	0	0	0	0
Urophycis spp.	0	0	0	0	0
Labridae-Limanda	0	0	0	0	0
Labridae	0	0	0	0	0
Scomber scombrus	0	0	0	0	0
Prionotus spp.	0	0	0	0	0
Paralichthys-Scophthalmus	0	0	0	0	0
Hippoglossoides platessoides	0.4 / 0-2	0	0	0	0.1 / 0-1
Total	2.0 / 0-4	1.0 / 0-3	0.4 / 0-1	0.1 / 0-1	0.1 / 0-1

*Represents G. morhua and P. virens eggs in all stages.

**Represents all three egg stages, January through April.

EGGS March	1975	1976	1977	1978	1979	1980	1981	1982	1983
Brevoortia tyrannus	0	NO SAMPLING	ONE SAMPLING PERIOD ONLY	0	0	0	0	0	0
Gadidae-Glyptocephalus	0.6 / 0-2			1.5 / 0-3	9.2 / 0-32	0.2 / 0-2	0	0	0.6 / 0-3
Gadidae*	0.8 / 0-3			(0.5) / 0-1	(0.5) / 0-1	(0.3) / 0-1	(1.5) / 0-9	(0.4) / 0-2	(5.2) / 0.6-24
Gadus morhua	-			0.5 / 0-1	0.5 / 0-1	0.3 / 0-1	1.5 / 0-9	0.4 / 0-2	5.2 / 0.6-24
Pollachius virens	-			0	0	0	0	0	0
Enchelyopus-Urophycis-Peprilus	-			-	-	-	-	-	-
Enchelyopus cimbrius**	0			0	0	0	0	0	0
Urophycis spp.	0			0	0	0	0	0	0
Labridae-Limanda	0			0	0	0	0	0	0
Labridae	0			0	0	0	0	0	0
Scomber scombrus	0			0	0	0	0	0	0
Prionotus spp.	0			0	0	0	0	0	0
Paralichthys-Scophthalmus	0			0	0	0	0	0	0
Hippoglossoides platessoides	0.4 / 0-1			0.9 / 0-4	2.1 / 0-7	0.2 / 0-1	3.7 / 0-14	-	7.7 / 0.5-17
Total	9.7 / 0.8-41			2.8 / 0-5	12.1 / 0.4-35	1.9 / 0-12	6.9 / 0.5-20	1.3 / 0-9	14.0 / 2-50

*Represents late-stage G. morhua and P. virens eggs.

**Represents all three egg stages, January through April

EGGS March	1984	1985	1986	1987	1988
Brevoortia tyrannus	0	0	0	0	0
Gadidae-Glyptocephalus	0.1 0-2	0	0	0.5 0-2	0.2 0-2
Gadidae*	(2.6) 0-11	(0.3) 0-2	(0.4) 0-2	(0.4) 0-2	(0.2) 0-1
Gadus morhua	2.6 0-11	0.3 0-2	0.4 0-2	0.4 0-2	0.2 0-1
Pollachius virens	0	0	0	0	0
Enchelyopus-Urophycis-Peprilus	-	-	-	-	-
Enchelyopus cimbrius**	0	0	0	0	0.1 0-1
Urophycis spp.	0	0	0	0	0
Labridae-Limanda	0	0	0	0	0
Labridae	0	0	0	0	0
Scomber scombrus	0	0	0	0	0
Prionotus spp.	0	0	0	0	0
Paralichthys-Scophthalmus	0	0	0	0	0
Hippoglossoides platessoides	4.5 0-22	0.3 0-1	0	0	0.1 0-1
Total	7.9 0.7-30	2.4 0-9	6.6 0-34	48.9 1-219	9.4 0-81

*Represents late-stage G. morhua and P. virens eggs.

**Represents all three egg stages, January through April.

EGGS April	1975	1976	1977	1978	1979	1980	1981	1982	1983
Brevoortia tyrannus	0	ONE SAMPLING PERIOD ONLY	0	0	0	0	0	0	0
Gadidae-*Glyptocephalus*	1.7 / 0-5		0.7 / 0-2	8.1 / 2-14	3.5 / 0.8-12	3.0 / 0-7	0	0	0.5 / 0-3
Gadidae*	2.4 / 0-6		(0.3) / 0-3	(8.4) / 0.6-14	(1.1) / 0-3	(1.5) / 0-4	(0.4) / 0-3	(0.2) / 0-3	(0.4) / 0-2
Gadus morhua	-		0.3 / 0-3	8.4 / 0.6-14	1.0 / 0-3	1.5 / 0-4	0.4 / 0-3	0.2 / 0-3	0.4 / 0-2
Pollachius virens	-		0	0	0.05 / 0-0.6	0	0	0	0
Enchelyopus-*Urophycis*-*Peprilus*	-		-	-	-	-	-	-	-
*Enchelyopus cimbrius***	2.9 / 0-10		0.5 / 0-1	0.1 / 0-1	0.3 / 0-2	0.7 / 0-4	0	0.1 / 0-2	0.5 / 0-2
Urophycis spp.	0		0.1 / 0-0.8	0	0	0	0	0	0
Labridae-*Limanda*	4.8 / 0-18		2.5 / 0-7	11.1 / 0-26	8.1 / 0-28	0	0	0	0
Labridae	0		0.2 / 0-0.9	0.5 / 0-3	0.1 / 0-1	0	0	0	0
Scomber scombrus	0		0	0	0	0	0	0	0
Prionotus spp.	0		0	0	0	0	0	0	0
Paralichthys-*Scophthalmus*	0.1 / 0-0.7		0	0	0	0	0	0	0
Hippoglossoides platessoides	14.2 / 0-41		4.7 / 0-9	31.8 / 0.8-79	15.9 / 0-49	8.3 / 1-18	1.0 / 0-5	0.2 / 0-1	2.0 / 0-6
Total	33.4 / 1-84		10.2 / 1-18	63.1 / 8-114	73.9 / 4-546	26.1 / 0-29	13.5 / 0-77	5.8 / 0-42	8.1 / 0.7-19

*Represents late-stage *G. morhua* and *P. virens* eggs.

**Represents all three egg stages, January through April.

EGGS April	1984	1985	1986	1987	1988
Brevoortia tyrannus	0	0	0	PUMPS DOWN - NO SAMPLING	0
Gadidae-*Glyptocephalus*	0.7 / 0-3	0	0		0.1 / 0-1
Gadidae*	(2.0) / 0-5	(1.6) / 0-4	(0.2) / 0-3		(2.2) / 0-7
Gadus morhua	2.0 / 0-5	1.5 / 0-4	0.2 / 0-3		2.2 / 0-7
Pollachius virens	0	0.06 / 0-0.7	0		0
Enchelyopus-*Urophycis*-*Peprilus*	-	-	-		-
*Enchelyopus cimbrius***	0.2 / 0-2	1.0 / 0-6	4.3 / 0-14		3.3 / 0-10
Urophycis spp.	0	0	0		0
Labridae-*Limanda*	0	0	0		0
Labridae	0	0	0		0
Scomber scombrus	0	0	0		0
Prionotus spp.	0	0	0		0
Paralichthys-*Scophthalmus*	0	0	0.3 / 0-2		0
Hippoglossoides platessoides	6.2 / 1.5-11	1.9 / 0-12	0.2 / 0-1		3.7 / 0-14
Total	11.0 / 5-16	10.1 / 0-25	7.6 / 0-21		14.1 / 3-29

*Represents late-stage *G. morhua* and *P. virens* eggs.

**Represents all three egg stages, January through April.

EGGS May	1975	1976	1977	1978	1979	1980	1981	1982	1983
Brevoortia tyrannus	0	0	0	0	0	0.1 0-1	0	0	0
Gadidae-*Glyptocephalus*	1.0 0-2	2.3 0-6	3.4 0-11	3.4 0-14	1.4 0-5	2.1 0-6	0.2 0-2	0.4 0-2	4.0 0-18
Gadidae*	1.1 0-3	(1.5) 0-4	(1.2) 0-3	(9.6) 0-61	(1.8) 0-5	(1.2) 0-4	(0.8) 0-3	(0.1) 0-0.8	(0.6) 0-3
Gadus morhua	-	1.5 0-4	1.2 0-3	9.6 0-61	1.8 0-5	1.2 0-4	0.8 0-3	0.1 0-0.8	0.6 0-3
Pollachius virens	-	0	0	0	0	0	0	0	0
Enchelyopus-*Urophycis*-*Peprilus*	8.3 0-30	13.3 0-72	12.5 5-22	27.8 2-125	9.5 0.6-34	8.5 4-14	7.8 1-19	3.4 1-8	6.7 3-18
Enchelyopus cimbrius	28.3 6-70	30.8 0-91	14.0 0-32	10.9 0-37	5.3 0-15	52.0 10-73	15.1 0-55	0.9 0-2	11.8 0-59
Urophycis spp.	0	0	0.4 0-3	0	0	0	0.1 0-1	0	0.1 0-0.5
Labridae-*Limanda*	145.8 2-1248	12.0 5-23	280.8 3-1240	1843.4 3-11809	1491.9 6-9475	3024.0 5-9331	74.1 2-94	917.8 4-248	30.2 0-209
Labridae	0.3 0-2	0	8.6 0-55	20.5 0-169	4.1 0-19	119.0 0-431	3.6 0-23	5.3 0.5-15	0.2 0-1
*Scomber scombrus***	2.5 0-8	3.0 0-11	46.0 0-104	56.8 0-308	82.2 0.2-355	231.6 57-621	47.2 0-195	160.9 2-705	116.4 0-424
Prionotus spp.	0.03 0-0.5	0	0	0	0	0	0	0	0
Paralichthys-*Scophthalmus*	10.1 0-64	6.3 0-19	12.5 2-32	30.4 0-169	21.0 0-76	34.0 7-67	22.2 0-64	11.7 0-43	9.6 0-27
Hippoglossoides platessoides	2.9 0-9	2.1 0-9	8.0 0-16	11.3 0-79	6.5 0-11	14.7 0-51	5.7 0.5-16	1.5 0-7	2.3 0.5-9
Total	196.5 12-1366	74.7 35-126	396.3 31-1324	2017.8 13-12428	1638.3 45-9925	3489.0 1-10314	151.6 29-368	251.9 40-425	185.9 10-524

*Represents late-stage *G. morhua* and *P. virens* eggs.

**Includes *Brosme*-*Scomber*, 1975-1983.

EGGS May	1984	1985	1986	1987	1989
Brevoortia tyrannus	0	0	0	0	0
Gadidae-*Glyptocephalus*	2.0 0-8	1.0 0-3	0.6 0-5	2.0 0-13	0.2 0-2
Gadidae*	(1.0) 0-5	(0.5) 0-2	(0.2) 0-2	(0.4) 0-3	(0.004) 0-1
Gadus morhua	1.0 0-5	0.5 0-2	0.2 0-2	0.4 0-3	0.004 0-1
Pollachius virens	0	0	0	0	0
Enchelyopus-Urophycis-Peprilus	8.5 0-41	14.9 0-98	46.0 3-189	19.8 1-66	27.5 0-131
Enchelyopus cimbrius	8.4 0-44	9.8 1-22	22.5 0-52	17.5 0-57	39.2 1-91
Urophycis spp.	0	0.9 0-9	0.1 0-1	0.1 0-1	0
Labridae-*Limanda*	9.5 0-40	1464.8 0-4622	54.0 2-225	20.2 0-141	108.8 3-424
Labridae	0.4 0-5	2.6 0-16	2.4 0-13	0.8 0-5	7.5 0-23
*Scomber scombrus***	17.9 0-44	2485.5 5-20871	116.1 30-236	36.1 0-125	1723.7 0-11981
Prionotus spp.	0	0.3 0-1	0	0.1 0-1	0
Paralichthys-Scophthalmus	7.5 0-23	25.0 3-85	27.4 2-92	9.9 0-[illegible]	74.3 0-392
Hippoglossoides platessoides	2.4 0-6	1.4 0-7	0.5 0-2	0.8 0-4	0.08 0-1
Total	59.5 19-123	4051.5 38-21505	275.8 75-513	111.2 21-407	1989.1 17-12625

*Represents late-stage *G. morhua* and *P. virens* eggs.

**Includes *Brosme-Scomber*, 1975-1983.

June EGGS	1975	1976	1977	1978	1979	1980	1981	1982	1983
Brevoortia tyrannus	0.5 / 0-2	0.3 / 0-1	0.3 / 0-3	1.7 / 0-9	0.7 / 0-2	19.1 / 0-83	1.9 / 0-10	3.1 / 0-11	0.7 / 0-4
Gadidae-*Glyptocephalus*	1.1 / 0-4	2.3 / 0-6	2.6 / 0-11	2.5 / 0-7	1.5 / 0-5	6.4 / 0-16	3.7 / 0-9	0.5 / 0-3	0.4 / 0-2
Gadidae*	0.8 / 0-3	(1.5) / 0-4	(5.3) / 0-27	(2.0) / 0-7	(0.4) / 0-2	(9.7) / 0-25	(3.2) / 0-22	(0.2) / 0-1	(0.8) / 0-5
Gadus morhua	-	1.5 / 0-4	5.3 / 0-27	2.0 / 0-7	0.4 / 0-2	9.7 / 0-25	3.2 / 0-22	0.2 / 0-1	0.8 / 0-5
Pollachius virens	-	0	0	0	0	0	0	0	0
Enchelyopus-*Urophycis*-*Peprilus*	28.5 / 16-55	11.3 / 2-25	24.4 / 0-96	75.8 / 0-308	38.0 / 17-98	14.7 / 2-26	93.7 / 4-634	8.8 / 0-19	39.8 / 6-160
Enchelyopus cimbrius	20.0 / 1-76	25.6 / 9-90	51.5 / 5-114	14.7 / 0-33	24.3 / 2-65	49.8 / 2-51	18.4 / 7-38	6.9 / 0-23	14.0 / 0-39
Urophycis spp.	1.5 / 0-6	0.7 / 0-2	4.7 / 0-15	4.3 / 0-14	10.2 / 0-27	2.2 / 4-5	9.9 / 0-56	1.8 / 0-6	2.7 / 0-6
Labridae-*Limanda*	2432.0 / 809-5501	699.0 / 147-2258	5739.1 / 289-19708	1317.7 / 24-3876	5217.8 / 1080-10505	631.0 / 248-1266	3497.7 / 184-12537	1607.8 / 276-4588	6978.7 / 57-17918
Labridae	137.1 / 0-294	75.4 / 7-249	185.4 / 26-1181	90.6 / 0-262	216.3 / 50-774	101.6 / 13-191	199.0 / 82-1492	155.2 / 75-238	189.7 / 14-650
*Scomber scombrus***	126.3 / 4-746	5.0 / 0.8-19	55.0 / 6-199	151.8 / 0-360	18.0 / 4-41	40.8 / 0-100	155.9 / 3-1083	135.2 / 0-663	144.1 / 5-202
Prionotus spp.	0	0	0.2 / 0-3	0.3 / 0-2	0.5 / 0-2	1.0 / 0-4	1.0 / 0-7	0.5 / 0-2	1.2 / 0-5
Paralichthys-*Scophthalmus*	18.2 / 2-78	17.2 / 0-73	38.6 / 3-129	41.8 / 0-132	61.2 / 20-141	27.5 / 14-26	64.3 / 0-501	38.7 / 5-83	45.2 / 2-76
Hippoglossoides platessoides	0.2 / 0-1	0.6 / 0-5	2.7 / 0-14	0.9 / 0-4	0.3 / 0-1	10.8 / 0-42	1.8 / 0-5	0	0.8 / 0-3
Total	2819.8 / 819-5718	856.2 / 342-2393	6301.5 / 609-19425	1934.7 / 228-5917	5620.2 / 1401-11522	930.5 / 414-1652	4158.4 / 407-22226	1974.2 / 420-4912	7614.9 / 309-18628

*Represents late-stage *G. morhua* and *P. virens* eggs.

**Includes *Brosme*-*Scomber*, 1975-1983.

EGGS June	1984	1985	1986	1987	1988
Brevoortia tyrannus	9.7 0-51	1.0 0-8	2.1 0-9	0.6 0-4	11.0 0-56
Gadidae-*Glyptocephalus*	2.4 0-14	0.9 0-3	1.0 0-4	0.4 0-4	1.7 0-5
Gadidae*	(0.8) 0-3	(0.2) 0-1	(0.1) 0-1	(0.8) 0-5	(0.3) 0-2
Gadus morhua	0.8 0-3	0.2 0-1	0.1 0-1	0.8 0-5	0.3 0-2
Pollachius virens	0	0	0	0	0
Enchelyopus-*Urophycis*-*Peprilus*	12.3 1-44	19.1 3-50	45.0 0-204	20.2 0-80	39.2 2-137
Enchelyopus cimbrius	3.1 0-12	8.6 0-19	74.5 1-223	23.3 3-52	51.0 4-196
Urophycis spp.	1.0 0-6	3.6 0-9	4.8 0-19	6.0 0-24	3.1 0-10
Labridae-*Limanda*	1489.9 47-5983	639.9 52-1126	1826.0 332-6515	5166.2 177-14223	1100.8 238-3907
Labridae	2.0 0-6	94.9 12-241	62.6 0-119	110.7 2-359	163.8 67-338
*Scomber scombrus***	33.4 1-88	109.8 3-349	276.7 0-990	122.6 12-411	2220.3 27-6243
Prionotus spp.	0.5 0-4	5.4 0-15	3.3 1-9	77.0 0-225	2.3 0-20
Paralichthys-*Scophthalmus*	9.9 0-31	43.9 2-95	25.9 7-42	51.7 9-119	49.9 3-97
Hippoglossoides platessoides	0.1 0-1	0	0	1.5 0-13	0.1 0-2
Total	1581.1 93-6074	936.7 79-1798	2326.7 499-6712	5589.8 313-14910	3654.5 474-7879

*Represents late-stage *G. morhua* and *P. virens* eggs.

**Includes *Brosme*-*Scomber*, 1975-1983.

LARVAE — January	1975	1976	1977	1978	1979	1980	1981	1982	1983
Clupea harengus harengus	0.2 / 0-0.6	NO SAMPLING	NO SAMPLING	0	0	0	0.1 / 0-0.5	0.1 / 0-0.6	1.1 / 0-3
Enchelyopus cimbrius	0			0	0	0	0	0	0
Tautogolabrus adspersus	0			0	0	0	0	0	0
Ulvaria subbifurcata	0			0	0	0	0	0	0
Pholis gunnellus	0.7 / 0-3			5.1 / 2-9	1.0 / 0-5	0.3 / 0-1	0.1 / 0-0.4	0.1 / 0-0.6	2.3 / 0-5.5
Ammodytes sp.	6.7 / 0-18			1.4 / 0-4	4.8 / 0-11	15.8 / 0-38	1.6 / 0-5	0.6 / 0-1	0.7 / 0-1
Scomber scombrus	0			0	0	0	0	0	0
Myoxocephalus spp.	1.4 / 0-6			0.3 / 0-1	(0.5) / 0-1	(0.3) / 0-0.6	0	(0.3) / 0-1	(3.8) / 0.5-12
M. aenaeus	-			-	0.5 / 0-1	0.2 / 0-0.6	0	0.1 / 0-0.6	0
M. octodecemspinosus	-			-	0	0.1 / 0-0.5	0	0.2 / 0-0.6	3.8 / 0.5-12
M. scorpius	-			-	0	0	0	0	0
Liparis spp.	0			0	0	0	0	0	(0.2) / 0-0.5
L. atlanticus	-			-	-	0	0	0	0
L. coheni	-			-	-	0	0	0	0.2 / 0-0.5
Pseudopleuronectes americanus	0			0	0	0	0	0	0
Total	9.4 / 0-25			7.4 / 3-13	8.1 / 0-12	17.0 / 0-39	1.8 / 0-5	1.1 / 0-2	8.2 / 4-14

LARVAE January	1984	1985	1986	1987	1988
Clupea harengus harengus	0	0	0.1 0-0.6	1.0 0-3	0
Enchelyopus cimbrius	0	0	0	0	0
Tautogolabrus adspersus	0	0	0	0	0
Ulvaria subbifurcata	0	0	0	0	0
Pholis gunnellus	0.3 0-1	0.2 0-0.6	1.1 0-3	0.5 0-1	0.5 0-1
Ammodytes sp.	0	44.1 0-111	1.3 0-3	0	0
Scomber scombrus	0	0	0	0	0
Myoxocephalus spp.	(0.2) 0-0.8	(1.6) 0-4	(0.6) 0-2	(0.3) 0-1	(0.4) 0-1
M. aenaeus	0	0.2 0-1	0	0.1 0-1	0.1 0-1
M. octodecemspinosus	0.2 0-0.8	1.5 0-4	0.6 0-2	0.2 0-1	0.3 0-1
M. scorpius	0	0	0	0	0
Liparis spp.	0	(0.1) 0-0.5	0	(0-1) 0-1	0
L. atlanticus	0	0	0	0	0
L. coheni	0	0.1 0-0.5	0	0.1 0-1	0
Pseudopleuronectes americanus	0	0	0	0	0
Total	0.8 0-3	46.0 0-113	4.1 0-11	1.9 0-5	1.0 0-2

LARVAE — February	1975	1976	1977	1978	1979	1980	1981	1982	1983
Clupea harengus harengus	0.1 0-0.5			0.6 0-2	0	0	0	0	0.3 0-2
Enchelyopus cimbrius	0			0	0	0	0	0	0
Tautogolabrus adspersus	0			0	0	0	0	0	0
Ulvaria subbifurcata	0			0	0	0	0.1 0-0.4	0	0
Pholis gunnellus	3.7 0-14			1.2 0-3	2.9 0-10	0.6 0-2	2.1 0-5	0.5 0-3	4.0 0.6-2
Ammodytes sp.	2.1 0-8	NO SAMPLING	NO SAMPLING	8.8 0.6-24	11.1 4-21	3.1 0.4-8	10.2 3-16	2.7 0-9	0.4 0.5-1.4
Scomber scombrus	0			0	0	0	0	0	0
Myoxocephalus spp.	2.2 0-7			0.2 0-1	(6.6) 0-26	(1.9) 0-5	(1.7) 0-4	(0.1) 0-0.6	(1.9) 0.5-3
M. aenaeus	-			-	6.6 0-26	1.8 0-5	0.2 0-0.5	0.1 0-0.6	1.7 0-3
M. octodecemspinosus	-			-	0	0.2 0-0.6	1.6 0-4	0	0.3 0-0.6
M. scorpius	-			-	0	0	0	0	0
Liparis spp.	0			0	0	0	0.1 0-0.5	0	(0.3) 0-0.9
L. atlanticus	-			-	-	-	-	0	0
L. coheni	-			-	-	-	-	0	0.3 0-0.9
Pseudopleuronectes americanus	0			0	0	0	0	0	0
Total	10.8 0-17			11.0 0.8-29	20.9 4-58	5.9 0.7-10	14.8 3-24	3.5 0-12	7.1 2-11

LARVAE February	1984	1985	1986	1987	1988
Clupea harengus harengus	0.1 0-1	0.4 0-0.9	0.5 0-1	0.1 0-1	0
Enchelyopus cimbrius	0	0	0	0	0
Tautogolabrus adspersus	0	0	0	0	0
Ulvaris subbifurcata	0	0	0	0	0
Pholis gunnellus	10.3 0-21	24.9 0-51	5.4 3-14	4.7 4-6	8.0 0-16
Ammodytes sp.	1.0 0-3	35.4 0-132	0.1 0-0.6	0	0.4 0-2
Scomber scombrus	0	0	0	0	0
Myoxocephalus spp.	(1.1) 0-3	(14.9) 0-44	(1.3) 0-2	(8.8) 9-16	(41.0) 1-93
M. aenaeus	0.7 0-2	7.7 0-24	0.9 0-2	8.5 5-10	7.3 0-17
M. octodecemspinosus	0.4 0-1	1.0 0-3	0.5 0-2	0.3 0-1	0.5 0-1
M. scorpius	0	6.2 0-20	0	3.4 0-7	33.1 1-75
Liparis spp.	0	(0.5) 0-1	0	0	(0.1) 0-1
L. atlanticus	0	0	0	0	0
L. coheni	0	0.5 0-1	0	0	0.1 0-1
Pseudopleuronectes americanus	0	0	0	0	0
Total	12.8 0-26	77.9 0-223	8.1 5-16	18.4 17-21	50.2 3-109

LARVAE (March)	1975	1976	1977	1978	1979	1980	1981	1982	1983
Clupea harengus harengus	0.8 / 0-2	NO SAMPLING	ONE SAMPLING PERIOD ONLY	0	0.4 / 0-1	0.1 / 0-2	2.4 / 0-8	0.3 / 0-2	4.3 / 1-10
Enchelyopus cimbrius	0			0	0	0	0	0	0
Tautogolabrus adspersus	0			0	0	0	0	0	0
Ulvaria subbifurcata	0			0	0	0	0.1 / 0-0.5	0	0
Pholis gunnellus	34.0 / 26-47			11.2 / 0.7-28	9.3 / 1-34	22.5 / 0-81	23.7 / 1-62	18.7 / 18-34	6.4 / 3-25
Ammodytes sp.	29.5 / 11-60			11.1 / 0.7-22	54.0 / 9-228	43.0 / 1-157	35.4 / 10-78	190.0 / 0-613	7.2 / 0-29
Scomber scombrus	0			0	0	0	0	0	0
Myoxocephalus spp.	61.4 / 17-137			32.8 / 11-65	(12.3) / 1-35	(63.1) / 0-182	(35.3) / 5-91	(27.6) / 0-67	(6.7) / 0-17
M. aenaeus	-			-	12.3 / 1-35	61.0 / 0-177	33.4 / 4-86	25.5 / 4-64	6.6 / 0-17
M. octodecemspinosus	-			-	0	1.0 / 0-3	1.7 / 0-5	1.2 / 0-1	0.1 / 0-1
M. scorpius	-			-	0	1.2 / 0-5	0.1 / 0-1	1.2 / 0-4	0
Liparis spp.	0.5 / 0-1			0	0.4 / 0-4	3.9 / 0-18	(0.5) / 0-2	(0.1) / 0-1	(1.9) / 0-8
L. atlanticus	-			-	-	-	0.04 / 0-0.5	0	1.4 / 0-8
L. coheni	-			-	-	-	0.5 / 0-2	0.1 / 0-1	0.4 / 0-2
Pseudopleuronectes americanus	0			0	0.03 / 0-0.5	0.1 / 0-0.7	0.8 / 0-5	2.6 / 0-12	1.3 / 0-7
Total	127.5 / 66-236			55.7 / 26-96	76.8 / 11-293	129.2 / 3-385	99.6 / 43-169	240.6 / 31-174	28.1 / 1-83

LARVAE March	1984	1985	1986	1987	1988
<u>Clupea</u> <u>harengus</u> <u>harengus</u>	0.5 / 0-5	1.2 / 0-4	0.2 / 0-1	0	1.7 / 0-18
<u>Enchelyopus</u> <u>cimbrius</u>	0	0	0	0	0
<u>Tautogolabrus</u> <u>adspersus</u>	0	0	0	0	0
<u>Ulvaria</u> <u>subbifurcata</u>	0.03 / 0-0.6	0	0.3 / 0-2	0	0
<u>Pholis</u> <u>gunnellus</u>	108.9 / 0-482	45.7 / 0-96	58.4 / 2-159	3.4 / 0-11	117.8 / 4-375
<u>Ammodytes</u> sp.	1.0 / 0-3	10.4 / 0-47	9.2 / 0-30	0.1 / 0-1	2.4 / 0-9
<u>Scomber</u> <u>scombrus</u>	0	0	0	0	0
<u>Myoxocephalus</u> spp.	(37.6) / 0-228	(23.3) / 0-61	(65.6) / 8-218	(4.1) / 0-10	(114.6) / 32-356
<u>M</u>. <u>aenaeus</u>	26.3 / 0-156	21.3 / 0-58	60.0 / 5-213	3.7 / 0-10	102.9 / 12-347
<u>M</u>. <u>octodecemspinosus</u>	0	0.7 / 0-2	1.0 / 0-3	0.2 / 0-1	0.3 / 0-2
<u>M</u>. <u>scorpius</u>	11.3 / 0.7-72	1.3 / 0-3	4.6 / 0-12	0.2 / 0-1	11.2 / 0-26
<u>Liparis</u> spp.	(0.04) / 0-0.8	(0.6) / 0-2	(0.8) / 0-5	(0.1) / 0-1	(0.5) / 0-1
<u>L</u>. <u>atlanticus</u>	0	0.06 / 0-0.7	0.4 / 0-4	0	0.1 / 0-1
<u>L</u>. <u>coheni</u>	0.04 / 0-0.8	0.5 / 0-2	0.4 / 0-2	0.1 / 0-1	0.4 / 0-2
<u>Pseudopleuronectes</u> <u>americanus</u>	0.1 / 0-0.9	0.3 / 0-3	1.5 / 0-7	0	0
Total	148.7 / 0-172	82.5 / 2-179	136.5 / 14-348	8.0 / 1-19	237.8 / 19-736

April LARVAE	1975	1976	1977	1978	1979	1980	1981	1982	1983
Clupea harengus harengus	1.3 / 0-12	ONE SAMPLING PERIOD ONLY	0.1 / 0-1	0.3 / 0-2	0.6 / 0-3	0.1 / 0-1	0	1.0 / 0.4-5	1.9 / 0-9
Enchelyopus cimbrius	0		0	0	0	0	0	0	0.04 / 0-0.5
Tautogolabrus adspersus	0		0	0	0	0	0	0	0
Ulvaria subbifurcata	5.4 / 0-19		3.9 / 0-19	0.2 / 0-2	0.3 / 0-1	2.5 / 0-6	0.3 / 0-2	0.1 / 0-2	3.9 / 0-11
Pholis gunnellus	1.8 / 0-8		4.0 / 0-19	1.5 / 0-5	3.7 / 0-13	0.4 / 0-1	3.4 / 0-14	32.8 / 0-75	3.4 / 0-21
Ammodytes sp.	6.6 / 0.8-18		36.8 / 6-85	388.8 / 6-1252	92.1 / 26-196	50.3 / 0-171	33.0 / 7-66	8.1 / 2-261	16.2 / 0-58
Scomber scombrus	0		0	0	0	0	0	0	0
Myoxocephalus spp.	7.2 / 3-12		30.7 / 14-57	21.3 / 0-57	(16.3) / 1-32	(16.4) / 0-59	(19.2) / 2-53	(88.5) / 0-347	(7.0) / 0-24
M. aenaeus	-		-	-	16.3 / 1-32	16.4 / 0-59	18.6 / 2-53	88.2 / 0-344	7.0 / 0-24
M. octodecemspinosus	-		-	-	0	0	0.4 / 0-2	0.2 / 0-1	0
M. scorpius	-		-	-	0	0	0.1 / 0-1	0.2 / 0-3	0
Liparis spp.	3.5 / 0-11		16.9 / 0-72	1.8 / 0-7	2.1 / 0-8	5.3 / 0-29	(0.9) / 0-3	(0.9) / 0-4	(15.3) / 1-69
L. atlanticus	-		-	-	-	-	0.9 / 0-3		15.3 / 1-69
L. coheni	-		-	-	-	-	0	0.9 / 0-4	0
Pseudopleuronectes americanus	3.1 / 0.8-10		9.5 / 0-21	35.6 / 0-127	2.9 / 0-8	8.9 / 2-24	2.1 / 0-3	5.6 / 0-36	3.6 / 0-13
Total	29.7 / 14-43		103.1 / 5?-154	458.2 / 21-1324	120.5 / 57-238	86.0 / 8-266	66.5 / 29-142	185.4 / 4-732	51.7 / 3-135

LARVAE April	1984	1985	1986	1987	1988
Clupea harengus harengus	0	0.1 0-0.9	0.4 0-2	PUMPS DOWN - NO SAMPLING	0.9 0-3
Enchelyopus cimbrius	0	0	0		0.1 0-1
Tautogolabrus adspersus	0	0	0		0
Ulvaria subbifurcata	0	4.8 0-21	2.2 0-8		0.8 0-3
Pholis gunnellus	2.9 0-11	29.1 0-77	8.4 0-27		3.5 0-8
Ammodytes sp.	0	22.4 1-89	35.7 0-156		11.0 0-64
Scomber scombrus	0	0	0		0
Myoxocephalus spp.	(2.9) 0-11	(121.1) 18-442	(72.6) 1-295		(43.0) 3-111
M. aenaeus	2.9 0-11	121.0 18-442	71.9 1-292		28.9 3-111
M. octodecemspinosus	0	0	0.5 0-4		0
M. scorpius	0	0.1 0-0.8	0.3 0-2		0.3 0-2
Liparis spp.	0	(6.5) 1-26	(8.2) 0-27		(17.4) 0-99
L. atlanticus	0	6.1 0-26	8.0 0-27		17.3 0-99
L. coheni	0	0.4 0-2	0.2 0-1		0.1 0-1
Pseudopleuronectes americanus	0	4.2 0-11	10.7 0-33		2.9 2-17
Total	6.7 0-17	189.5 54-524	139.4 12-358		68.3 9-307

LARVAE (May)	1975	1976	1977	1978	1979	1980	1981	1982	1983
Clupea harengus harengus	2.2 / 0-24	0	0	0.1 / 0-1	0.03 / 0-0.5	0	0	0.2 / 0-1	0.04 / 0-0.5
Enchelyopus cimbrius	2.6 / 0-10	2.9 / 0-13	0.3 / 0-1	4.0 / 0-19	4.5 / 0-19	5.4 / 5-11	1.0 / 0-3	0.04 / 0-0.6	0.3 / 0-1
Tautogolabrus adspersus	0	0	0	0	0.2 / 0-2	1.3 / 0-8	0.04 / 0-0.2	0	0
Ulvaria subbifurcata	65.4 / 10-235	7.3 / 1-24	5.7 / 0-20	43.5 / 11-141	5.2 / 0-23	10.2 / 5-21	10.7 / 4-27	4.0 / 0-16	19.5 / 2-73
Pholis gunnellus	0.1 / 0-0.5	0	0	0.4 / 0-4	0.08 / 0-1	0	0	0.2 / 0-2	0.2 / 0-0.6
Ammodytes sp.	4.0 / 0-22	2.5 / 0-8	2.2 / 0-7	79.9 / 0-265	20.1 / 0-88	3.8 / 2-9	1.8 / 0-4	23.2 / 0-29	6.4 / 0.5-17
Scomber scombrus	0.1 / 0-0.4	0	0	2.6 / 0-27	6.1 / 0-29	3.8 / 0-12	0.9 / 0.5-5	0.1 / 0-1	0
Myoxocephalus spp.	3.2 / 0-11	0.5 / 0-2	1.2 / 0-9	0.3 / 0-37	(5.9) / 0-17	(0.5) / 0-3	(0.2) / 0-1	(1.5) / 0-10	(6.3) / 0-25
M. aenaeus	-	-	-	-	5.9 / 0-17	0.5 / 0-3	0.2 / 0-1	1.5 / 0-10	6.3 / 0-25
M. octodecemspinosus	-	-	-	-	0	0	0	0	0
M. scorpius	-	-	-	-	0	0	0	0	0
Liparis spp.	9.2 / 0-30	13.0 / 6-31	38.9 / 0-112	37.0 / 1-92	20.3 / 6-40	27.8 / 16-45	(16.1) / 2-69	(2.8) / 0-12	(13.5) / 0.5-37
L. atlanticus	-	-	-	-	-	-	16.1 / 2-69	2.7 / 0-12	13.5 / 0.5-37
L. coheni	-	-	-	-	-	-	0	0.1 / 0-2	0
Pseudopleuronectes americanus	13.9 / 2-36	7.4 / 2-18	16.3 / 4-29	38.0 / 0-129	18.4 / 3-40	29.1 / 11-75	11.1 / 0-98	30.3 / 1-49	15.8 / 0.5-7
Total	99.6 / 28-283	37.9 / 15-76	81.9 / 24-185	222.2 / 33-660	104.1 / 66-210	104.4 / 59-167	69.9 / 12-234	65.4 / 8-182	62.4 / 9-192

LARVAE May	1984	1985	1986	1987	1988
Clupea harengus harengus	0.1 / 0-1	0	0.1 / 0-1	0	0.08 / 0-1
Enchelyopus cimbrius	0	4.4 / 0-6	5.5 / 0-27	1.3 / 0-3	5.3 / 0-31
Tautogolabrus adspersus	0	0	0.2 / 0-1	0	0
Ulvaria subbifurcata	0.9 / 0-4	15.6 / 0-75	5.8 / 1-16	2.0 / 0-5	3.3 / 0-15
Pholis gunnellus	0.9 / 0-4	0.1 / 0-0.6	0.1 / 0-1	0	0.9 / 0-3
Ammodytes sp.	16.6 / 0-57	0.6 / 0-3	1.2 / 0-5	0.2 / 0-1	2.5 / 0-14
Scomber scombrus	0	0.5 / 0-6	0.2 / 0-1	0.1 / 0-1	0
Myoxocephalus spp.	(1.9) / 0-10	(2.1) / 0-11	(0.5) / 0-2	(0.2) / 0-1	(2.0) / 0-10
M. aenaeus	1.9 / 0-10	2.1 / 0-11	0.5 / 0-2	0.2 / 0-1	2.0 / 0-10
M. octodecemspinosus	0	0	0	0	0
M. scorpius	0	0	0	0	0
Liparis spp.	(3.3) / 0-11	(15.7) / 0-30	(2.2) / 0-6	(16.0) / 0-101	(28.3) / 1-146
L. atlanticus	3.3 / 0-11	15.7 / 0-30	2.2 / 0-6	16.0 / 0-101	28.3 / 1-146
L. coheni	0	0	0	0	0
Pseudopleuronectes americanus	9.6 / 0-27	14.1 / 0-27	7.4 / 2-13	10.2 / 0-52	23.6 / 0-105
Total	33.7 / 0-64	55.4 / 8-79	24.1 / 15-41	27.5 / 0-158	67.6 / 10-291

LARVAE — June	1975	1976	1977	1978	1979	1980	1981	1982	1983
Clupea harengus harengus	0	0	0	0	0	0	0	0	0
Enchelyopus cimbrius	50.1 / 0-137	28.7 / 0-46	128.8 / 84-248	40.2 / 0-145	7.4 / 1-15	34.5 / 4-102	36.2 / 0-149	0.9 / 0-5	13.6 / 0-47
Tautogolabrus adspersus	11.3 / 0-39	2.6 / 0-13	11.5 / 0-750	19.5 / 0-107	38.8 / 4-78	35.4 / 0-83	232.3 / 0-1639	6.5 / 0-26	12.6 / 0.5-46
Ulvaria subbifurcata	0.6 / 0-2	5.1 / 0-28	0	4.3 / 0-12	1.3 / 0-3	2.0 / 0-12	0.4 / 0-3	1.4 / 0-5	0.9 / 0-5
Pholis gunnellus	0	0	0	0.2 / 0-2	0	0	0	0	0
Ammodytes sp.	0	0.1 / 0-2	0	0.2 / 0-2	0.1 / 0-1	0	0.1 / 0-0.6	0	0.1 / 0-0.6
Scomber scombrus	39.9 / 0-149	4.2 / 0-15	14.0 / 0-55	31.5 / 0-126	9.9 / 0-37	35.3 / 0-109	318.1 / 0-3662	14.6 / 0-81	70.4 / 0-354
Myoxocephalus spp.	0	0	0	0	0	(0.6) / 0-7	0	0	0
M. aenaeus	-	-	-	-	0	0.6 / 0-7	0	0	0
M. octodecemspinosus	-	-	-	-	0	0	0	0	0
M. scorpius	-	-	-	-	0	0	0	0	0
Liparis spp.	2.1 / 0-7	0.7 / 0-50	6.2 / 0-28	16.0 / 2-65	1.3 / 0-4	6.2 / 0-21	(1.6) / 0-13	(0.5) / 0-4	(1.0) / 0-8
L. atlanticus	-	-	-	-	-	-	1.6 / 0-13	0.5 / 0-4	1.0 / 0-8
L. coheni	-	-	-	-	-	-	0	0	0
Pseudopleuronectes americanus	3.5 / 0.5-15	6.6 / 0-47	4.6 / 0-16	15.9 / 0-54	9.7 / 0-39	5.8 / 3-19	1.8 / 0-8	3.8 / 0-17	0.4 / 0-2
Total	117.9 / 14-260	55.1 / 8-139	297.2 / 125-641	176.7 / 51-343	82.5 / 27-154	145.8 / 49-377	710.7 / 5-5423	35.8 / 0-136	102.5 / 2-383

LARVAE June	1984	1985	1986	1987	1988
Clupea harengus harengus	0	0.07 0-1	0	0	0
Enchelyopus cimbrius	0.1 0-1	28.3 3-73	21.1 2-74	6.4 0-33	1.4 0-4
Tautogolabrus adspersus	0	50.7 0-208	40.4 0-157	0.8 0-6	1.0 0-5
Ulvaria subbifurcata	1.0 0-4	3.4 1-5	2.4 0-6	0.2 0-2	1.5 0-12
Pholis gunnellus	0.1 0-1	0	0	0	0
Ammodytes sp.	0.1 0-1	0	0	0	0
Scomber scombrus	0.1 0-1	86.5 0-376	113.2 0-393	0.4 0-2	5.6 0-52
Myoxocephalus spp.	0	0	0	0	0
M. aenaeus	0	0	0	0	0
M. octodecemspinosus	0	0	0	0	0
M. scorpius	0	0	0	0	0
Liparis spp.	(4.4) 0-13	(1.6) 0-3	(2.6) 0-11	(1.5) 0-13	(6.9) 1-32
L. atlanticus	4.4 0-13	1.6 0-3	2.6 0-11	1.5 0-13	6.9 1-32
L. coheni	0	0	0	0	0
Pseudopleuronectes americanus	4.7 0-24	2.2 0-7	1.3 0-6	0.3 0-4	0.6 0-4
Total	11.3 0-41	201.6 4-681	198.6 17-663	15.2 0-61	19.6 5-69

IMPINGEMENT OF ORGANISMS AT

PILGRIM NUCLEAR POWER STATION

(January - June 1988)

Prepared by: Robert D. Anderson

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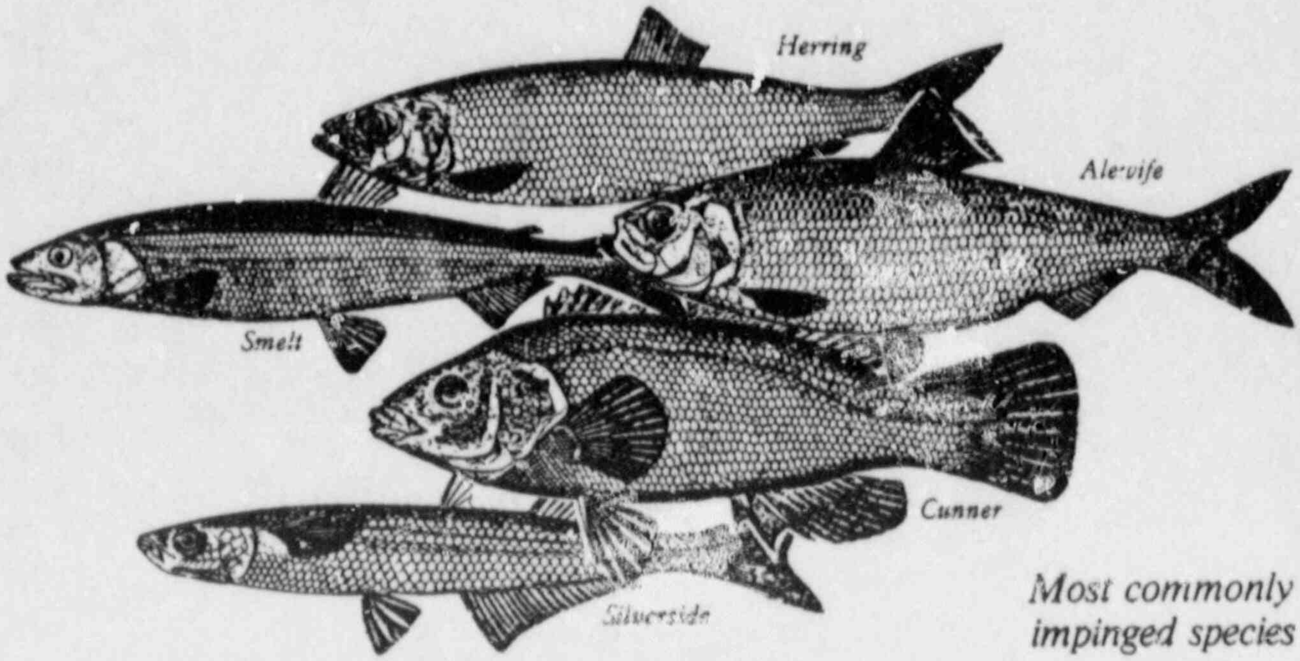
October 1988



Most commonly
impinged species

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SECTION I

SUMMARY

Fish impingement averaged 0.30 fish/hour during the period January-June 1988. Atlantic silverside (*Menidia menidia*), winter flounder (*Pseudopleuronectes americanus*), Atlantic tomcod (*Microgadus tomcod*) and rainbow smelt (*Osmerus mordax*) accounted for 73.7% of the fishes collected. Initial impingement survival for all fishes from static screen wash collections was approximately 36% and from continuous screen washes 53%.

The collection rate (no./hr.) for all invertebrates captured from January-June 1988 was 2.43. Polychaetes and sand shrimp (*Crangon septemspinosa*) accounted for 62.4% of the invertebrates impinged. Mixed species of algae collected on intake screens amounted to 376 pounds.

The relatively low fish impingement rate (0.30) from January-June 1988 reflected no circulating water pumps operating during portions of this period. The relatively moderate invertebrate impingement was also representative of minimal intake flow.

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 barracks 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 (EPA) and No. 359 (Mass. DWPC) for Pilgrim Nuclear Power Station, Unit I. The report describes impingement of organisms carried onto the vertical travelling water screens at Unit I. It presents analysis of the relationships between impingement, environmental factors, and plant operational variables.

The report is based on data collected from screen wash samples during January-June 1988.

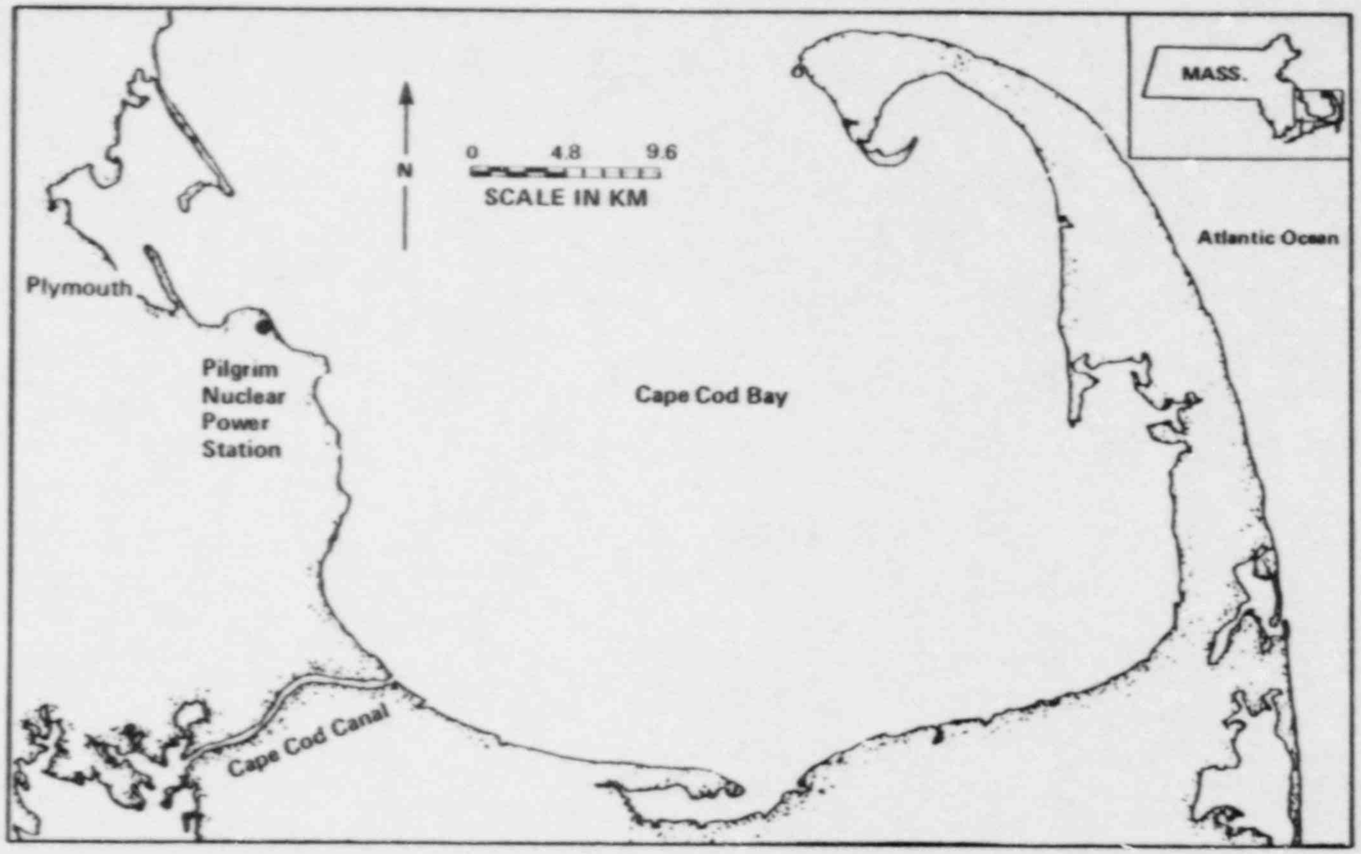

Figure 1. Location of Pilgrim Nuclear Power Station.

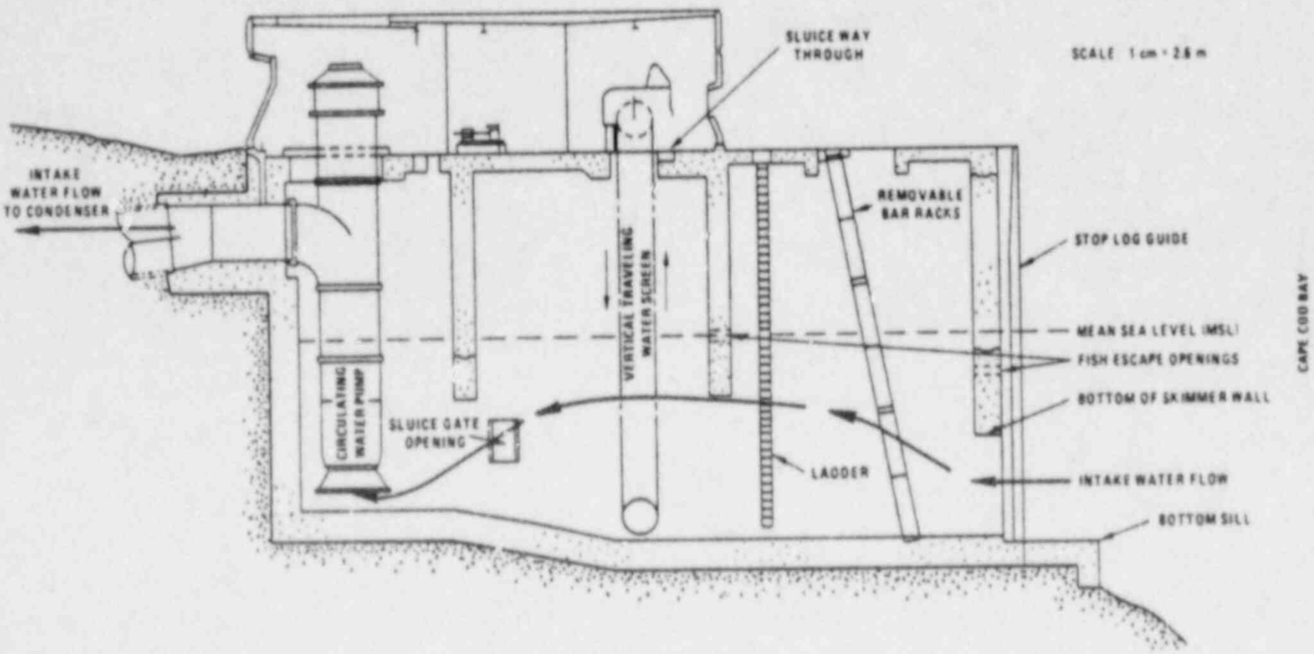

Figure 2: Cross-section of intake structure of Pilgrim Nuclear Power Station.

SECTION 3

METHODS AND MATERIALS

Three screen washings each week were performed from January-June 1988 to provide data for evaluating the magnitude of marine biota impingement and associated survival. 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 ligh: 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 is made of galvanized screen (3/8-inch mesh) attached to a removable steel frame and collected impinged biota, in the screenhouse, 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.

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.

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 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).

SECTION 4

RESULTS AND DISCUSSION

4.1 Fishes

In 188 collection hours, 57 fishes of fifteen species (Table 1) were collected from Pilgrim Nuclear Power Station intake screens during January-June 1988. The collection rate was 0.30 fish/hour. Atlantic silverside (Menidia menidia) was the most abundant species accounting for 50.9% of all fishes collected (Table 2). Winter flounder (Pseudopleuronectes americanus), Atlantic tomcod (Microgadus tomcod) and rainbow smelt (Osmerus mordax) accounted for 8.8, 7.0 and 7.0% of the total number of fishes collected. Atlantic silverside were impinged in highest numbers during March. These were primarily adult fish that averaged 104 mm total length. Winter flounder were also mostly impinged in March, Atlantic tomcod in February and rainbow smelt during January. The January-June 1988 fish impingement rate increased by a factor of about 1 1/2 from the rate for the same period in 1987 (0.21). This increase is possibly attributable to somewhat greater circulating water pump operating capacity, although still less than normal, from January-June 1988.

4.2 Invertebrates

In 188 collection hours, 457 invertebrates of 18 species (Table 3) were collected from Pilgrim Station intake screens between January-June 1988. The collection rate was 2.43 invertebrates/hour. Polychaetes and sand shrimp (Crangon septemspinosa), accounted for 31.5 and 30.8%, respectively, of the total number of invertebrates collected.

Table 1. Monthly Impingement For All Fishes Collected From Pilgrim Station Intake Screens, January-June 1988

Species	Jan.	Feb.	March	April	May	June	Totals
Atlantic silverside			28	1			29
Winter flounder	1		3	1			5
Atlantic tomcod		2		1		1	4
Rainbow smelt	4						4
Threespine stickleback			3				3
Grubby			1		1		2
Rock gunnel				2			2
Alewife						1	1
American shad				1			1
Atlantic cod					1		1
Atlantic herring	1						1
Blueback herring				1			1
Lumpfish					1		1
Red hake					1		1
Tautog		1					1
TOTALS	6	3	35	7	4	2	57
Collection Time (hrs.)	18	27	31	26	32	54	188
Collection Rate (#/hr.)	0.33	0.11	1.13	0.27	0.13	0.04	0.30

Table 2. Species, Number, Total Length(mm), Weight(gms) and Percentage For All Fishes Collected From Pilgrim Station Impingement Sampling, January-June 1988

Species	Number	Length Range	Mean Length	Weight Range	Mean Weight	Percent of Total Fish
Atlantic silverside	29	83-130	104	3-10	5	50.9
Winter flounder	5	48-123	75	1-20	6	8.8
Atlantic tomcod	4	72-125	106	3-17	10	7.0
Rainbow smelt	4	90-110	96	3-6	4	7.0
Threespine stickleback	3	55-65	59	3	3	5.3
Grubby	2	64-74	69	4-5	5	3.5
Rock gunnel	2	128-145	137	7-9	8	3.5
Alewife	1	103	103	8	8	1.8
American shad	1	165	165	27	27	1.8
Atlantic cod	1	190	190	72	72	1.8
Atlantic herring	1	265	265	123	123	1.8
Blueback herring	1	110	110	9	9	1.8
Lumpfish	1	85	85	21	21	1.8
Red hake	1	57	57	3	3	1.8
Tautog	1	65	65	5	5	1.8

Table 3. Monthly Impingement For All Invertebrates Collected From Pilgrim Station Intake Screens, January-June 1988

Species	Jan.	Feb.	March	April	May	June	Totals
Polychaete	103	40	1				144
Sand shrimp	30	6	84	21			141
Nudibranch		6	28	4	3		41
Horseshoe crab					1	37	38
Rock crab	1	12	10		13	1	37
Nemertea			7	5	1		13
Amphipoda					10		10
Isopoda	1	1	1			6	9
Green seaurchin	2	2	1			2	7
Nereis sp.			3	1			4
Common starfish					1	2	3
Nematoda				2	1		3
Green crab					2		2
Actinaria					1		1
American lobster						1	1
Hermit crab			1				1
Littorina sp.			1				1
Ophiuroidea					1		1
TOTALS	137	67	137	33	34	49	457
Collection Time (hrs.)	18	27	31	26	32	54	188
Collection Rate (#/hr.)	7.61	2.48	4.42	1.27	1.06	0.91	2.43

The collections of polychaetes occurred primarily in January, and sand shrimp during March which is typical for this species. One specimen of the commercially important American lobster (<u>Homarus americanus</u>) was captured.

Approximately 376 pounds of mixed algae species were recorded during impingement sampling, or 2.0 pounds/hour. Unlike the January-June 1988 fish impingement rate, the algal impingement rate was noteably higher than recorded for the same period in 1987.

4.3 <u>Fish Survival</u>

Fish survival data collected while impingement monitoring was conducted are shown in Table 4. Static screen wash collections provided the greatest numbers of fishes and revealed relatively low initial impingement survival rates for most species. Continuous screen wash collections had higher initial survival rates, although not many fishes were sampled. After 1-hour and 56-hour holding periods data were biased on the low side because of survival pump problems during January, or fishes being collected in the screenhouse where no survival facilities are located, or fishes being lost from the survival pool due to predation by sea gulls, etc.

Table 4. Survival Summary for the Fishes Collected During Pilgrim Station Impingement Sampling, January-June 1988. 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		1-Hour*		56-Hour *			
			Static	Cont.	Static	Cont.	Static	Cont.	Mean	Range
Atlantic silverside	24	5	7	0	-	0	-	0	104	83-130
Winter flounder	3	2	3	2	-	-	-	-	75	48-123
Atlantic tomcod	1	3	0	2	0	-	0	-	106	72-125
Rainbow smelt	4	0	0	-	0	-	0	-	96	90-110
Threespine stickleback	1	2	0	2	0	-	0	-	59	55-65
Grubby	2	0	2	-	-	-	-	-	69	64-74
Rock gunnel	2	0	1	-	1	-	1	-	137	128-145
Alewife	1	0	0	-	0	-	0	-	103	103
American shad	1	0	1	-	0	-	0	-	165	165
Atlantic cod	0	1	-	1	-	0	-	0	190	190
Atlantic herring	0	1	-	1	-	-	-	-	265	265
Blueback herring	1	0	1	-	0	-	0	-	110	110
Lumpfish	1	0	0	-	0	-	0	-	85	85
Red hake	0	1	-	0	-	0	-	0	57	57
Tautog	1	0	0	-	0	-	0	-	65	65
All Species:										
Number	42	15	15	8	-	-	-	-		
(% Surviving)			(35.7)	(53.3)						

* Limited data for some species because survival pumps were down in January 1988, fish were lost from the survival pool or fishes were sampled in the screenhouse.

SECTION 5

CONCLUSIONS

1. The average Pilgrim I collection rate for the period January-June 1988 was 0.30 fish/hour. The collection rate was comparatively lower in 1987, possibly due to somewhat more circulating water pump capacity during 1988.

2. Fifteen species of fish were recorded in 188 impingement collection hours.

3. The major species collected and their relative percentages of the total collections were Atlantic silverside, 50.9%; winter flounder 8.8%; Atlantic tomcod 7.0%; and rainbow smelt, 7.0%.

4. The hourly collection rate for invertebrates was 2.43 with polychaetes 31.5% and sand shrimp 30.8% of the catch. One American lobster was caught. Impingement rates for invertebrates were higher and algae lower for this period in 1987 than in 1988.

5. Initial impinged fish survival was relatively low for species during static screen washes, and higher for continuous washes.

SECTION 6

LITERATURE CITED

American Fisheries Society. 1980. A list of Common and Scientific Names of Fishes From the United States and Canada. Spec. Pub. No. 12: 174 pp.

Smith, R. I. (Ed.). 1964. Keyes to Marine Invertebrates of the Woods Hole Region. Marine Biological Laboratory. Woods Hole, Massachusetts

The Commonwealth of Massachusetts

Division of Marine Fisheries

~~449 Route 6A~~
~~East Sandwich, Massachusetts 02537~~
18 Route 6A
Sandwich, MA 02563

PHILIP G. COATES
DIRECTOR

888-1155

MEMORANDUM

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

FROM: Vincent Malkoski, Recording Secretary, Massachusetts Division of Marine Fisheries

SUBJECT: Minutes of the 69th meeting of the Pilgrim Administrative-Technical Committee

DATE: July 18, 1988

The 69th Pilgrim Administrative-Technical (A-T) Committee was called to order by Chairman Szal on 16 June, 1988 at 10:22 a.m. at the Upper Blackstone Pollution Abatement District facility in Millbury, Massachusetts. The following agenda items were addressed.

I. <u>Minutes of the 68th Meeting</u>

Corrections and additions to the 68th Committee minutes were tendered by Bob Anderson and are attached as an addendum to these minutes. Gerry Szal motioned that the 68th Meeting minutes be accepted with appropriate corre[illegible] and proposed a new procedure to better address the i[illegible] future corrections or additions. Gerry proposed that the [illegible] of future meetings be available for review within thirt[illegible]ys after the meeting and that any comments or correct[illegible] sent to the secretary within thirty days after receipt for inclusion in the final draft of the minutes. Corrections will be incorporated into the minutes, whereas additions will be placed in an addendum. Carolyn Griswold seconded the motion, which passed unanimously.

II. <u>Pilgrim Station 1987/1988 Outage Review</u>

Bob Anderson reviewed the prolonged outage which began in April 1986 and reported on work currently in progress at the plant. Prior to "start-up", an intensive inspection of the physical plant and operational procedures will be performed by the Nuclear Regulatory Commission (NRC). If formal approval for start-up is received from the NRC, the plant could resume operation by mid-September. Bob reported that the plant had already passed an intensive inspection conducted by the Institute of Nuclear Power Operations. Gerry Szal asked why start-up had not occurred as expected in November 1987. Bob answered that at that time, plant management felt the station was not yet ready to resume operation.

Bob also provided information on of the two plans under consideration by Boston Edison Company (BECo) for additional sources of energy. One plan calls for reconstructing their now-closed Edgar Station, located in Weymouth, with the objective of resuming power generation at the site. Another calls for the purchase of power which would be transmitted along underwater cable laid from a power plant in Nova Scotia to Pilgrim Station.

III. 1987_Impingement/Overflight_Monitoring_Results

Summarizing the impingement data, Bob Anderson reported that the average 1987 rate of impingement (0.28 fish/hour) was the second lowest since 1975. Bob attributed this low rate to the absence of circulating water pump operation during the period-February through September. Dominant species impinged were rainbow smelt, Atlantic silverside, and cunner. Invertebrate collections were dominated by blue mussels. Relatively high mussel impingement was believed due to the inability to perform thermal back-washes during outage. No lobsters were impinged or have been impinged since 1985.

Bob also reported there has been a significant build-up of sand in the intake embayment. It was his belief that it may become necessary to dredge the intake channel in the near future which was last done in 1982.

Reviewing the observations made by the pilots during the weekly overflights, Bob reported that overall sightings of fish in the area of the plant were low. Evaluation of the overflight data seems to indicate that fish abundance in the Pilgrim Station plume area, as measured by qualitative observation, is a function of the presence or absence of a thermal effluent.

IV. 1987_Marine_Fisheries_Monitoring_Results

Bob Lawton informed the committee that the final report on sportfish studies had been published by BECo. Bob Anderson said that, as soon as possible, copies of the report would be sent to all the members of the A-T committee. Bob Lawton then highlighted some of the findings, principally the attraction of gamefish to the thermal effluent. Although no formal creel interviews will be conducted by DMF personnel, an effort to continue the database will be made using qualitative information collected by the public relations personnel stationed at the Shorefront.

Summarizing the work performed by DMF in 1987, Bob noted that studies were essentially the same as in 1986. Several species of finfish (winter flounder, tautog, and cunner) were found to have decreased relative abundance, with cunner abundance at the lowest level yet recorded. The experimental lobster study benefited from the the prolonged outage in that two year's of essentially non-operational data have been collected. This has allowed DMF to concentrate on comparisons between stations based on natural variation without the influence of the plant. It is believed that the current program will be sensitive to the detection of impact on the local lobster fishery induced by plant operation.

V. 1987 Benthic Monitoring Results

Before reviewing the 1987 findings, Jim Blake from Battelle reported on the personnel changes that have resulted in his assuming the position of project leader for the work performed at Pilgrim Station. Jim indicated that he will be the principal investigator for 1988 and that he will author the reports.

Summarizing 1987 data, Jim noted that the most obvious finding was the recolonization of the denuded zone. In the absence of the thermal effluent this area appears much the same as the control areas. Further, statistical analysis of the faunal communities at the various stations indicates a high degree of similarity between the discharge and control areas. Analysis of the data at a seasonal level indicated the presence of distinct early spring and late summer communities. Further analysis will determine if there is repeatability to this pattern.

Discussion ensued as to the effect of renewed plant activity on the benthic community in the discharge area. Jim stated that he felt the timing of start-up would determine the severity of the impact. If plant operation resumed at a time when the benthic community was undergoing change, the effect would be greater than if the community were in a period of stability.

Gerry Szal initiated discussion of some of the tests used by the Battelle group to measure diversity and species richness. Bob Lawton stated that he would like to see more explanation of the significance of a given test result, rather than just a listing of test results.

VI. 1987 Entrainment Monitoring Results

Mike Scherer first described the change in testing methodology necessitated by the absence of flow from the circulating water pumps. Samples were collected using the flow of the service water pumps. Comparison of 1987 fish larvae data with that from 1983 - 1986, indicated that the 1987 data were very different from the previous years, even the outage years of 1984 and 1986. Mike attributed the difference to the virtual absence of circulating water flow during much of 1987, whereas at least one pump was operated during most of 1984 and all of 1986. No lobster larvae were entrained in 1987.

VII. 1988-89 Fisheries and Benthic Subcommittee Membership and Meeting Schedules

As in 1987, Jack Finn will chair the fisheries subcommittee and Don Miller will chair the benthic subcommittee. The membership of both subcommittees will remain as it was in 1987. The benthic subcommittee met during the lunch break of the A-T meeting, and the fisheries subcommittee was scheduled to meet on 28 July, 1988 at Pilgrim Station.

VIII. Biofouling Program Update

Derek McDonald and Joe Egan of Marine Biocontrol spoke on modifications and repairs under way at the plant. The highlight of their presentation was a videotape made inside the intake structure with a remote-operated-vehicle (ROV) in June 1986. Narrated by Derek and Joe, the tape provided an excellent look at the inner structure of the intake system. A similar dive is planned for this year.

IX. Other Business

This consisted of a brief discussion of NPDES permits up for review at other facilities in Massachusetts and related issues.

X. Adjournment

The meeting adjourned at 3:30 p.m.

Pilgrim Administrative-Technical Committee Meeting Attendance

June 16, 1988

Gerald Szal, Chairman	Mass. DEQE/DWPC
Vincent Malkoski, Recording Secretary	Mass. DMF (non-voting)
Robert Anderson	BECo
Michael Bilger	U.S. EPA, Lexington
James Blake	Battelle (non-voting)
Joseph Egan	MBC (non-voting)
Carolyn Griswold	NMFS, Narragansett
Robert Lawton	Mass. DMF
Robert Maietta	Mass. DEQE/DWPC
Derek McDonald	MBC (non-voting)
Don C. Miller	U.S. EPA, Narragansett
Michael Scherer	MRI (non-voting)

MEMORANDUM

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

FROM: Vincent Malkoski, Recording Secretary, Massachusetts Division of Marine Fisheries

SUBJECT: Addendum to the 68th meeting minutes of the Administrative-Technical Committee

DATE: July 19, 1988

The following corrections and additions were made at the request of Boston Edison Company in order to avoid any potential misunderstanding. Due to the volume of suggested changes, the 2nd, 3rd, and 4th paragraphs have been reproduced in their entirety with the appropriate insertions and deletions.

Page 4, Section VII, 2nd, 3rd, and 4th paragraphs:

The effluent water at Pilgrim Station is a pathway through which radioactivity 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 and activation products in the reactor. Cesium-137 has a half-life of 30.2 years and is initially strongly radioactive when produced. Cobalt-60 has a half-life of 5.27 years.

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 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 past samples of mussels from the discharge canal outfall was 100 picocuries/kg of mussel meat (background). The concentrations of cobalt-60 found in mussels sampled in June inside 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) and 0.4/year in the G.I. tract. To put this in perspective, the International Commission on Radiological 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 and legal limit.

BOSTON EDISON
Pilgrim Nuclear Power Station
Rocky Hill Road
Plymouth, Massachusetts 02360

Ralph G. Bird
Senior Vice President — Nuclear

BECo 88-112

October [illegible], 198[illegible]

United States Environmental Protection Agency
Region I
Permits Processing Unit - Room 2109
John F. Kennedy Federal Building
Boston, MA 02038

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. 32 is submitted. This report covers the period from January through June 1988.

R. G. Bird

Attachment: Semi-Annual Marine Ecology Report No. 32

RDA/amm/1292

C001
1/1

BOSTON EDISON
Pilgrim Nuclear Power Station
Rocky Hill Road
Plymouth, Massachusetts 02360

BECo 88-112

Ralph G. Bird
Senior Vice President — Nuclear

October 31, 1988

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. 32 is submitted. This report covers the period from January through June 1988.

R. G. Bird

Attachment: Semi-Annual Marine Ecology Report No. 32

RDA/amm/1292

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