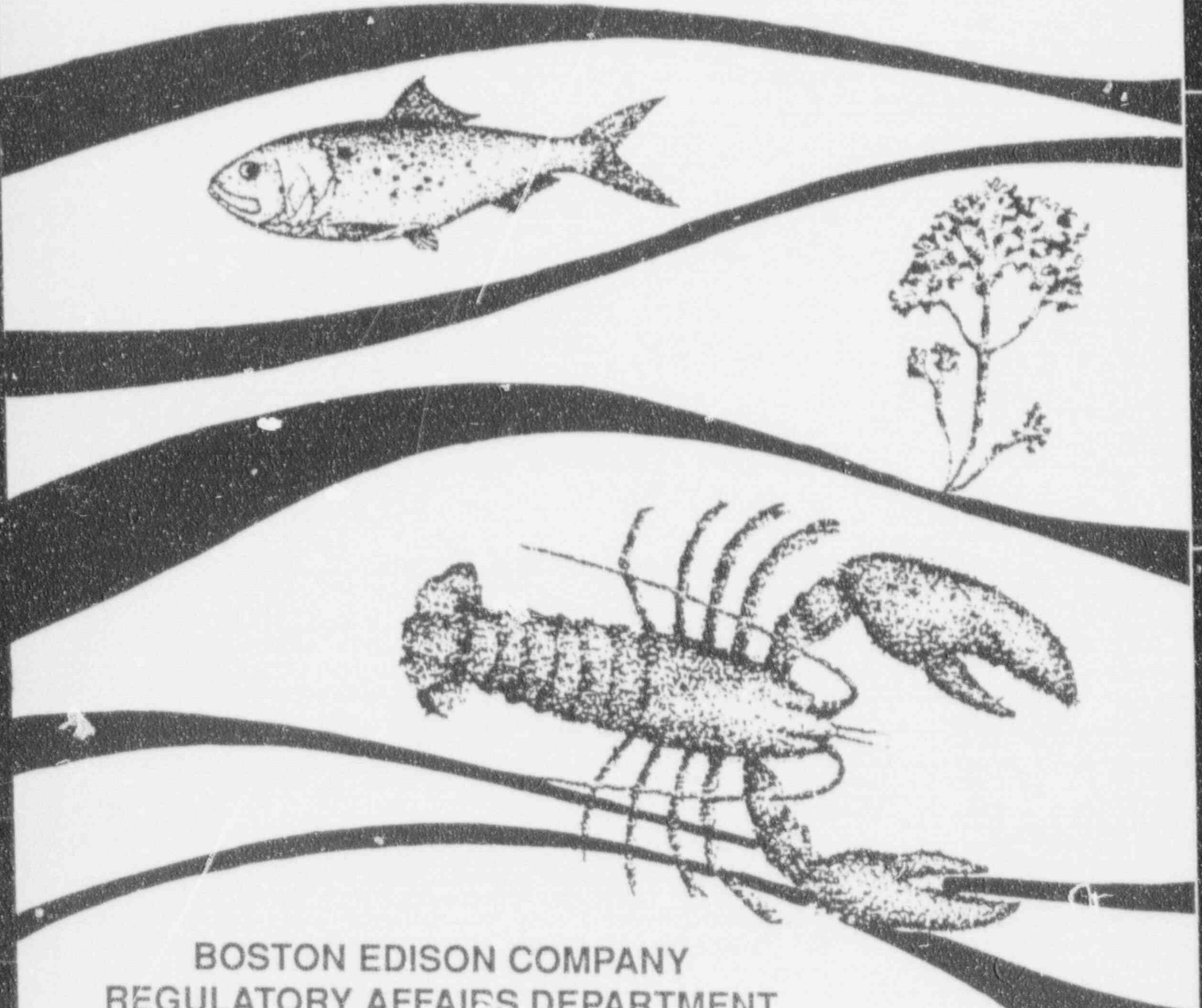
marine ecology studies

Related to Operation of Pilgrim Station

SEMI-ANNUAL REPORT NUMBER 38
JANUARY 1991 – JUNE 1991



BOSTON EDISON COMPANY
REGULATORY AFFAIRS DEPARTMENT
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MARINE ECOLOGY STUDIES
RELATED TO OPERATION OF PILGRIM STATION

SEMI-ANNUAL REPORT NO. 38

REPORT PERIOD: JANUARY 1991 THROUGH JUNE 1991

DATE OF ISSUE: OCTOBER 31, 1991

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SUMMARY

Highlights of the environmental surveillance and monitoring program results obtained over this reporting period (January - June 1991) are presented below (Note: PNPS was operating at normal power level from January - June 1991 with the exception of a refueling outage during May and June).

Marine Fisheries Monitoring:

1. Pelagic fish mean catch from January - June 1991 at the gill net station (74 fishes/set) was similar to 1990 when 72 fishes/ set were taken. Pollock (58%), cunner (8%), tautog (7%), smooth dogfish (6%) and Atlantic herring (4%) made up (83%) of the total catch. Striped bass were sampled in much lower numbers than during 1990 due to a lack of thermal effluent in May and June 1991.

2. Shrimp trawl catch from January - June 1991 recorded twelve benthic fish species with Atlantic herring (68%), winter flounder (14%), little skate (7%) and Atlantic cod (5%) composing 94% of the total. Mean catch-per-unit-effort (CPUE) for all species was highest at the Priscilla Beach Station (23.4) and 7.7 for all stations pooled in 1991 (40% higher than in 1990). CPUE from January - June 1991 for commercially important winter flounder was highest at the Priscilla Beach Station. The mean smallest winter flounder recorded were also sampled off Priscilla Beach.

3. Adult lobster mean monthly catch rate per pot haul in May - June 1991 was 0.30 lobsters (0.26 in 1990). This reflected a general constancy in CPUE in the whole Cape Cod Bay commercial lobster fishery. The surveillance area (thermal plume) catch rate was 0.34 while the reference area (control) was 0.36.

4. In May - June 1991 fish observational dive surveys five species were observed in the discharge area. Cunner (65%) were the most numerous species seen, with pollock second (22%) and tautog third (10%) in observational aubundance. 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 in the denuded zone (63%). Blue mussel proliferation and algal growth in the denuded zone were dense during the PNPS outage of May and June 1991.

5. Atlantic herring accounted for 93% of the June 1991 haul seine (shore zone) fish catch, and sand lance spp. 6%, with a total of ten species collected. Diversity was greatest at the Long Point Station. CPUE was highest in the PNPS intake embayment where Atlantic herring were dominant.

6. The late-May through June 1991 shorefront sportfish survey at Pilgrim Station recorded 402 angler-trips on selected days. A PNPS outage, which resulted in no thermal discharge to attract sportfish species in May and June, reflected modest catches of striped bass and bluefish compared with the previous, high operational years.

7. The research lobster study commenced in June 1991 and recorded 0.29 adult lobsters (0.21 in 1990) per pot as a catch rate in 650 pot-hauls. The catch rate for all lobsters was similar at Rocky Point and Priscilla Beach reference areas but noticeably lower at the PNPS discharge.

8. Cunner tagging study feasibility concentrated on assessing tagging technique, retention, visibility and fish survival for the planned 1992 project.

Impingement Monitoring:

1. The mean January - June 1991 impingement collection rate was 1.31 fish/hr. The rate ranged from 0.33 fish/hr (May) to 8.19 fish/hr (June) with Atlantic silverside comprising 36.6% of the catch, followed by Atlantic herring 33.6%, grubby 5.2%, and winter flounder 4.1%.

2. For the period March-April 1991, when the fish impingement rate was 1.91, Atlantic silverside accounted for ~64% of the fishes collected. Fish impingement rate was notably higher in 1989, 1990 and 1991 than in 1988 (0.30) because Pilgrim Station had less circulating water pump capacity than normal that year.

3. The mean January - June 1991 invertebrate collection rate was 0.86+/hr with sevenspine bay shrimp accounting for 37.2% and common starfish 23.4% of the enumerated catch. Twenty-one American lobsters were caught.

4. Initial impinged fish survival at the end of the Pilgrim Station intake sluiceway was approximately 23% for static washes and 77% for continuous washes.

Benthic Monitoring.

1. Three new species of invertebrate fauna were added to the list of sampled biota since 1990 as a result of analysis of the April 1991 samples, making the total number 102 species in the PNPS area the last two years.

2. Species richness between the PNPS discharge and the Manomet Point/Rocky Point stations was not notably different in April 1991 or 1990.

3. Greatest faunal densities in April 1991 occurred at Effluent. Faunal densities were exceptionally high at the Effluent because of a dense mussel population (380,000/m^2). Approximately a 300% greater difference in density was found for the Effluent when compared to Manomet Point and Rocky Point. Changes in rank were not found among stations for density without blue mussels (Mytilus edulis).

4. There was a consistency between pairs of stations for dominance patterns, with only 7 of the 15 dominant species at each station not being shared. Amphipods were the majority of the dominant taxa, and blue mussels ranked first representing a minimum of 61% of the total fauna at each station. 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 April 1991. Algal community overlap was high (~85%) among all three station pairs, showing like species present at all stations.

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

7. April and June 1991 mappings of the near-shore acute impact zones were performed. Negligible Chondrus growth in the denuded zone was evident for both April and June indicating continuing impact since the 1986 - 1983 PNPS outage. The warm-water alga, Gracilaria tikvahiae, was present in the discharge area because of increased operation of PNPS since January 1990.

Entrainment Monitoring:

1. A total of 28 species of fish eggs and/or larvae were found in the January - June 1991 entrainment collections.

2. Egg collections for January - April 1991 (winter-early spring spawning) were dominated by Atlantic cod, American plaice 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 1991 were dominated by rock gunnel, grubby and sand lance. For May and June larvae, winter flounder, cunner, Atlantic mackerel and radiated shanny dominated.

4. No lobster larvae were collected in the entrainment samples for January - June 1991.

5. In no cases were unusually high densities of ichthyoplankton found, requiring contingency sampling to be initiated.

INTRODUCTION

A. Scope and Objective

This is the thirty-eighth 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 twenty-sixth semi-annual report in accordance with the environmental monitoring and reporting requirements of the PNPS Unit 1 NPDES Permit from the U.S. Environmental Protection Agency (#MA0003557) and Massachusetts Division of Water Pollution Control (#359). A multi-year (1969-1977) report incorporating marine fisheries, benthic, plankton/entrainment and impingement studies was submitted to the NRC in July 1978 as required by the PNPS Appendix B, Tech. Specs. Programs in these areas have been continued under the PNPS NPDES permit. Amendment #67 (1983) to the PNPS Tech. Specs. deleted Appendix B non-radiological water quality requirements as the NRC felt they are covered in the NPDES Permit.

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

These studies are guided by the Pilgrim Administrative-Technical Committee (PATC) which was chaired by a member of the Mass. Division of Water Pollution Control in 1991 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 Mass. Office of Coastal Zone Management, 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 once/month (January - March) and twice/month (April - December) at 4 stations (Figure 2) and haul seining biweekly during June - November at 4 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 (May-November).

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

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

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

2. Benthic Monitoring

The benthic monitioring described in this report was conducted by Science Applications International Corp., Woods Hole, MA.

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 1991 emphasized consideration of ichthyoplankton entrainment. Results of the ichthyoplankton entrainment monitoring for this reporting period are discussed in Section IIIC.

4. Impingement Monitoring

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 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. Fish Surveillance Studies

March - November, weekly fish spotting overflights were conducted as part of a continuing effort to monitor the times when large concentrations of fish might be expected in the Pilgrim vicinity.

An annual summary report for this effort for 1991 will be presented in Semi-Annual Report No. 39.

D. Station Operation History

The daily average, reactor thermal power levels from January through June 1991 are shown in Figure 6. As can be seen, PNPS was in a normal operating stage during most of this reporting period, with the exception of May and June when a refueling outage was ongoing.

E. 1991 Environmental Programs

A planning schedule bar chart for 1991 environmental monitoring programs related to the operation of Pilgrim Station, showing task activities and milestones from December 1990 - June 1992, is included as Figure 7.

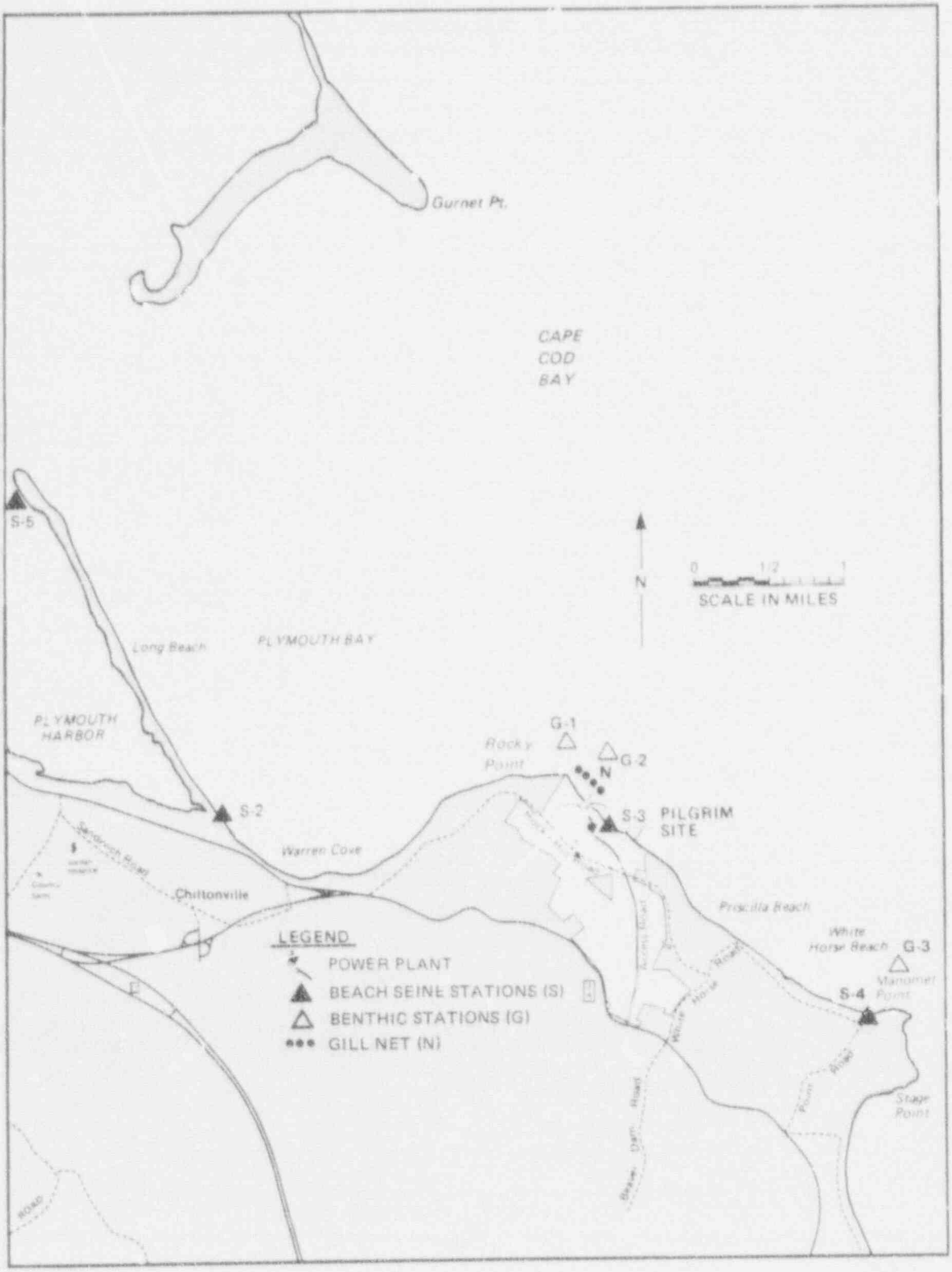

Figure 1. Location of Beach Seine and Gill Net Sampling Stations for Marine Fisheries Studies, and Benthic Studies Sampling Stations

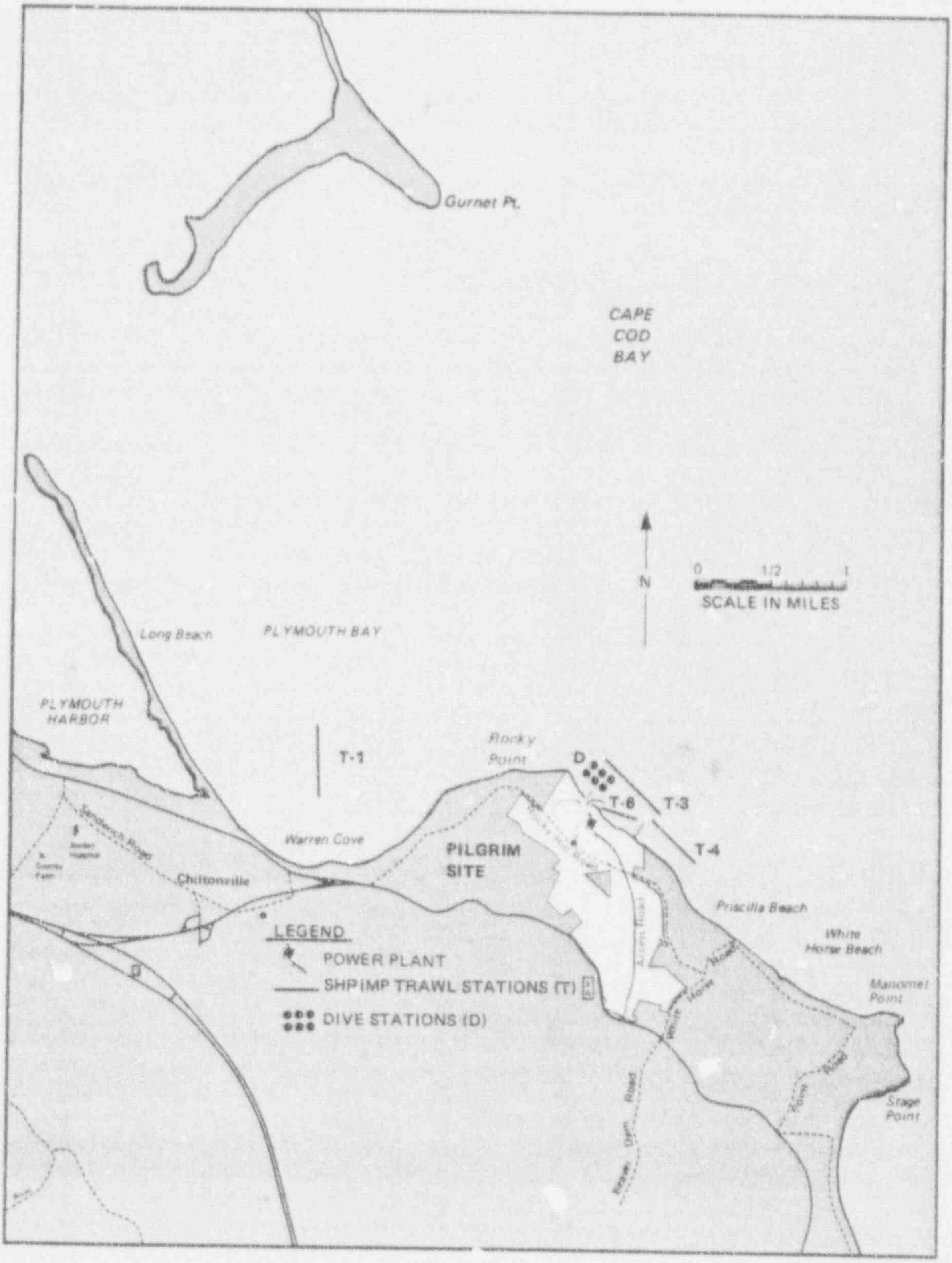

Figure 2. Location of Shrimp Trawl and Dive Sampling Stations for Marine Fisheries Studies

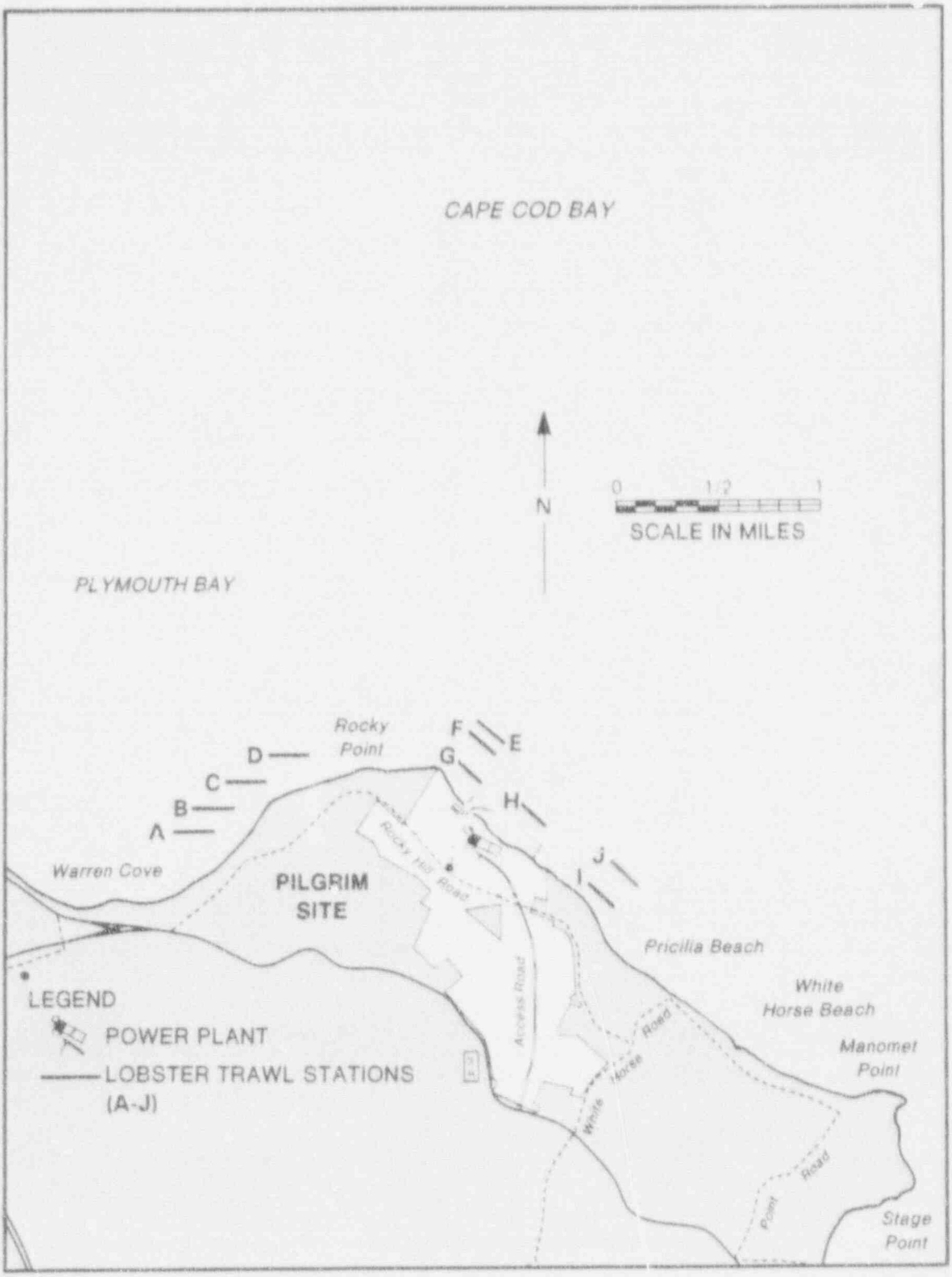

Figure 3. Location of experimental lobster gear (5-pot trawls) for Marine Fisheries Studies.

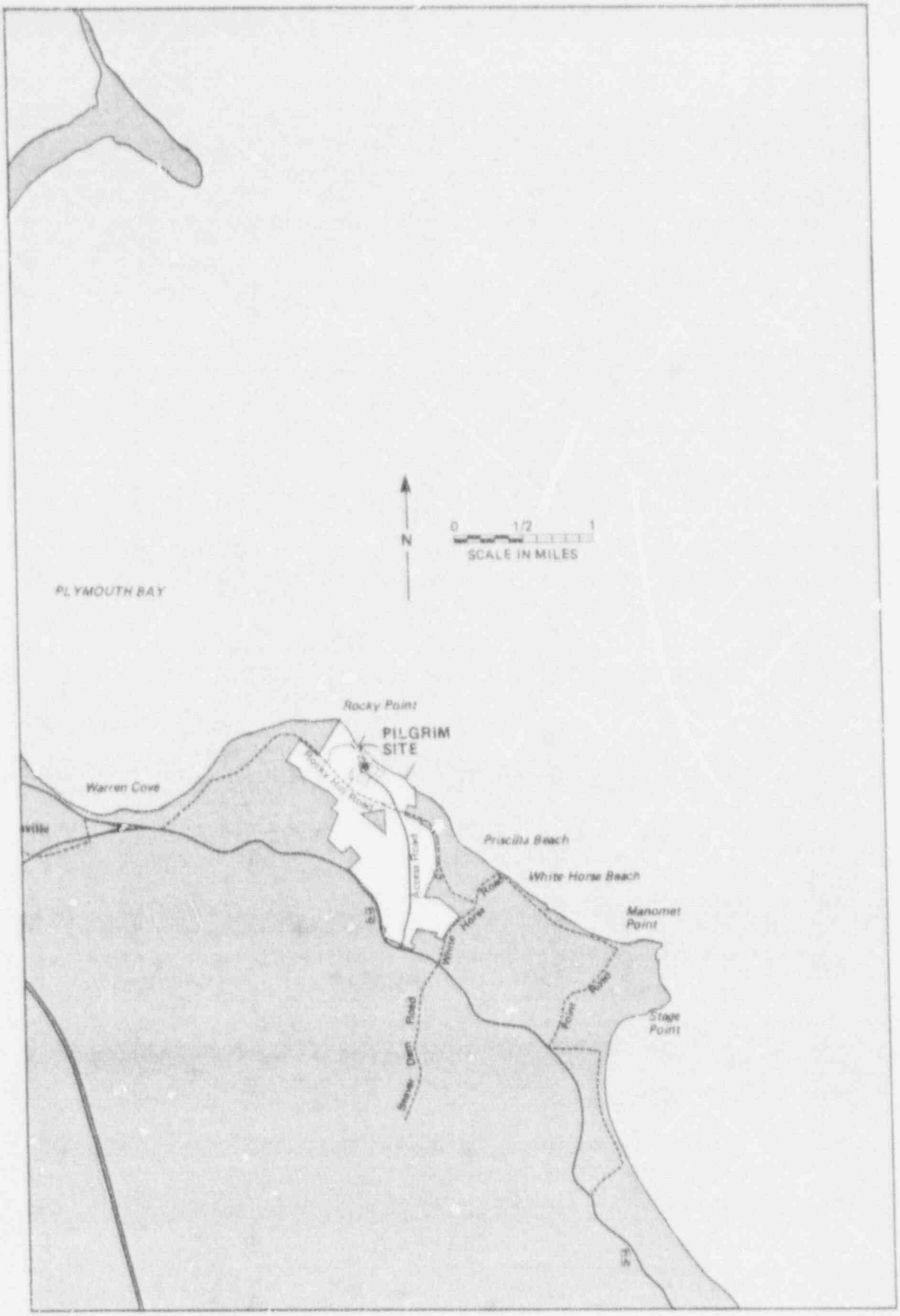

Figure 4 Lobster Put Sampling Grid for Marine Fisheries Studies.

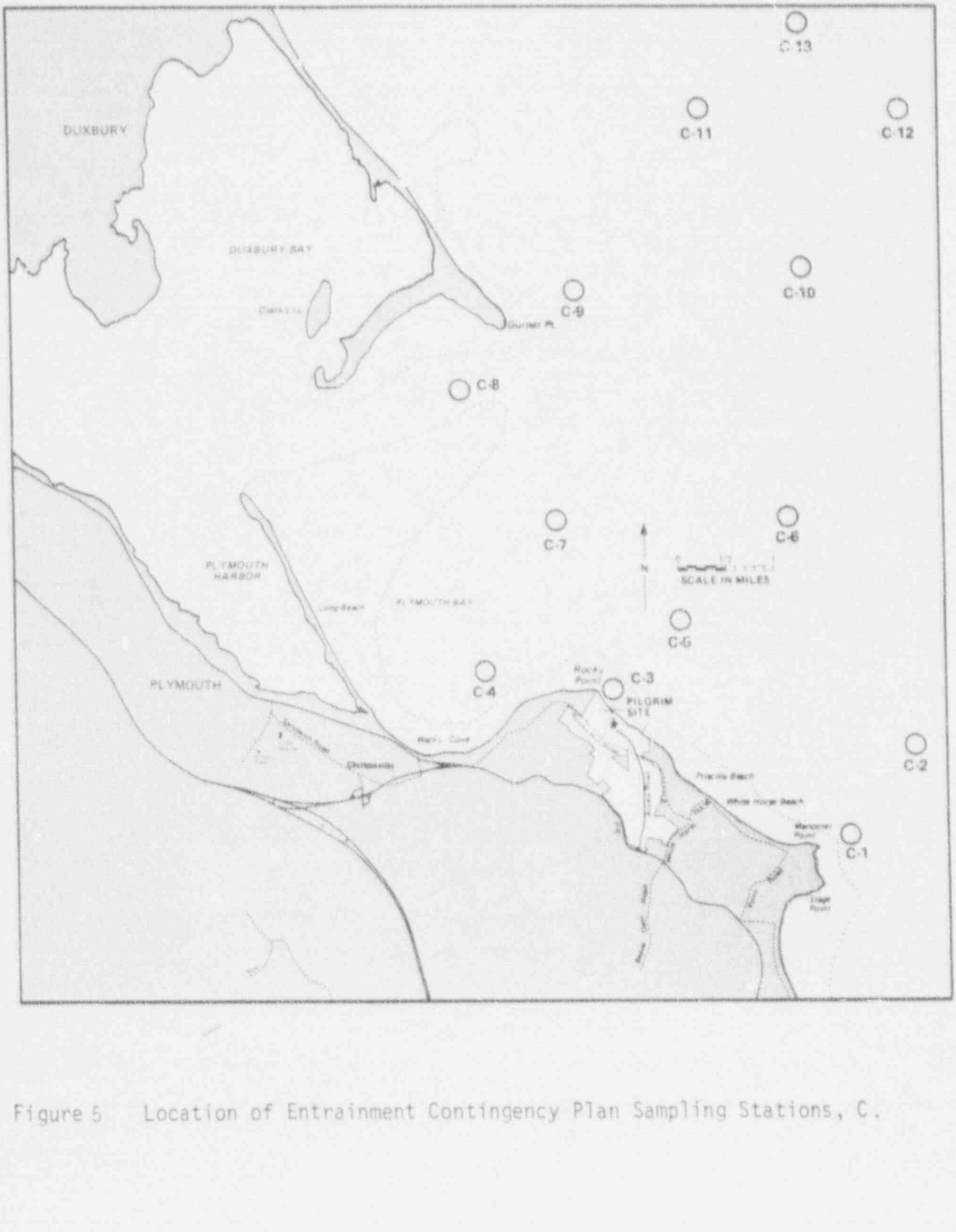

Figure 5 Location of Entrainment Contingency Plan Sampling Stations, C.

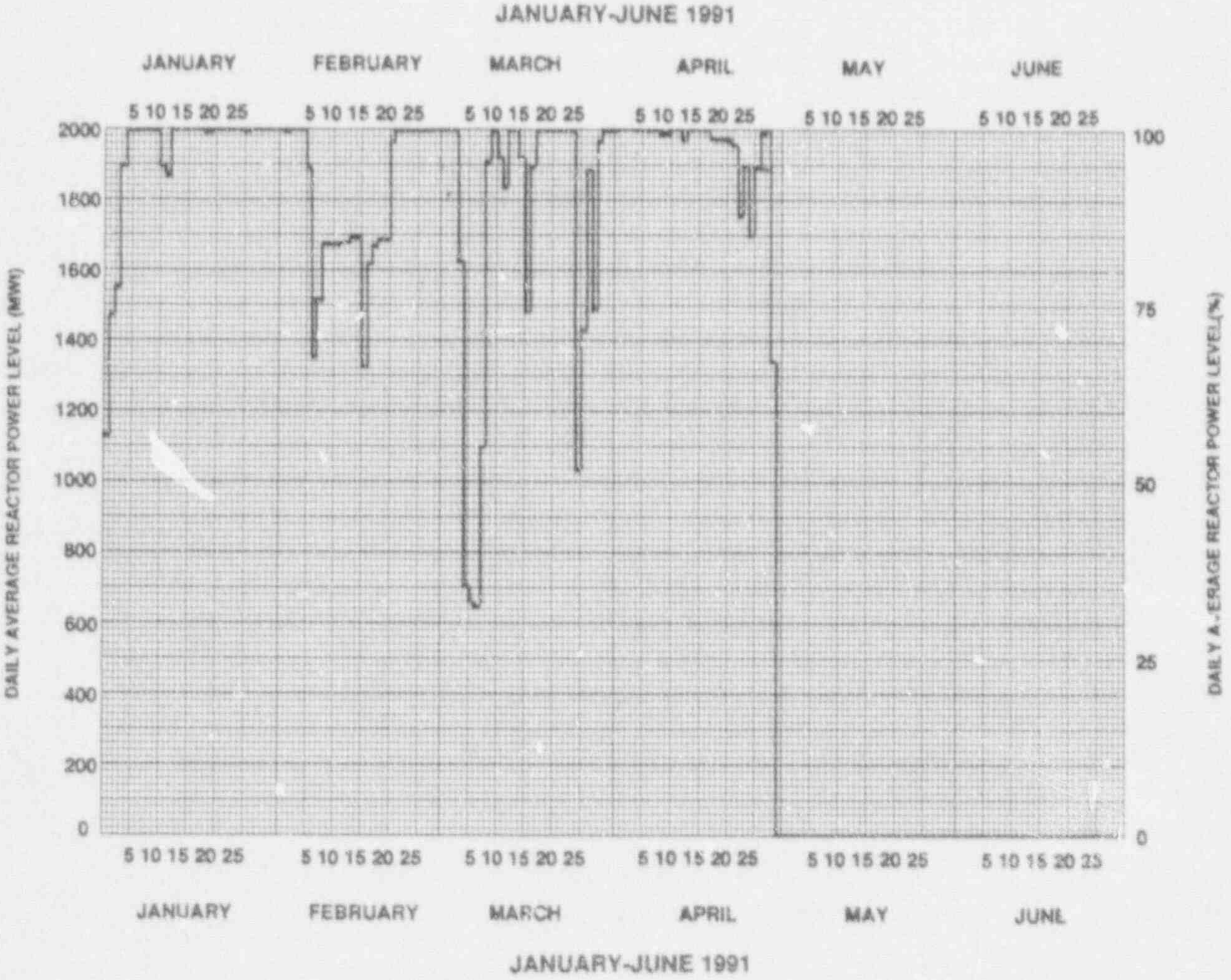

Figure 6. Daily Average Reactor Thermal Power Level(Mwt And %) from January-June 1991 for Pilgrim Nuclear Power Station.

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. 51 (January through June, 1991)

By

Robert P. Lawton, Brian C. Kelly,
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October 1, 1991
Massachusetts Department of Fisheries,
Wildlife, and Environmental Law Enforcement
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I. EXECUTIVE SUMMARY

Commercial Lobster Pot-Catch Fishery

From May to June (spring) of 1991, data were obtained from the trap catch of one commercial lobsterman who fishes in the vicinity of Pilgrim Nuclear Power Station. Sample size included a total of 846 pots hauled and 1,745 American lobster *(Homarus americanus)* captured. Of the total catch, 14% of the lobster were legal in size (≥ 82.55 mm). Legal catch rate for the overall inshore area averaged 0.30 legals per pot-haul, a slight increase from last year.

Controlled Research Lobster Fishing

Thirteen sampling trips were completed in June, with data procured from 650 trap-hauls. Of the 2,145 lobster sampled in the study area, 9% were legal in size (≥82.55 mm CL). Mean legal catch rates ranged from 0.28 to 0.31 lobster per trap-haul at the three study locations.

Nearshore Benthic Finfish

A bottom trawl survey of groundfish in the Pilgrim area was conducted January to June 1991. A total of 444 finfish representing 12 species was collected in 58 trawl tows. Overall catch per unit effort (CPUE) for all stations and species pooled was 7.7 fish/tow, as compared to last year's mean of 5.5. Catch rates were strongly influenced by the catch of nearly 300 Atlantic herring *(Clupea harengus harengus)* during a single tow. Excluding this tow, catches were depressed, continuing a downward trend. Numerically dominant species in the catch were Atlantic herring, winter flounder *(Pleuronectes americanus)*, little skate *(Raja erinacea)*, Atlantic cod *(Gadus* *morhua)*, and windowpane *(Scophthalmus aquosus)*. CPUE of winter flounder was highest off Priscilla Beach, while little skate catch rate was highest in the Intake. Windowpane were most abundant at Priscilla Beach.

Pelagic and Benthi-pelagic Fishes

Gill-net sampling was conducted monthly in the environs of Pilgrim Station during the first half of 1991. The dominant species captured in order of abundance were pollock *(Pollachius vire* cunner *(Tautogolabrus adspersus)*, tautog *(Tautoga onitis)*, smooth dogfish *(Mustelus canis)*, and Atlantic herring. The overall half year catch per unit of effort for all species pooled was similar to last year's value but is substantially down from the level of the years 1987-1989. Of note, the numbers of striped bass *(Morone saxatilis)* were lower probably due to the plant being in an outage since May, while the local cunner population showed some signs of increasing abundance.

Shorezone Fishes

Sampling of the shore zone for fish using 45.7 m haul seines began in June. Ten finfish species were seined, with Atlantic herring and sand lance *(Ammodytes* spp.) comprising 99% of the catch that month. The majority of the sea herring were taken during a single haul in the Intake. Sand lance were taken predominantly (80% of species total) from Warren Cove.

Diversity, (the number of species sampled at a location) was highest at Long Point where eight species were captured. Catch per unit of effort was highest in the Intake and lowest at Warren Cove.

Underwater Finfish Observations

Biweekly observational dives were performed in May and June 1990 at six stations in and around the Pilgrim Station discharge canal. Five species of finfish were sighted, with cunner, pollock, and tautog comprising 97% of the total observed. Distributionally, 63% of all fish were observed in the "denuded" zone, 26% in the "stunted", and 11% in the "control" area. No striped bass or bluefish *(Pomatomus saltatrix)* were observed by project divers.

Sportfishing

Sportfishing at Pilgrim Shorefront was monitored in late May and during June. In May, fishing activity at the Shorefront was minimal. In June, angling effort increased. The monthly catch rate in June was 0.3 fish per angling-trip. Bluefish (58%), cunner (35%), striped bass (5%), and pollock (2%) comprised the total catch of 121 fish. The landings of bluefish were much greater than from 1986 to 1988 when Pilgrim Station was in an extended outage and in 1989 when the plant gradually returned to full operational status.

Cunner Capture-Tagging Program

A feasibility study was continued this spring on tagging and subsequently observing marked cunner with the intent of a full scale effort in 1992. As part of our observational diving program, this work should generate information on the mobility and dispersion of cunner as related to the influence of the thermal discharge. We utilized the Floy plastic anchor tag to mark fish. We have investigated ways to catch cunner in good condition with baited eel pots and have standardized our tagging technique. As for tag retention and fish survival, we have recaptured cunner tagged up to nine months prior at Pilgrim Station. The tag's visibility underwater has been confirmed by divers near the power plant's outer breakwater. The anchor tag appears suitable for our tagging operations.

II. INTRODUCTION

Monitoring of the marine environment in the vicinity of the Pilgrim Nuclear Power Station is conducted to assess environmental effects of plant operation. Ecological investigations conducted by the power plant team of the Massachusetts Division of Marine Fisheries (DMF) address the lobster and fish populations in the off-site waters of western Cape Cod Bay. DMF is funded by Boston Edison Company under Purchase Order No. 68004 in 1991.

In this report, sampling data collected from reference and surveillance sites for January through June 1991 are summarized. Measurements, counts, percentages, and indices of abundance are employed to detect trends or relationships in the data both spatially and temporally.

The 1991 operational status of Pilgrim Station, including its seawater circulating pumps, was as follows. The plant ran at 90% capacity through April with both pumps operating. However, since early May, the plant has been in a planned refueling outage with one or both pumps not operating and only minimal waste heat released.

III. RESULTS AND DISCUSSION

1. COMMERCIAL LOBSTER POT-CATCH FISHERY

Seasonal monitoring of the commercial lobster fishery around Pilgrim Station was continued in 1991. We began sampling the catch of our cooperating lobsterman in early May and continued through June with a total of 1,745 lobster *(Homarus americanus)* caught from 846

Figure 1. Number of lobster pots sampled per quadrat for commercial lobster study in the Pilgrim area, May-June, 1991.

pot-hauls. Figure 1 depicts the distribution of pots sampled by designated quadrat.

The sampled catch included 253 legal (≥ 82.55 mm carapace length - CL) lobster, representing 14% of the total catch, for a mean catch rate in the study area of 0.30 legals per pot-haul over the two months, a slight increase from last year's rate of 0.26.

The mean legal catch rate for reference quadrats (E-13 & 14, F-13) of 0.36 (35 legal lobster in 98 pot-hauls) is greater than the rate for 1990 of 0.21. The spring 1991 legal catch rate for the surveillance quadrats (H-11 & 12, I-11 & 12) was 0.34, which also was larger than last spring's rate of 0.27.

2. CONTROLLED RESEARCH LOBSTER FISHING

In June 1991 we began the sixth year of the research lobster trap study in the environs of Pilgrim Nuclear Power Station (Figure 2). Thirteen sampling days were completed in which 2,145 lobster were caught in 650 trap-hauls. The incidence of null pots (pots with zero lobster) was 7%. The lobster sampled were predominantly (91%) sublegal (< 82.55 mm CL) in size. A total of 191 legal-sized (≥82.55 mm CL) lobster was captured. The catch ratio of sublegal to legal lobster was 10.2:1. The mean catch rate for all lobster sampled was 3.3 lobster per trap-haul for the study area. Overall catch rates for legal and sublegal lobster were 0.29 and 3.01 lobster per trap-haul, respectively.

A graphic comparison of June's lobster catch rates at the three sampling locations (Figure 3) suggests that the discharge site was lower than the other two sampling areas (Rocky Point and

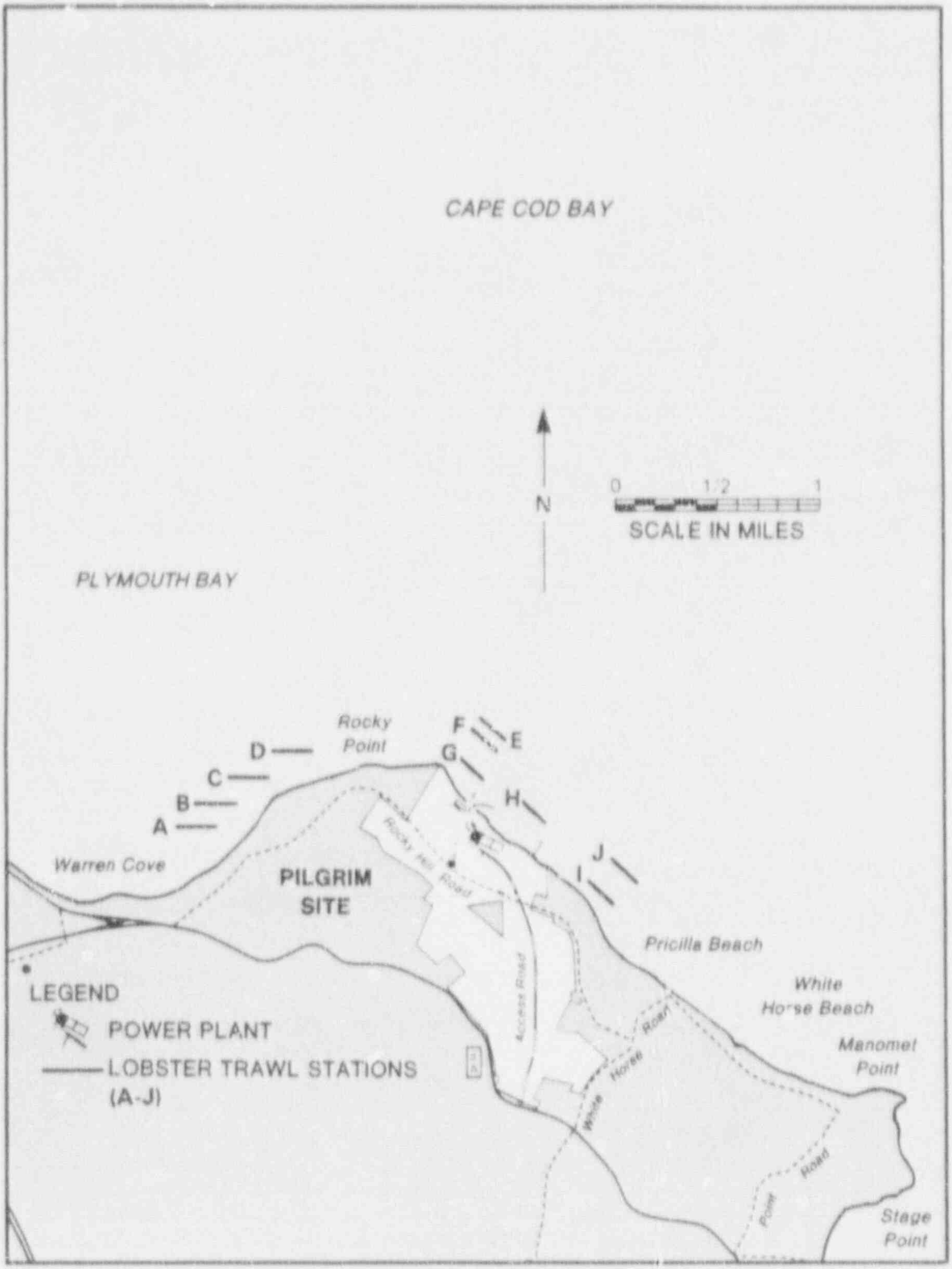

Figure 2. Location of experimental lobster gear (5-pot trawls) for Marine Fisheries Studies.

Priscilla Beach) in both sublegal and legal catch rates. With only one month's data, it is presumptuous to assign significance to the lower catch rates obtained at the discharge site at this time.

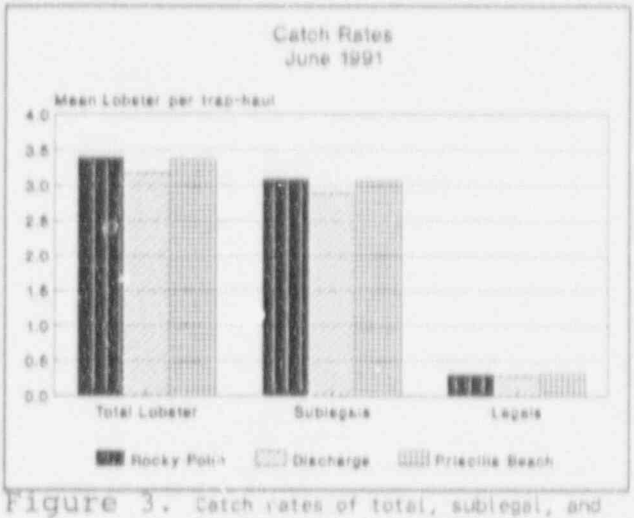

Figure 3. Catch rates of total, sublegal, and legal lobster in research lobster traps fished in the area around Pilgrim Station, June 1991.

3. NEARSHORE BENTHIC FINFISH

Nearshore bottom trawling for 1991 commenced in mid-January and continued through June. Station locations (Figure 4) included Warren Cove, off Priscilla Beach, in the area of Pilgrim Station's Discharge, and in the Intake embayment at the power plant. Sampling was conducted monthly during January through March, thence biweekly through 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 minutes was rejected *a priori*.

A total of 444 finfish (expanded catch) comprising 12 species was collected during 58 tows in the study area (Table 1). Thirteen species totaling 344 finfish were collected in 62 tows for the same period in 1990. Five species: Atlantic herring *(Clupea harengus harengus)*, winter flounder *(Pleuronectes americanus)*, little skate *(Raja erinacea)*, Atlantic cod *(Gadus morhua)*, and windowpane *(Scophthalmus aquosus)* comprised

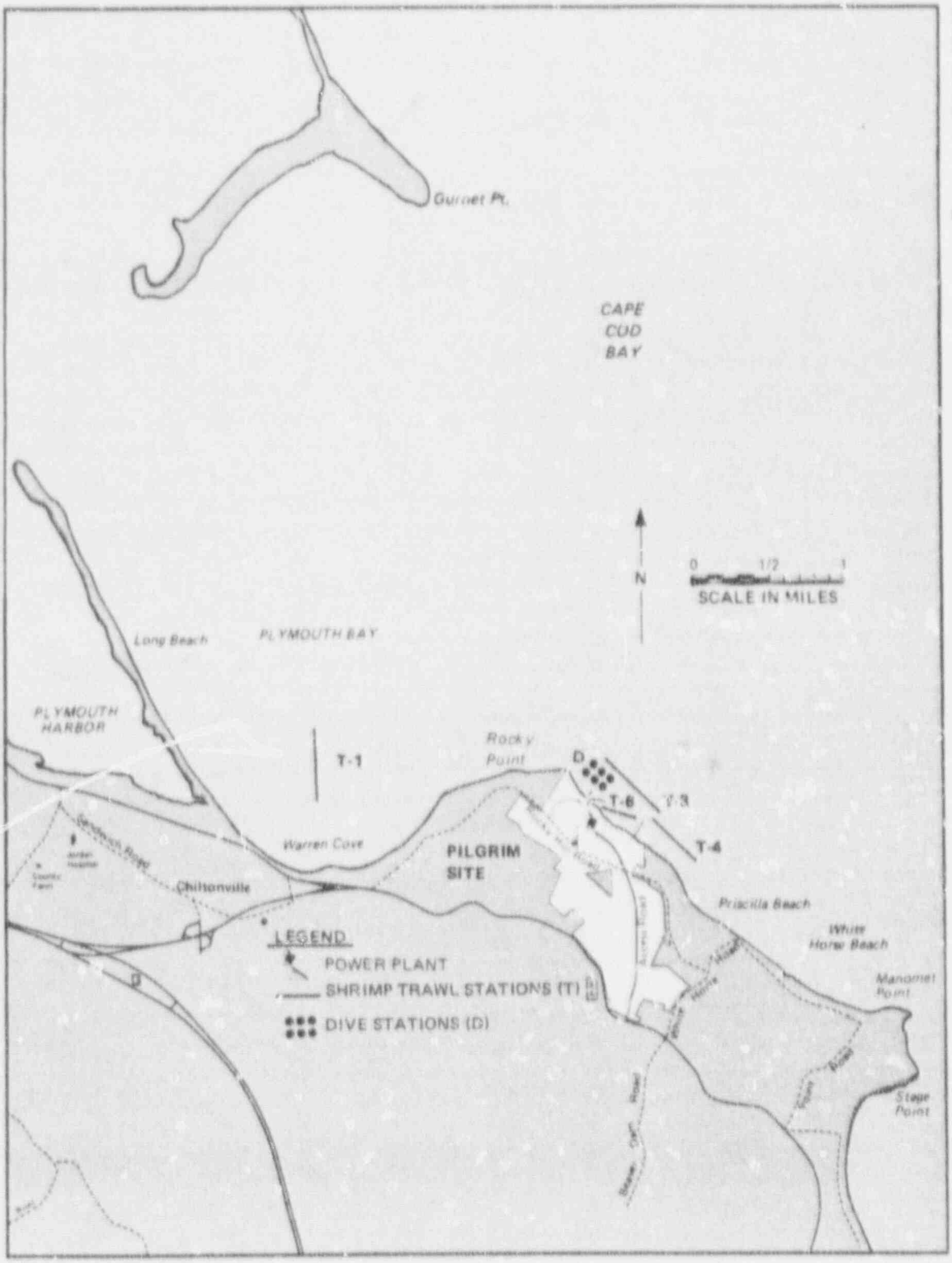

Figure 4. Location of Shrimp Trawl and Dive Sampling Stations for Marine Fisheries Studies,

Table 1. Expanded trawl catch[1] and percent composition of finfish captured by nearshore trawling in the vicinity of Pilgrim Station, January through June, 1991.

Species	Warren Cove	Pilgrim Discharge	Priscilla Beach	Pilgrim Intake	Total	Percent of Catch
Atlantic herring	0	2	297	1	300	67.6
Winter flounder	0	14	34	14.2	62.2	14.0
Little Skate	0	10	6	16.5	32.5	7.3
Atlantic cod	0	8	4	8	20	4.5
Windowpane	0	7	7	3	17	3.8
Other spp.[2]	0	3	3	6.1	12.1	2.7
Total catch	0	44	351	48.8	443.8	
Number of tows	16	13	15	14	58	
Catch per tow	0	3.4	23.4	3.5	7.7	
Percent catch	0	9.9	79.1	11.0		
Number of species	0	8	7	8	12	

[1] Catch rates were expanded for tows less than the standard 15-minute duration.
[2] Represent combined totals from 7 species of low catch.

97% of the total catch through the first half of 1991.

CPUE (mean catch per standard 15 minute tow) for all stations and species pooled was 7.7 fish per tow, as compared to last year's mean of 5.5. Calculated by station, CPUE for all species pooled ranged from 23.4 off Priscilla Beach to 0.0 fish per tow in Warren Cove (Table 1). For the same sampling period in 1990, CPUE was greatest in the Intake (7.2) and lowest off the Discharge (4.7). It should be noted, however, that the higher fish per tow values calculated for the total area and Priscilla Beach in 1991 were skewed by the capture of nearly 300 juvenile Atlantic herring during a single tow off Priscilla Beach in early June. Calculating CPUE for the entire area and Priscilla Beach excluding data from this tow yielded values of 2.5 and 3.6, respectively. Clearly the yield from this one tow greatly inflated overall catch rates even with a half-year value of 0.0 fish per tow in Warren Cove. As large numbers of juvenile sea herring (20,000+) were also captured by our haul seine this spring, local abundance is obviously up.

However, this species has not been a common component of our trawl catches over the years.

Winter flounder ranked second in trawl catch at 14% of the total. Relative abundance was highest off Priscilla Beach at 2.3 fish per tow, while none were caught in Warren Cove (Table 2). An overall winter flounder abundance index (catch per tow) of 1.1 is down from last year's value of 2.2.

Ranked third, little skate comprised 7.3% of the trawl catch. CPUE ranged from 1.2 fish per tow in the Intake to 0.0 in Warren Cove (Table 2). The overall half-year little skate relative abundance index (0.6) declined from 1.1 in 1990.

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 through June, 1991.

Station	Winter flounder	Windowpane	Little skate
WARREN COVE			
Mean catch/tow	0.0	0.0	0.0
Mean size (cm)	-	-	-
Size range (cm)	-	-	-
PILGRIM DISCHARGE			
Mean catch/tow	1.1	0.5	0.8
Mean size (cm)	28	25	34
Size range	12-39	16-37	24-48
PRISCILLA BEACH			
Mean catch/tow	2.3	0.5	0.4
Mean size (cm)	25	24	36
Size range	11-39	14-29	24-48
PILGRIM INTAKE			
Mean catch/tow	1.0	0.2	1.2
Mean size (cm)	26	23	32
Size range	11-38	17-28	20-48

Atlantic cod ranked fourth in catch abundance at 4.5% of the total catch. As with sea herring, this species is not a traditional dominant in our trawl catches. The cod caught in 1991 were small individuals (3-5 cm total length) caught in tows that contained fair amounts of macro-algae.

Ranked fifth in trawl catch at 3.8%, windowpane relative abundance ranged from 0.5 at Priscilla Beach and the Discharge to 0.0 in Warren Cove (Table 2). Relative abundance in the study area decreased from 1.2 for the first half of last year to 0.3 in 1991.

In general, catches continued the downward trends reported by Lawton et al (1991) in 1990, a mirror image of that reported by the National Marine Fisheries Service (NMFS) for the entire northeast coastal region (NEFC 1991). NMFS scientists attribute the declines to over-fishing. Of particular note was a half-year relative abundance value of 0.0 in Warren Cove, the first time since the inception of nearshore trawl sampling that we have not caught any fish at a given station.

4. PELAGIC AND BENTHO-PELAGIC FISH

Gill-net catches totaled 441 fish, comprising 17 species in 6 overnight sets (Table 3). Sampling was conducted monthly at one location in the immediate vicinity of the Pilgrim Station discharge (Figure 5). Comprising 83% of the catch, the top five species were pollock *(Pollachius virens)*, cunner *(Tautogolabrus adspersus)*, tautog *(Tautoga onitis)*, smooth dogfish *(Mustelus canis)*, and Atlantic herring. Pollock, cunner, and Atlantic herring have been among the dominants in gill-net catches over the years at Pilgrim Station.

The mean catch per standard gill-net (7 panels) set (catch per unit effort) for all species pooled was 74 fish. This catch rate is remarkably similar to that in 1990 (CPUE = 72) but is

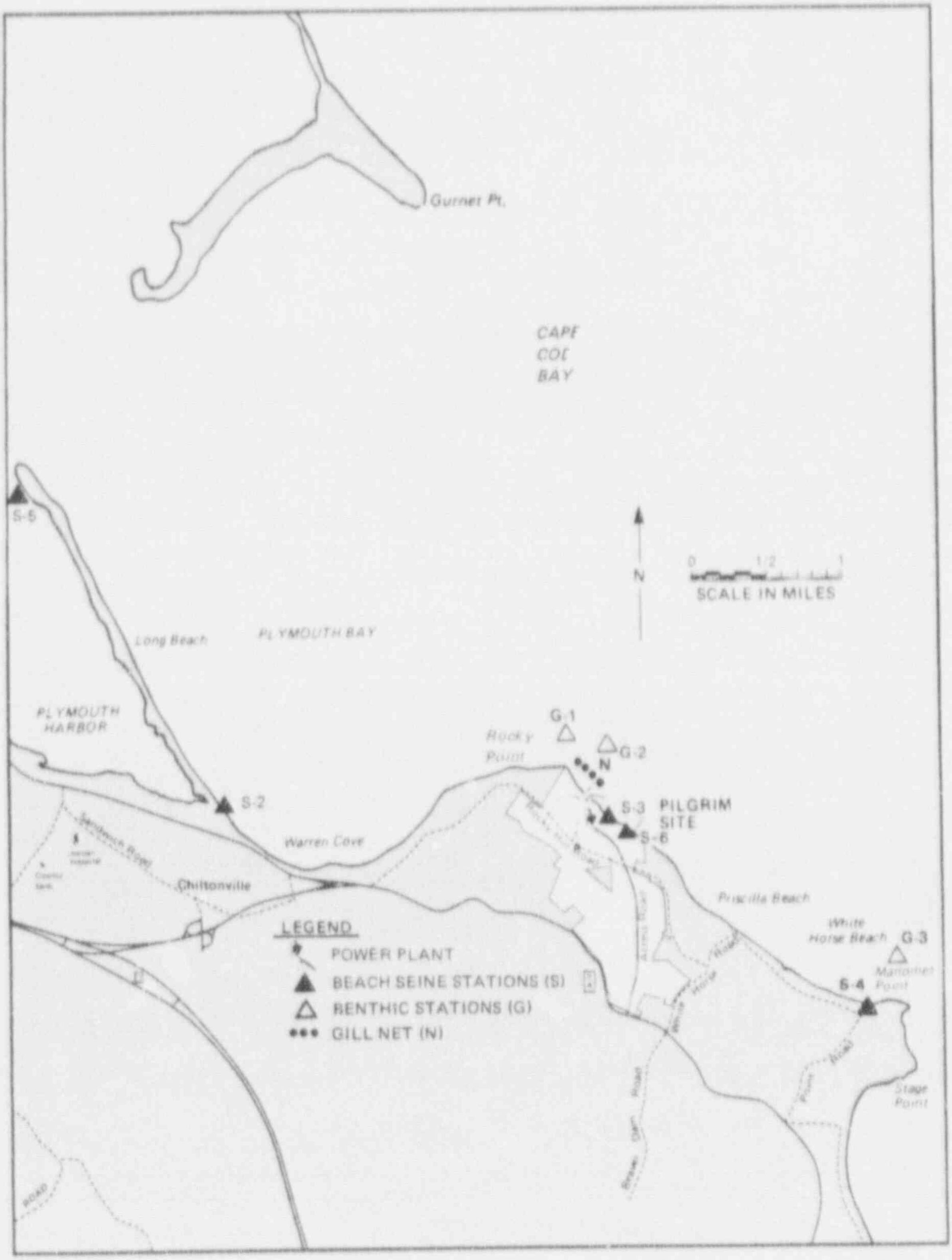

Figure 5. Location of Beach Seine and Gill Net Sampling Stations for Marine Fisheries Studies, and Benthic Studies Sampling Stations.

substantially down from the first half of 1989 (117), 1988 (315), and 1987 (356).

Table 3. Numerical rank and percent of total catch for fish species captured by gill net (7 panels of 3.8-15.2 cm mesh) in the marine waters off the Pilgrim Nuclear Power Station, January through June 1991.

	Species	Percent of Total Catch		Species	Percent of Total catch
1.	Pollock	58.0	9.	Atlantic cod	1.4
2.	Cunner	8.2	10.	Winter flounder	1.1
3.	Tautog	6.8	11.	Bluefish	0.9
4.	Smooth dogfish	5.9	12.	Alewife	0.7
5.	Atlantic herring	3.9		Shorthorn sculpin	0.7
6.	Scup	3.6	13.	Red hake	0.5
	Striped bass	3.6		Sea raven	0.5
7.	Northern searobin	2.5	14.	Longhorn sculpin	0.2
8.	Little skate	1.6			

Pollock comprised 58% of the catch and most often has been the dominant fish caught by gill net in the Pilgrim area. Cunner (8%) increased in the hierarchy of catch from fifth to second. The local stock of cunner had been showing signs of declining abundance until 1990 when there was evidence of a strong year class of young fish. Striped bass declined from 16% of the gill-net catch in 1990 to 3.6%, falling from second to sixth in the hierarchy of catch. The number of bass found in the discharge at Pilgrim Station, as evidenced by gill-net catches, sportfish catches, and diving observations, during the first half of 1991 is markedly down concomitant with the plant being in an outage since late April, when bass seasonally arrive inshore in Cape Cod Bay.

5. SHOREZONE FISHES

Thirteen sets of the 45.7 m haul seines were made during 2 sampling days in June. Four stations (Figure 5) were sampled during ± 3 hours of low tide. Over 24,000 fish comprising 10 species were sampled (Table 3). The average catch per unit of effort was 1,882.1 fish per seine haul. For the same time period last year, we collected 8 species (5 species in common), but overall average catch rate was magnitudes lower at 16.0 fish per set. The high 1991 value is no doubt strongly influenced by the capture of over 20,000 Atlantic herring during one set in the Intake in June. Surface water temperature and salinity at time of sampling this June ranged from 16° to 18° C and 31‰ to 32‰, respectively.

Table 3. Haul-seine catch of shore-zone fishes in number of fish, species composition (% number), and catch per standard seine haul at sampling stations in the environs of Pilgrim Nuclear Power Station during June 1991.

Species	Warren Cove	Pilgrim[1] Intake	Manomet Point	Long Point	Total Catch	Percent of Total Catch
Atlantic herring	0	22,842	0	1	22,843	93.4
Sand lance (spp.)	1,194	275	0	2	1471	6.0
Atlantic silverside	0	5	1	75	81	0.3
Atlantic tomcod	0	0	0	26	26	0.1
Blueback herring	21	0	0	0	21	0.1
Northern pipefish	0	0	0	10	10	*
Three-spine stickleback	0	1	0	8	9	*
Winter flounder	0	0	0	4	4	*
Rock gunnel	0	0	0	2	2	*
Four-spine stickleback	1	0	0	0	1	*
Total fish	1,216	23,123	1	128	24,468	
Number of sets	4	3	2	4	13	
Catch per set	304.0	7,707.6	0.5	32.0	1,882.1	
Percent catch	5.0	94.5	*	0.5		
Number of species	3	4	1	8	10	

* Represents less than 1% of the total catch

[1] 45.7 m long x 3.0 m deep seine; other sites sampled by 45.7 m x 1.8 m seine

Atlantic herring ranked first in seine catch (93.4% of the total), but as noted for nearshore trawling, this species is not normally a prominent member of the dominance hierarchy. The capture of this species is sporadic, and catch rates can be greatly affected by a single large haul.

Sand lance (*Ammodytes* spp.) ranked second and comprised 6% of the seine catch in June. This species accounted for 82% of June's seine catch in 1990. This ranking is actually a result of the extraordinary catch of sea herring. If the herring data are excluded, sand lance account for 90% of the fish seined in June, 1991. Eighty percent of the sand lance catch this year was taken at the Warren Cove station.

Comprising less than 1% of the total catch, the remaining 8 species were not captured in abundance. Overall catch rate for this group (pooled species and stations) was 11.9 fish per haul.

Diversity, as measured by number of species present in a community, was highest at Long Point where eight species were captured (Table 3). Catch per unit of effort (pooled species), was highest in the Intake and lowest at Manomet Point. It should be noted, however, that these estimates of community species diversity and relative abundance are based on only one month's data and cannot be comprehensively analyzed.

6. UNDERWATER FINFISH OBSERVATIONS

Biweekly observational SCUBA dives were made at six stations in and around the discharge canal in May and June, 1991 (Figure 4). Five species of finfish (Figure 6) were recorded, as well as such invertebrate species as blue mussel (*Mytilus edulis*), American lobster, starfish (*Asterias* spp.), and rock and jonah crabs (*Cancer irroratus* and *C. borealis*). Macro-algal species sighted included kelp (*Laminaria* spp.) and Irish moss (*Chondrus crispus*).

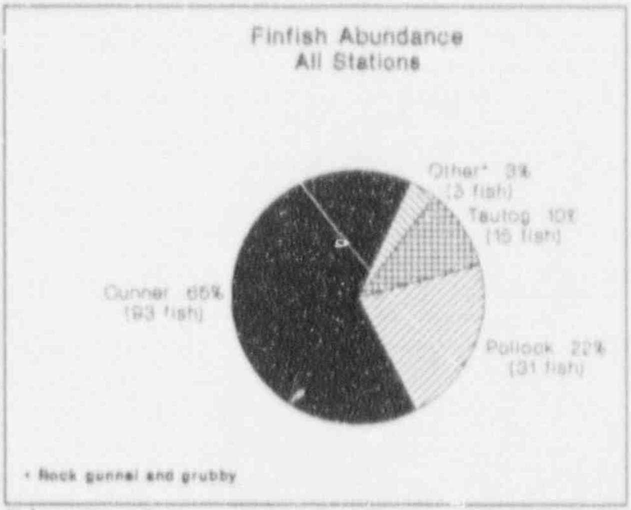

Figure 6. Finfish abundance as observed by divers in the area around the Pilgrim Station discharge canal, May and June, 1991.

Observations of the benthos revealed patches of blue mussels extending from inside the discharge canal out to the large boulder at Station D_1. As has occurred in the past, by late June the mussel bed had attracted large numbers of starfish to the "denuded" zone. Several species of macro-algae (especially kelp) flourished throughout the discharge area, vying with mussels for exposed rock surfaces. As in 1990, Irish moss was observed growing inside the mouth of the discharge canal.

The total number of finfish observed (144) was less than for May and June of 1990 (346 fish), although far more cunner (93) were sighted this spring than in 1990 (17). Cunner were, in fact, the most commonly sighted species, present on three of the four dives. Pollock ranked second in number observed, recorded primarily during one dive. Tautog was third, with 15 fish recorded which is lower than 1990 sightings (39). No striped bass or bluefish were sighted, no doubt because the plant was in an outage during this period.

Of the fish observed, 63% were found in the "denuded" zone (Figure 7), 26 % in the "stunted" and the remainder (11%) in the "control" zone. Cunner and tautog were found primarily in the "denuded" (discharge) area, a common pattern of distribution when at least one of the circulating seawater pumps is in operation, but no heat is being produced. Past observations (Lawton et al. 1990) have revealed a marked preference for this area by these species, perhaps partly due to the abundance of blue mussels and structure provided by the boulders in that area. Observations of pollock have always been sporadic, while no pattern of distribution was discernable for the other species.

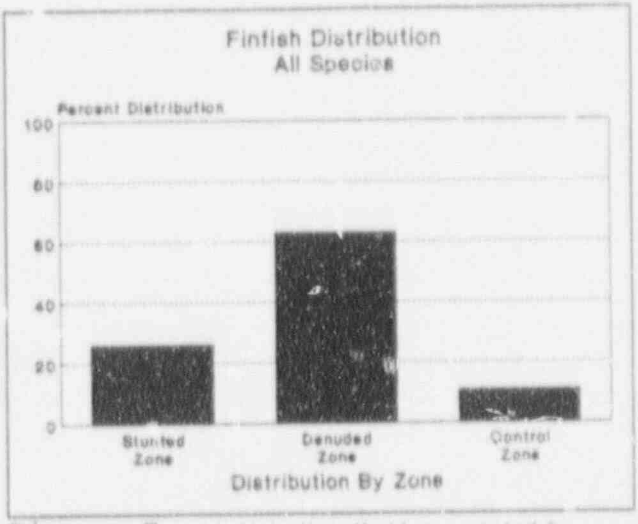

Figure 7. Finfish distribution as noted by divers in the area around the Pilgrim Station discharge canal, May and June, 1991.

7. SPORTFISHING

Creel data on the shore-based sportfishery at Pilgrim Station Shorefront were collected by seasonal Boston Edison Company (BECo) public relations personnel stationed on the grounds. Anglers are checked at an access point. A sample data interview form used in this survey is found in Figure 8. Daily effort (number of angler-trips) and catch by species are needed information with which to derive an index of the recreational fishery off Pilgrim Station. This cooperative endeavor with BECo allows us to continue monitoring sportfishing off the Station.

The Shorefront was opened to the public in 1991 on the 1st of April. The area routinely remains open until the end of November.

Interviewer's Initials

Sheet #

1991

Recreational Fish Survey - PNPS Shorefront

	Date
	Weather
	Wind Direction and Speed
	Number of Anglers for the Day
	Fishing Locations
	Hours the Shorefront was open and fishing allowed (e.g., 6 am - 5:30 pm)

Species	Total Number Caught for Day
Flounder (Flatfish)	
Striped Bass	
Bluefish	
Cod	
Pollock	
Tautog	
Mackerel	
Cunner (Sea Perch)	
Other	

Comments:

Figure 8. Creel data form used at Pilgrim Shorefront to record sportfishing information.

During daylight hours, anglers have access to fish off the outer breakwater, both discharge jetties, and the sandy beach and rip-rap at the head of the intake embayment. The creel survey began on Saturday, May 18th, and continued on weekends through mid-June. The collection of daily information began on Wednesday, June 19th.

As to plant operation during the first three months of fishing this year, throughout April both circulating seawater pumps were operated most of the time, and the plant was discharging waste heat; whereas, in May and June one or no circulating pumps were run, with the discharge of minimal waste heat into the receiving waters.

No creel data were collected systematically from April through May 17. From our observations, fishing pressure appeared to be fairly light in April. During the last two weekends of May, 33 angler-trips were recorded at the Shorefront. Fishing techniques included casting artificial lures and bottom fishing with bait. Reportedly, no fish were caught.

In June, 18 days were sampled: 10 weekend days and 8 weekdays. A total of 369 angler-trips was recorded at the Shorefront during this month's sampling. The catch (121 fish) was comprised of four species of fish: two pelagics - bluefish (58%) and striped bass (5%) and two groundfish - cunner (35%) and pollock (2%). The catch rate averaged 0.3 fish per angler-trip or 7 fish per day. Cunner and pollock were caught off the outer intake breakwater, while bass and bluefish were taken in the discharge. Some bluefish were also caught in the Intake embayment. The catch of bluefish was larger than for the years, 1986 to 1988, when the plant was also in an outage, but was 26% lower than in 1990 when the plant was operating.

8. CUNNER CAPTURE - TAGGING PROGRAM

We are tagging cunner in order to follow their movement patterns and distribution in relation to the waste-heat discharge at Pilgrim Station and resultant zones of impact. We selected the Floy plastic t-bar anchor tag to mark individual fish. In general, we will rely on our SCUBA diving surveys to visually resight ("recapture") tagged fish. To capture cunner for tagging, baited eel pots are being used which also provide recapture information. This study should provide information on the mobility and dispersion of cunner as related to their susceptibility to impact of the discharge current.

Cunner are abundant in Cape Cod Bay, forming discrete localized populations which exhibit only seasonal inshore/offshore movements that are regulated by temperature. As a bottom fish, they occupy small home ranges, inhabiting inshore temperate reefs, i.e., ledges and other rocky areas and other structures including piers, pilings, jetties, and shipwrecks. These serve as refuge areas. This makes the cunner an ideal candidate for monitoring environmental perturbation. Cunner are especially vulnerable after dark since low responsiveness, characteristic of the sleep state of labrid fishes, reduces their ability to avoid environmental stress.

The sources of Pilgrim Station impact to cunner include entrainment of their pelagic eggs and larvae in the circulating seawater system, and entrapment in the intake structure and impingement on the travelling water screens of juveniles and adults. The circulating water discharge generates a current of water that is laden with waste heat and at times containing chlorine and radionuclides which can affect cunner in the receiving waters. Cunner feed benthically and in the water column and show evidence of being attracted to the discharge current on flood tide to feed on suspended food items carried in the effluent.

During May of this year in an overnight gill-net set made at the existing gill-net station, we captured a cunner that was marked last August off the outer intake breakwater during our preliminary tagging operations. This fish was at large nine months before being recaptured. In late May 1991, we began potting cunner for this year. The pots were baited with crushed mussels and frozen fish. Many cunner were caught off the outer breakwater at a control location. Some appeared to be ripening. We retained a sub-sample of cunner for aging. In June we captured 181 cunner at a control location, tagging 66 (≥12 cm total length) of the larger fish using a blue anchor tags. One of these fish was a recapture, having been tagged by us last summer in about the same area. Tagging will continue throughout the summer and into the fall.

IV. ACKNOWLEDGMENTS

The authors thank staff members John Chisholm and John Costa for collecting field data and acknowledge the contributions of Neil Churchill, Paul Caruso and H. Arnold Carr, who assisted in diving operations. We thank Chris Kyranos for his assistance in lobster sampling, and Raymond Dand and Robert Ellenberger for collecting sportfish data at the Pilgrim Shorefront. A word of thanks to Kim Trotto of the Division for word-processing sections of this report. Finally, we appreciate the guidance of Robert D. Anderson of Boston Edison Company, W. Leigh Bridges of the Division, and the Pilgrim Administrative-Technical Committee. Their input on study programs and editorial comments on project reports have been most helpful.

VI. LITERATURE CITED

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SEMI-ANNUAL REPORT
Number 38

on

BENTHIC ALGAL AND FAUNAL MONITORING AT THE PILGRIM NUCLEAR POWER STATION

January-June 1991

to

BOSTON EDISON COMPANY
Regulatory Affairs Department
Licensing Division
25 Braintree Hill Office Park
Braintree, Massachusetts 02184

From

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION
89 Water Street
Woods Hole, MA 02543
(508) 540-7882

1 October 1991

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EXECUTIVE SUMMARY

This report represents results of quantitative data collected in April 1991 at established stations in the vicinity of the Pilgrim Nuclear Power Station (PNPS) and qualitative transect surveys conducted in the thermal effluent in April and June of 1991. These investigations represent the most recent phase of the long-term efforts to monitor the effects of thermal effluents on the benthic communities adjacent to the PNPS.

A variety of analytical techniques were used to assess community structure. Specific data on algal biomass, dominant fauna, species diversity, and faunal densities were analyzed along with overall community relationships. Field collections and laboratory techniques were identical with previous efforts.

QUANTITATIVE STUDIES

Faunal Studies

A total of 102 species of benthic invertebrates were found in the April 1991 samples. The majority of species consisted of polychaetes and molluscs (32 each) followed by crustaceans (27). The total number of species recorded at the Effluent (72), Manomet Point (62), and Rocky Point (78) stations were very similar to those recorded in the spring samples in 1990 (Eff: 70; MP: 71; RP: 79) except for a noticeable decline at the Manomet Point station.

Total densities recorded at the three stations were very high, due in large part to high counts of the blue mussel, *Mytilus edulis*. The Effluent station was highest in total density (517,631 individuals per m^2), whereas the Rocky Point station was lowest (158,804 individuals per m^2). Densities of the two highest ranked species, *Mytilus edulis* and the amphipod *Jassa falcata*, were also highest at the Effluent station.

The 15 highest ranked species at each station accounted for approximately 96 to 99% of the total density at each station. The larger list of rare species (47 to 63) recorded at each station thus contributed little to total density. *Mytilus edulis* and *Jassa falcata* are the first and second ranked species at all three stations, whereas the third rank is occupied by the amphipod *Corophium acutum* at both reference stations and *C. insidiosum* at the Effluent station. A total of 23 species comprise the lists of 15 highest ranked species at all three stations. Among the dominance lists, amphipods are the dominant taxon in terms of species with ten different species among the top 21 listed.

Species diversity indices are obscured by the high density of *Mytilus edulis*. When the mussels are removed from the species list, the diversity patterns reflect the high values expected of communities having high numbers of species. For example, Shannon's H' ranged from 2.04 (Effluent station), 2.85 (Manomet Point), to 3.88 (Rocky Point). These values are indicative of high diversities expected in healthy faunal communities of subtidal coastal environments.

Community analysis by clustering or similarity techniques indicates that there is a clear difference between the Effluent station and the reference stations. Replicates of the Effluent station form a separate cluster regardless of whether the Bray-Curtis or NESS similarity measures are used. Bray-Curtis produces some mixed clusters of samples taken at the reference stations, whereas each reference station is separate with NESS. The similarity patterns thus returned to the historically observed condition.

Algal Studies

No additions to the cumulative algal lists were made as a result of analysis of the March 1991 samples. The rock and cobble substrata found at the Effluent, Manomet Point, and Rocky Point stations were heavily populated with red algae, especially *Phyllophora* spp. and Irish moss, *Chondrus crispus*. Epiphytic algal species were observed at all stations, with *Chondrus* and *Phyllophora* serving as primary hosts.

Algal community overlap measures the similarity in algal species composition between stations or replicates. In March 1991, the range of replicate percent overlap at the Effluent station (19.7%) was lower than at Manomet Point (25.0%) or Rocky Point (21.7%), indicating that individual samples at the Effluent station were more similar to each other than replicates at the two reference stations. Community overlap between the three stations was high, indicating a high degree of homogeneity in species shared.

Biomass of *Chondrus crispus*, epiphytic species, and total algae was highest at the Manomet Point station and lowest at the Effluent station. Biomass of *Phyllophora* spp. and of benthic algal species other than *Chondrus* and *Phyllophora* was highest at the Rocky Point station and lowest at Manomet Point. Analysis of varance (ANOVA) indicated no significant difference in biomass values for *Chondrus*, *Phyllophora* spp., or the remaining benthic species between the three stations. However, for epiphytic and total algal biomass there was a significant difference between stations. Scheffé's method (Sokal & Rohlf, 1981) showed that biomass of epiphytic and total algae at the Effluent station was significantly different from the mean biomass of both control stations combined and from the biomass at Manomet Point, but was not different from Rocky Point station biomass.

QUALITATIVE TRANSECT SURVEYS

The qualitative transect studies performed to evaluate the *Chondrus crispus* community in the effluent canal indicated that in March 1991 the areas of the denuded and stunted *Chondrus crispus* zones were comparable to those seen in past spring seasons when the plant was in operation. Although the *Chondrus* denuded area in March 1991 (1321 m^2) was the largest denuded zone seen in any spring between 1983 and 1991, the total affected area (1546 m^2) was similar to the total affected areas seen from March 1983 through March 1986 (range 1260 m^2 to 2029 m^2). In June 1991, the area of the denuded zone (1265 m^2) had decreased slightly from that of March, a pattern that was also seen in June 1985 when the plant was in full operation and in June 1986 just after the plant had shut down.

By June 1991 the stunted zone had disappeared and *Chondrus* plants outside the denuded zone, although distributed sparsely, looked normal. The elimination of the stunted zone by June 1991 was apparently a short-term response to the refueling outage and cessation of thermal effluent that began in late April 1991 and continued until August 12, 1991. A sparse zone also appeared early in 1989 shortly after the plant became operational following a 2½-year hiatus; the stunted zone did not become reestablished until April 1990, a year later.

1.0 INTRODUCTION

This report represents a continuation of the long-term (18 yr) algal and faunal studies at Pilgrim Nuclear Power Station (PNPS) that are intended to monitor the effects of the thermal effluent (under Boston Edison Company Purchase Order No. 68003 for 1991). The 1991 program is essentially the same as previous monitoring efforts conducted over the last 11 years. Quantitative benthic algal and faunal sampling is conducted during the spring and summer at two reference sites at Rocky Point and Manomet Point, and at a site offshore of the effluent canal (Figure 1). Qualitative SCUBA surveys of algal cover at the effluent canal are conducted quarterly during March, June, September, and December. This Semi-Annual Report includes quantitative data from samples that were collected in April 1991 and qualitative observations recorded in April and June 1991.

2.0 METHODS

2.1 FIELD SAMPLING

The sampling sites are the same locations that have been sampled since the beginning of the current monitoring program, approximately 10 years ago. The stations are located by the following established procedur . Line-of-sight positions are established using highly visible structures located on the shore as reference points. The Rocky Point station is located by lining up the microwave relay tower with the PNPS red and white off-gas stack. The Effluent station is identified along the center line between the two discharge jetties, located approximately 120 m offshore. The Manomet Point station is fixed by lining up the two southernmost telephone poles on top of Manomet Point. Line-of-sight position combined with lead-line depth checks ensures station relocation to within a radius of 20 to 30 m of the original station position.

All sampling is done by SCUBA-equipped biologists operating from a small boat. For the quantitative algal and faunal studies, five replicate samples delineated by a metal pipe frame quadrant measuring 0.33 m on a side (0.1089 m^2) are taken from the surface of rocks at each station.

Upon arrival at a station, the divers descend to the bottom and locate suitable rocks for placement of the quadrat. Divers are able to assess algal and faunal cover and select rocks that are considered typical for the station.

All attached flora and fauna within the quadrat are scraped from the rock and drawn through an airlift device into a 0.5-mm mesh bag (Figure 2). Field labels with station, collection date, and replicate number are placed in sample bags before sample collection. The bag is tied and placed in a large catch bag; a new bag is then attached to the airlift. The divers then locate the next suitable rock

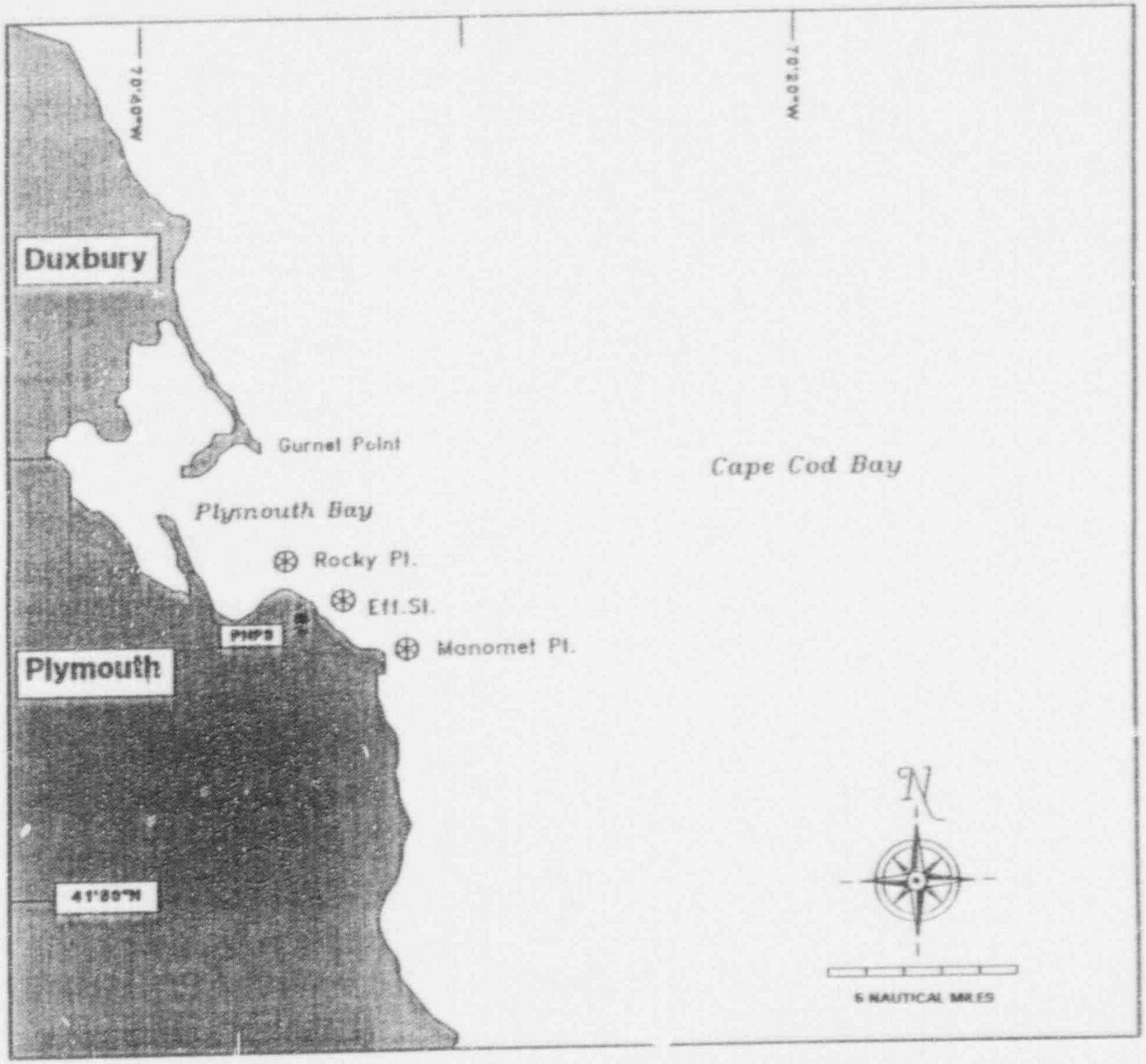

Figure 1. Location of Benthic Sampling Sites near Pilgrim Station.

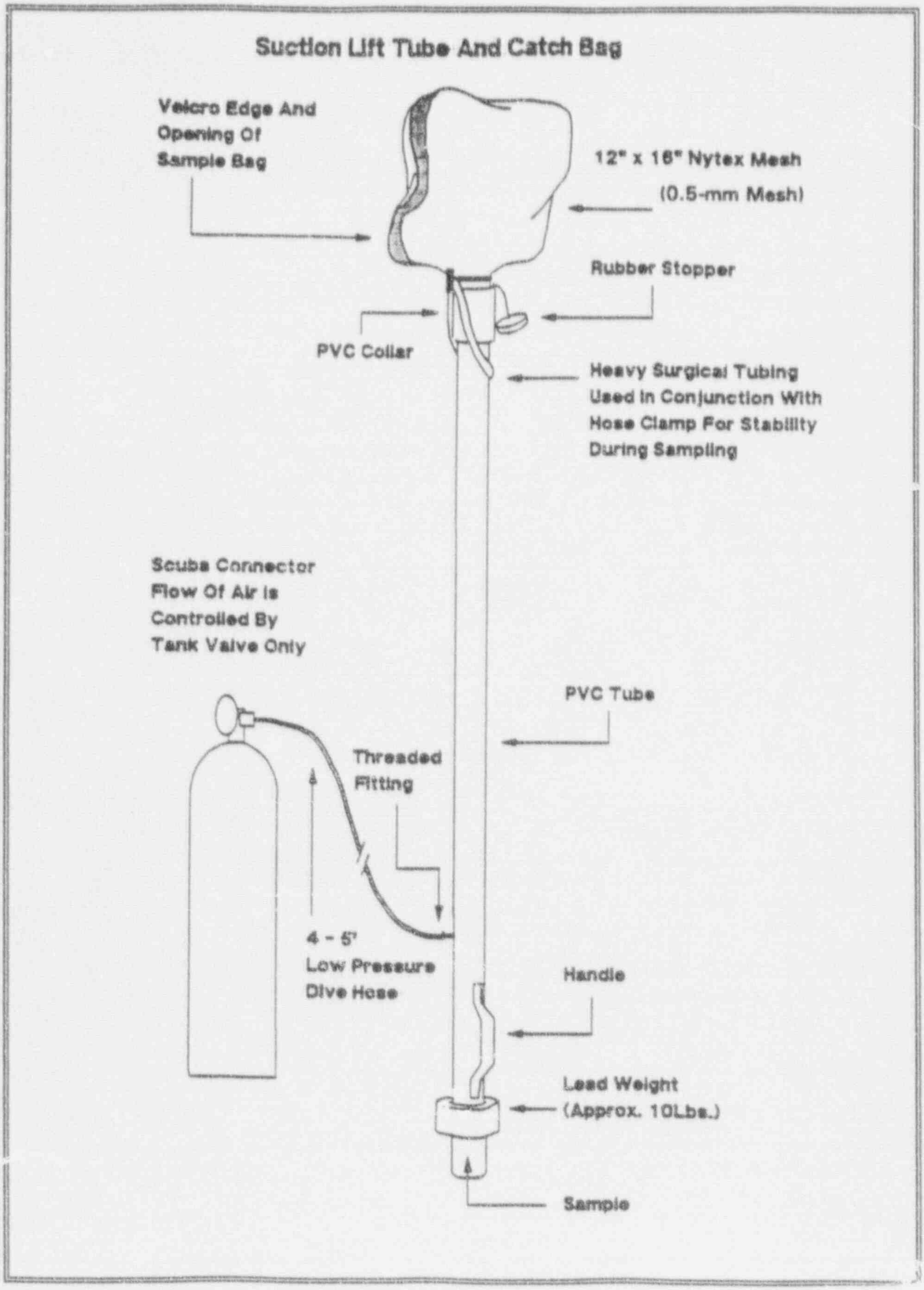

Figure 2. Suction Lift Device Used by Divers to Collect Benthic Samples.

and repeat the sampling process. After the five replicates are collected at a station they are delivered to a biologist on the boat for processing.

While the vessel is underway to the next station, the contents of each bag are transferred to a 1-gal plastic jar, labeled, and preserved with 10% buffered formalin. Approximately 100 g of Borax is added to each jar as a buffering agent to prevent softening of calcified shells.

For the qualitative transect survey, SCUBA observations are made along the axis of the discharge canal. A line is extended across the mouth of the discharge jetty (Figure 3). A weighted transect line, marked at 10-m intervals, is then attached to the center of this line and deployed along the central axis of the canal to a distance of 100 m offshore. A 30-m measuring line, marked at 1-m intervals, is extended perpendicular to the transect line by the divers and oriented to the transect line with a compass. A diver traverses this third line underwater and records changes in algal cover at 10-m intervals from the transect line through the denuded and stunted *Chondrus* areas to where the algal cover becomes normal.

According to procedures established by Taxon (1982) and followed in subsequent years, the distinction between "denuded" and "stunted" is based on *Chondrus crispus*. The denuded zone is defined as that area where *Chondrus* occurs only as stunted plants restricted to the sides and crevices of rocks. In this area, *Chondrus* is found on the upper surfaces of rocks only where the microtopography of the rock surfaces creates small protected areas. In the stunted zone, *Chondrus* is found on the upper surfaces of the rock, [illegible] is noticeably inferior in height, density, and frond development. The normal zone is considered to begin at the point where these factors are typical for the depth and substratum in question.

In addition to observing algal cover, the divers record any unusual occurrences or events in the area and note the location of any distinctive algal or faunal associations.

2.2 LABORATORY ANALYSIS

In the laboratory, the algal and faunal fractions of the samples are separated by washing the animals off the algae onto a 0.5-mm-mesh screen. The animals are preserved in a solution of 70% ethanol. The algal fraction is preserved in a 10% formalin solution. The faunal samples are labeled and stored in 16-oz glass or plastic jars until sorting. Algal samples are labeled and stored in 1-gal plastic jars until sorting.

Each replicate sample is processed separately. The algal component of each sample is examined, using both dissection and compound microscopes, to identify all species of macroalgae and

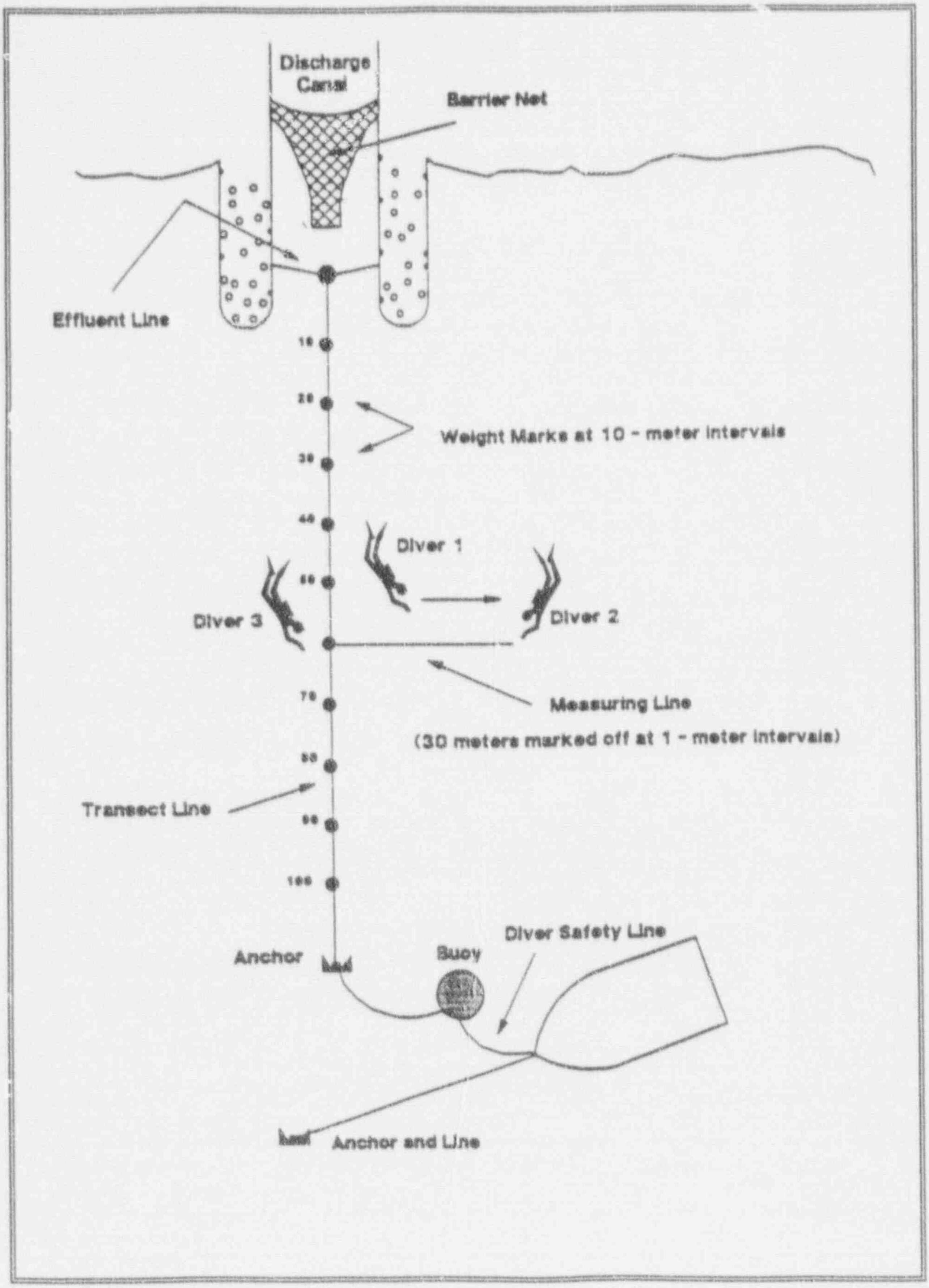

Figure 3. Design of the Qualitative Benthic Transect Sampling Program at Pilgrim Station.

to determine the presence or absence of 38 indicator species. Important algal references used to identify and confirm names are Taylor (1957), Parke and Dixon (1976), and South (1976). The indicator species were originally chosen in September 1978, and were carefully selected from a list of the several hundred algal species recorded from the PNPS study sites during the 1974-1978 period (Taxon, 1982). The indicator species include members of each of the major algal families from a variety of habitats, including all of the dominant species within the study area, the majority of the macrophytic species, and the most common epiphytic species (Table 1). Therefore, the indicator species comprise the most substantial part of the algal community as measured by both percent cover and biomass, although they constitute only a small fraction of the flora inhabiting the study area in terms of the number of species. Dry-weight biomass of each sample is reported for four separate algal fractions: *Chondrus crispus*, *Phyllophora* spp., epiphytic species, and the remaining benthic species. Total algal biomass is also reported. Each fraction is weighed on a Mettler balance after drying for 72 h in a drying oven set at 80°C.

A 25% aliquot of the faunal fraction of each sample is processed, and the remaining 75% of the sample is archived. Prior to sorting, the 25% aliquot is stained with a saturated alcoholic solution of Rose Bengal for at least 4 h, but no longer than 48 h to avoid overstaining. The samples are examined under a dissecting microscope and each organism or fragment thereof removed. Invertebrates are sorted to major taxonomic groups, such as polychaetes, crustaceans, bivalves, gastropods, echinoderms, and other miscellaneous phyla. The blue mussel *Mytilus edulis* is left with the residue and counted during the sorting process.

Final identification is to the lowest possible taxon (usually to species). During identification, the counts of each species are recorded. A new reference collection for the PNPS program has been developed from the April 1990 samples and will serve as a voucher collection for subsequent identifications. The samples are archived for a minimum of three years after collection.

2.3 DATA ANALYSIS

All faunal data are kept on specially designed project data sheets to facilitate computer entry. Data are keypunched into a spreadsheet, using Quattro Pro®, on a personal computer. Some basic data summaries and calculations can be made while the data is in this form. Following data entry and reorganization in the spreadsheet, a hard copy of the raw data is generated and verified against the original coding sheets. All keypunching errors are corrected at this point. Data files are then transferred to the WHOI (Woods Hole Oceanographic Institution) VAX computer for analysis.

Table 1. Algal Indicator Species used for Quantitative Community Analysis.

Chlorophyta (Green Algae)

Bryopsis plumosa
_Chaetomorpha linum_*
_C. melagonium_*
Cladophora spp.*
_Enteromorpha flexuosa_*
_Rhizoclonium riparium_*
_Ulva lactuca_*

Phaeophyta (Brown Algae)

Chordaria flagelliformis
_Desmarestia aculeata_*
_D. viridis_*
Laminaria digitata
L. saccharina
_Sphacelaria cirrosa_*

Rhodophyta (Red Algae)

_Ahnfeltia plicata_*
_Antithamnion americanum_*
_Bonnemaisonia hamifera_*
Callophyllis cristata
_Ceramium rubrum_*
_Chondrus crispus_*
_Corallina officinalis_*
_Cystoclonium purpureum_*

Gracilaria tikvahiae
Gymnogongrus crenulatus
_Membranoptera alata_*
Palmaria palmata
_Phycodrys rubens_*
_Phyllophora truncata_*
_P. pseudoceranoides_*
P. traillii
Plumaria elegans
_Polyides rotundus_*
Polysiphonia elongata
_P. fibrillosa_*
_P. harveyi_*
_P. nigrescens_*
_P. urceolata_*
_Rhodomela confervoides_*
_Spermothamnion repens_*

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* Species found in March 1991 samples.

Analytical software consists of a suite of programs developed specifically for the analysis of benthic data. In addition to a variety of data-management and modification utilities, these programs include PRARE1 and COMPAH. PRARE1 summarizes the data for each sample, calculates a variety of diversity-related indices, and generates a rarefaction curve. COMPAH is a multivariate classification package that allows a wide variety of user-specified options for similarity indices and clustering strategies, including both normal (i.e. by station) and inverse (i.e. by species) analyses

The individual species composing the fauna at each station are rank ordered by abundance. The most abundant species is listed first, followed in order by less abundant forms. The percent contribution of each species to the total fauna is denoted by a decreasing total percentage starting with the most abundant species and ending with the most rare. Basic statistical treatments include calculation of means of abundances per station and extrapolation to density per m^2.

Species richness is interpreted by using a jackknife procedure in combination with pooled species data to evaluate the contribution of rare species in the communities (Heltshe and Forrester, 1983). This procedure takes into account that random samples are not necessarily representative of a population. The jackknife estimate of species richness is a function of the number of so-called "unique" species present at a station, that is those that are present in one and only one replicate out of five. The jackknife estimate of species richness ($\hat{S}$) is expressed as:

$$\hat{S} = S + \left[\frac{(n-1)}{n}\right] k$$

where $\boldsymbol{S}$ represents the pooled species numbers at each station, $\boldsymbol{n}$ is the number of replicates, and $\boldsymbol{k}$ is the number of unique species. The variance of estimated species richness [**var** ($\hat{S}$)] is also calculated to measure the spatial distribution of unique species.

Measures of diversity calculated for each sample and station include the Shannon-Wiener information (***H'***) and evenness (*J'*) indices and rarefaction curves according to the method of Hurlbert (1971). Shannon's H' has been shown to be a biased estimator and for small samples will underestimate true population information (Smith and Grassle, 1977). Hurlbert's expected species index of diversity is an unbiased estimator and is thus particularly useful when small and unequal sample sizes must be compared.

The measure of similarity developed by Grassle and Smith (1976), the Normalized Expected Species Shared (NESS), combined with group average sorting is used for cluster analysis. NESS is based on the expected number of species shared between random samples of size *m* drawn from a population, and is sensitive to the less common species in the populations to be compared. The Bray-Curtis similarity measure, combined with group average sorting, is also used (Boesch, 1977). These values are calculated for stations (normal) and species (inverse), using numbers of individuals of species.

In the event that patterns in the station and species analysis require further interpretation, a nodal analysis is performed using the results of the similarity procedures described above. This procedure is especially useful when evaluating the combined spring and summer data. Nodal analysis is a method of relating normal and inverse classifications to aid in the interpretation of cluster analyses. The method uses two-way tables that show replicate groups on the vertical side and species groups on the horizontal side. This technique is used to measure constancy and fidelity. Constancy is a proportion derived from the number of occurrences of a species group in a replicate group as compared with the total possible occurrences. Fidelity is the degree of restriction of a species group to a replicate group. In this report we elected to not use nodal analysis because the stations and species clustering patterns were readily explained.

For the algae, community overlap was calculated using Jaccard's coefficient of community (Grieg-Smith, 1964) to measure the similarity in algal species composition among the Effluent, Manomet Point, and Rocky Point stations. Jaccard's coefficient provides a mathematical evaluation of the similarity between two replicates or stations using only species occurrence and does not consider differences in their abundance.

3.0 RESULTS

3.1 QUALITATIVE TRANSECT SURVEY

Qualitative transect surveys of acute nearfield impact zones were initiated in January 1980 and have been conducted quarterly since 1982. Two surveys were performed (March 28 and June 28) during the current reporting period, bringing the total number of surveys conducted since 1980 to 42. Results of surveys conducted from January 1980 to June 1983 are reviewed in Semi-Annual Report 22 to Boston Edison Co. (BECO, 1983). Results of the four surveys performed in 1990 are reviewed in Semi-Annual Report No. 37 to Boston Edison Co. (BECO, 1991). Detailed results of the mapping conducted in March and June 1991 are presented in the next two sections.

3.1.1 March 1991 Transect Survey

The extent of the denuded and stunted areas mapped on March 28, 1991 immediately offshore from PNPS is shown in Figure 4. A large boulder that is nearly exposed at mean low water, and that is used as a landmark by both the SAIC and the Massachusetts Division of Marine Fisheries dive teams is plotted in the figure. The denuded zone is essentially devoid of *Chondrus crispus* whereas the stunted zone has *Chondrus* that is smaller and less dense than that growing under normal conditions. The dive team must keep in mind while taking measurements that the shallower depths to the northwest of the discharge canal preclude normal *Chondrus* growth.

In March 1991, the *Chondrus* denuded zone was characterized by bare rock and very sparse, scattered patches of *Ulva* that extended approximately 8 to 13 m north and 3 to 4 m south of the baseline. This asymmetrical distribution around the transect line was a return from the more symmetrical distribution seen during the December 1990 survey to the configuration seen during the first three 1990 surveys. The denuded zone reached 24 m further offshore than in April 1990, extending approximately 94 m along the transect line. The area (approximately 1320.5 m^2) of the denuded zone was 46% larger than in April 1990 and 5% larger than in December 1990. Assemblages of *Cystoclonium purpureum* and a species tentatively identified as *Gracilaria tikvahiae* growing near the 40-m mark were more dense than those seen during the previous two surveys. North of the transect line, between the 50- and 60-m marks, an alga species, *Membranoptera alata*, not seen during the September or December 1990 surveys, was observed living in conjunction with the *Ulva* patches and collected for identification. Between the 70 to 80-m marks and within 8 m of the baseline, dense patches of juvenile mussels had settled on several of the rocks.

The stunted zone, with an area of about 225 m^2, was 25% larger than in December 1990. On the northwest side the stunted zone occurred as a band from the tip of the jetty to the 90-m mark on the transect line, while along the southeast side it occurred only as a thin strip from the 49-m to 80-m mark on the transect. The greatest width reached by the stunted zone was 6.5 m at the 65-m mark on the transect.

3.1.2 June 1991 Transect Survey

Results of the divers' survey for June 27, 1991 are mapped in Figure 5. The denuded zone extended 85 m along the transect line. The area (1265 m^2) of the denuded zone was slightly less (4%) than in March, 1991 and much less (31%) than it had been in June, 1990. The distribution of the denuded zone around the transect line was slightly asymmetrical with more area denuded of

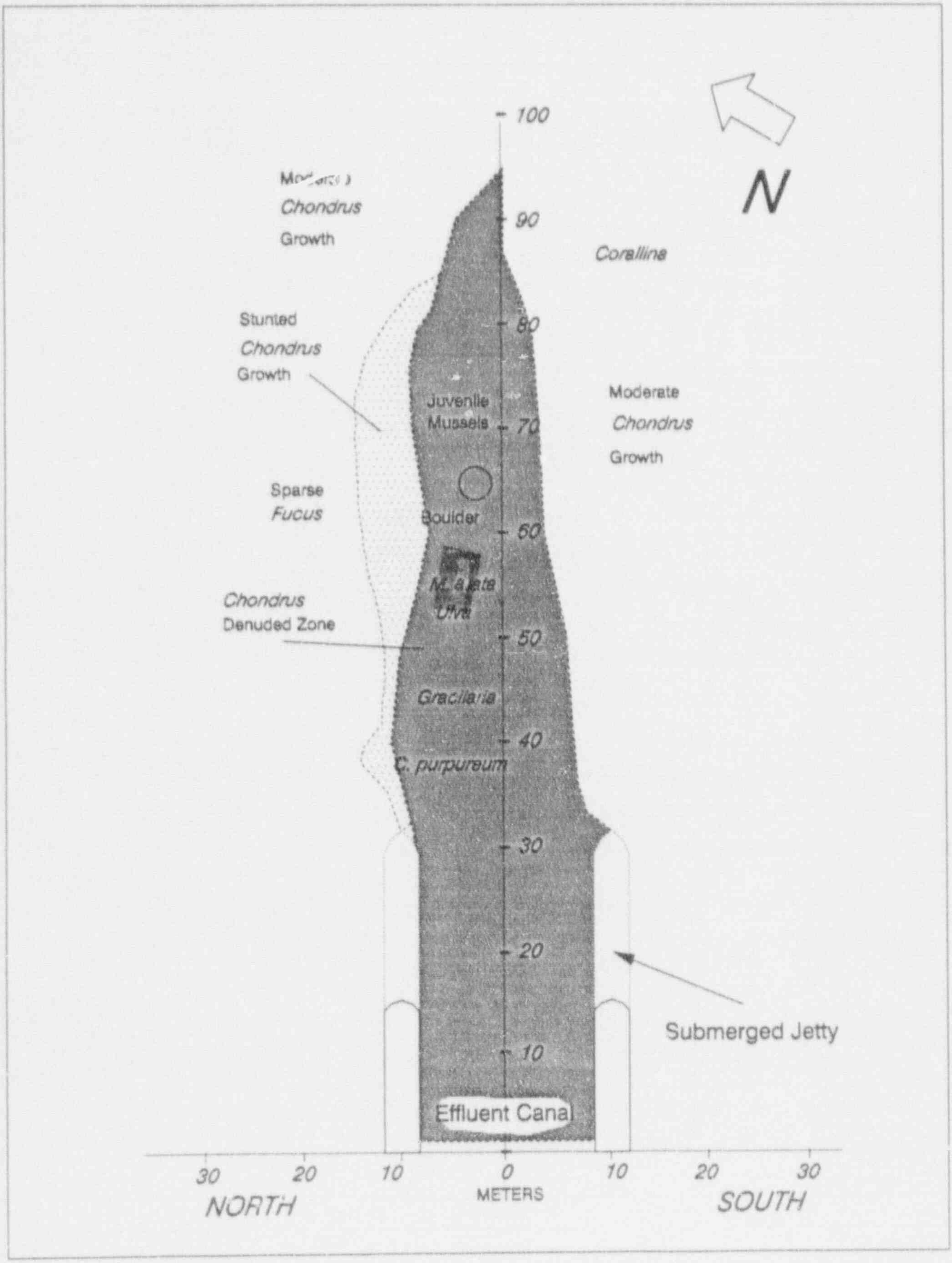

Figure 4. Stunted and Denuded *Chondrus* Zones Observed in March 1991.

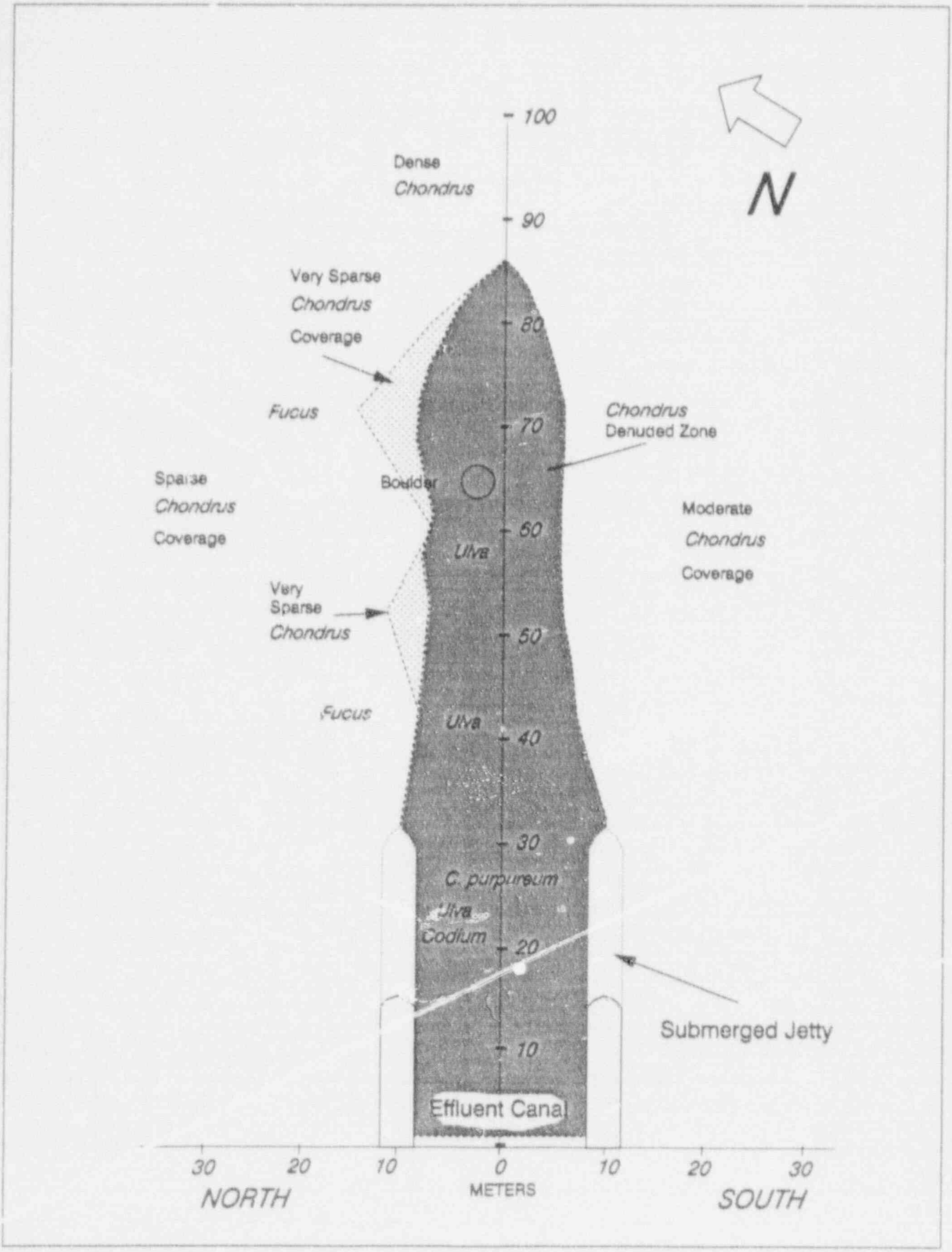

Figure 5. Stunted and Denuded *Chondrus* Zones Observed in June 1991.

Chondrus north of the line than to the south. The northern region was characterized by areas of bare rock and sparse coverage by *Chondrus* beyond the denuded zone, except at the 60-m mark where dense patches of *Chondrus* occurred on the sides of large rocks only 8 m north of the transect line. *Fucus*, more abundant than in March, was present north of the transect line. No *Laminaria* was observed during the dive. Within the discharge canal there was dense coverage of the red, fibrous alga, *Cystoclonum purpureum*, along with patches of *Ulva* and *Codium*. *Ulva* was present north of the transect line from the jetties to the 70-m mark.

There was no true region of stunted *Chondrus* growth as seen in previous surveys. The northern border of the denuded zone was delineated by the presence of sparsely distributed but normal looking *Chondrus*; the southern boundary was clearly delineated by moderate coverage of normal *Chondrus* growth and increased algal diversity.

3.2 QUANTITATIVE FAUNAL MONITORING

3.2.1 Systematics

In the spring of 1991, 102 species were found in the study area. Sixty-four percent of the fauna were polychaetes and mollusks with each group contributing 32 species. Crustaceans included 27 species (26%), and the remaining species included 5 echinoderms (5%), 3 nematodes (3%), and small groups such as turbellarians, anemones, and tunicates. A list of the species collected in the April 1991 survey is included in Appendix A.

Three species were added to the list produced during the surveys in 1990, including two nudibranchs, *Coryphella rufibranchialis* and *Coryphella salmonacea*, and a nemertean, *Tetrastemma vittatum*[1].

3.2.2 Species Richness

Species richness values for all three stations for April 1991 are presented in Table 2. Data are presented as total species per replicate for each station (25% aliquot), with a mean value over all replicates at each station and a cumulative total representing pooled species numbers at each station. Because the area included within each replicate is 0.1089 m^2, the cumulative species total at each station represents a total area of 0.5445 m^2.

In April 1991, the Rocky Point reference station had 78 species for pooled replicates, the highest number among the three stations. The Manomet Point station had 62 species, and the Effluent station was intermediate with 72 species. The average number of species per replicate again resulted in Rocky Point being first (48.6) followed by the Effluent (43.2) and Manomet Point (38.8).

In order to assess the rare species that might be present at the stations but were not found because of the relatively small area sampled, the jackknife estimate of Heltshe and Forrester (1983) was calculated (See Section 2.3). Again the Effluent station proved to be intermediate (estimated species: about 96) between Manomet Point (77 estimated species) and Rocky Point (about 102 estimated species). The very high variance of $\hat{S}$ at the Effluent station indicates that the unique species were distributed unevenly among the replicates; more than half of all unique species were found in one replicate.

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[1] This nemertean has undoubtedly been present prior to this sampling period, but has not been identified to species before.

Table 2. **Faunal Species Richness at the Effluent, Manomet Point, and Rocky Point Stations in April 1991.**

	Effluent	Manomet Point	Rocky Point
No. Species/Replicate	47, 35, 44, 53, 37	42, 42, 39, 35, 36	50, 51, 51, 43, 48
Mean ± Standard Deviation	43.2 ± 7.36	38.8 ± 3.27	48.6 ± 3.36
No. Species/Station	72	62	78
Jackknifed Estimate Species Richness ($\hat{S}$)	95.8	77.0	101.8
Variance ($\hat{S}$)	42.24	0.96	11.84

In comparison with data from the previous year, no trends are evident in the number of species actually found in the samples; however, if the jackknife estimate technique is used, a short-term seasonal pattern emerges. The number of species found in the samples was consistently lowest at the Effluent station during both seasons in 1990, whereas it was intermediate in spring 1991; during all three sampling seasons, the Rocky Point station consistently ranked highest. On the other hand, the number of estimated species at the Effluent station in the spring seasons of 1990 and 1991 was intermediate (about 90) between the numbers calculated for Manomet Point (about 80) and those for Rocky Point (about 100), whereas in the fall of 1990, the Effluent station was clearly lower (75) than both reference stations (about 100).

3.2.3 Faunal Density

Total faunal densities recorded in April 1991 differed greatly among stations. Table 3 shows the average number of individuals per replicate and the extrapolated number of individuals per square meter. Calculations were made with and without the mussel *Mytilus edulis*; mussel densities are also shown separately. Total faunal density at the Effluent station was exceptionally high in spring 1991 (almost 518,000 individuals per m^2), mostly because of a very dense mussel population of more than

Table 3. Faunal Densities at the Effluent, Manomet Point, and Rocky Point Stations in April 1991.

Station	Total Density				Density of *Mytilus edulis*	
	With *Mytilus edulis*		Without *Mytilus edulis*			
	Mean ($\bar{x}$) No. Indiv./ Rep.	Density per m^2	Mean ($\bar{x}$) No. Indiv./ Rep.	Density per m^2	Mean ($\bar{x}$) No. Indiv./ Rep.	Density per m^2
Effluent	59,340.8	517,631	14,396.0	132,263	41,944.8	385,368
Manomet Point	20,534.4	188,660	6,620.0	60,821	13,914.4	127,839
Rocky Point	17,284.8	158,804	6,772.0	62,218	10.512.8	96,586

380,000 individuals per m^2. Rocky Point ranked lowest with a total faunal density of approximately 159,000 individuals per m^2 (about 97,000 mussels per m^2), and the Manomet Point station was intermediate with about 189,000 individuals per m^2 (about 128,000 mussels per m^2). Since the spring of 1990, total densities at the Effluent stations increased consistently, whereas at the reference stations, total density declined between spring and fall 1990 and did not change considerably between fall 1990 and spring 1991.

Some of the abundant species were examined in detail to further elicit changes in faunal density over time. Figure 6 depicts the total faunal densities and densities of *Mytilus edulis*, *Jassa falcata*, and *Lacuna vincta* at the three stations from the spring 1990, fall 1990, and spring 1991 data. The graphics show that total densities at the Effluent station have increased since the spring of 1990, whereas the two reference stations exhibit a decline in total faunal density in the fall and a more or less pronounced increase in the spring of 1991. The sharp increase in total faunal density at the Effluent station in spring 1991 was caused both by the mussels and by *Jassa falcata*, the most common amphipod in the study area and usually among the top 3 dominants at each station. *Jassa* also caused the increase of total densities at the two reference stations between fall 1990 and spring 1991, whereas the mussel populations at those

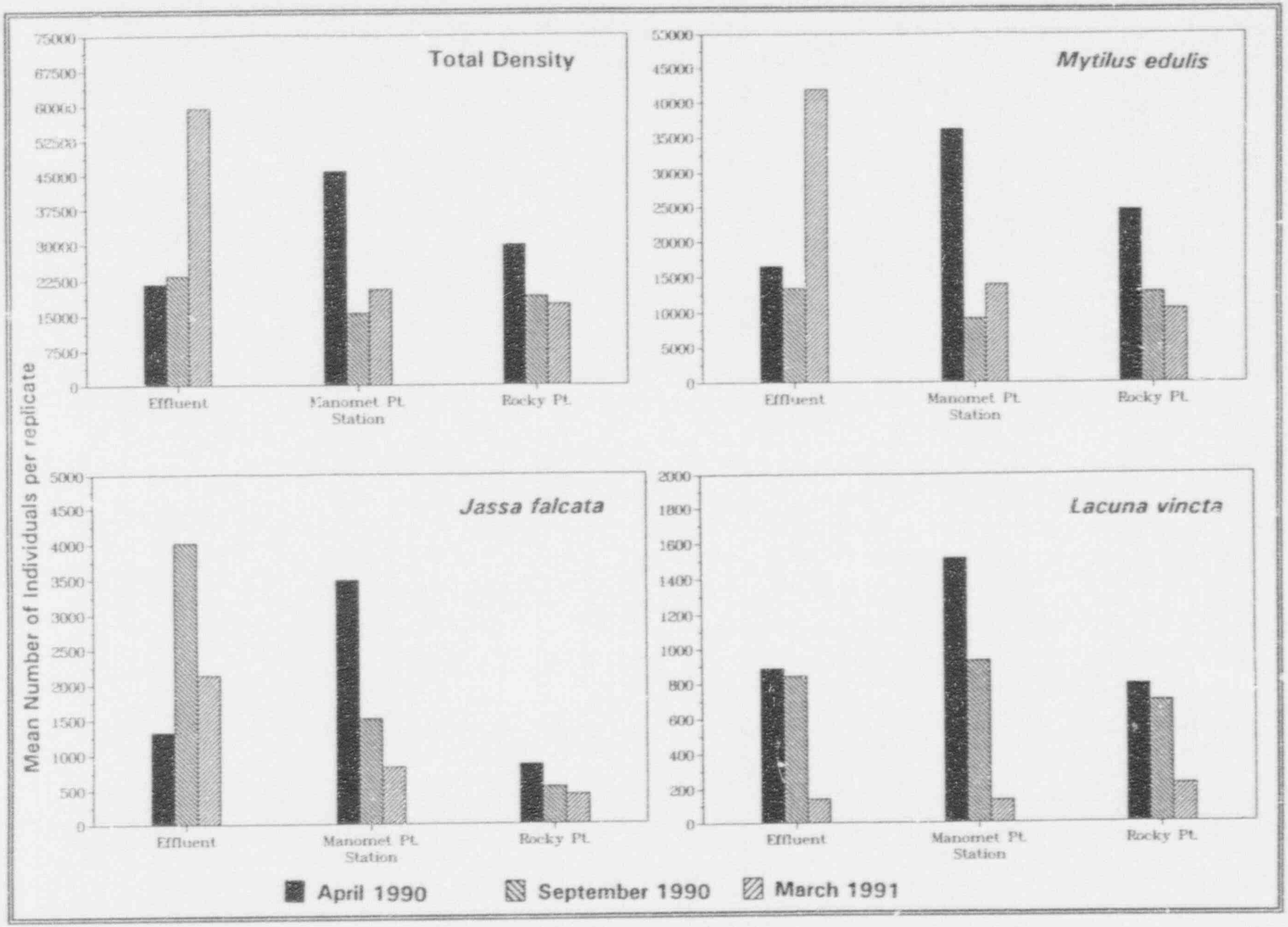

Figure 6 Density of Benthic Fauna in April and September of 1990 and March of 1991.

stations increased only slightly at Manomet Point and decreased at Rocky Point during the same time. The snail *Lacuna vincta*, a very important faunal element in both seasons of 1990, generally showed a steady decline in density since spring 1990, except for Rocky Point where its density increased between fall 1990 and spring 1991.

3.2.4 Species Dominance

The 15 numerically dominant species collected at the Effluent, Manomet Point, and Rocky Point stations in April 1991 are shown in Table 4. Data are presented as the average number per replicate (¼ aliquot) and percent composition at each station. The composite list of species making up the fifteen dominants at each of the three stations contains 23 species. Eight of those 23 species occurred at all three stations, and 4 species (3 amphipods and the sea urchin *Strongylocentrotus*) were shared among any combination of two stations. Five species occurred among the dominants of the Effluent station only, including an amphipod, a nemertean, the starfish *Asterias*, and 2 polychaetes; two amphipods occurred among the dominants at Manomet Point only, and one amphipod and three snails occurred among the dominants at Rocky Point only.

The 15 most abundant species comprised 96% (Rocky Point station) to more than 99% (Effluent station) of the total fauna. The longer list of rare or infrequently encountered species (47 to 63, depending upon station) accounted for no more than 0.6 to 4.1% of the total fauna. Most of the dominant species were amphipods (10 species); other dominants were gastropods (4 species), echinoderms (2 species), tunicates (1 species), isopods (1 species), and caprellids (1 species). The blue mussel *Mytilus edulis* was the only bivalve included in the top 15 dominants.

The benthic communities at all three stations were dominated by *Mytilus* (Effluent, 74%, Manomet Point, 68%, and Rocky Point, 61%), but were also characterized by the amphipod *Jassa falcata*, contributing 10 to 16% of the total fauna. It is noteworthy that the species ranking third was the amphipod *Corophium acutum* at both reference stations, but *C. insidiosum* at the Effluent station, where it pushed *C. acutum* into fourth position. The snail *Lacuna vincta* ranked fourth at the reference stations and fifth at the Effluent station, respectively.

Table 4. Rank Order of 15 Dominant Species Collected in April 1991.

Sta.	Rank	Species	Mean Number per Replicate[1]	Percent of Identified Fauna
EFF	1	*Mytilus edulis* (Bivalve)	10,486.0	74.45
	2	*Jassa falcata* (Amphipod)	2,137.4	15.18
	3	*Corophium insidiosum* (Amphipod)	613.4	4.36
	4	*Corophium acutum* (Amphipod)	447.8	3.18
	5	*Lacuna vincta* (Gastropod)	142.6	1.01
	6	*Caprella penantis* (Caprellid)	60.8	0.43
	7	*Calliopius laeviusculus* (Amphipod)	18.0	0.13
	8	*Dexamine thea* (Amphipod)	17.2	0.12
	9	*Cerebratulus lacteus* (Nemertean)	14.2	0.10
	10	*Idotea phosphorea* (Isopod)	13.2	0.09
	11	*Asterias forbesi* (Echinoderm)	11.4	0.08
	12	*Pholoe minuta* (Polychaete)	10.0	0.07
	13	*Eulalia viridis* (Polychaete)	9.4	0.07
	14	*Molgula* sp. (Tunicate)	7.2	0.05
	15	*Strongylocentrotus droebachiensis* (Echinoderm)	6.8	0.05
	TOTAL OF 15 SPECIES		13,995.4	99.37
	REMAINING IDENTIFIED FAUNA - 57 SPECIES		89.8	0.63
	TOTAL IDENTIFIED FAUNA - 72 SPECIES		14,085.2	100.00
MP	1	*Mytilus edulis* (Bivalve)	3,478.6	67.76
	2	*Jassa falcata* (Amphipod)	827.0	16.11
	3	*Corophium acutum* (Amphipod)	200.6	3.91
	4	*Lacuna vincta* (Gastropod)	133.0	2.59
	5	*Corophium bonelli* (Amphipod)	127.8	2.49
	6	*Margarites umbilicalis* (Gastropod)	76.4	1.49
	7	*Molgula* sp. (Tunicate)	46.4	0.90
	8	*Idotea phosphorea* (Isopod)	35.0	0.68
	9	*Calliopius laeviusculus* (Amphipod)	23.4	0.46
	10	*Dexamine thea* (Amphipod)	18.8	0.37
	11	*Caprella penantis* (Caprellid)	18.8	0.37
	12	*Ischyrocerus anguipes* (Amphipod)	18.0	0.35
	13	*Amphitoe rubricata* (Amphipod)	16.2	0.32
	14	*Pleusymtes glaber* (Amphipod)	15.2	0.30
	15	*Pontogeneia inermis* (Amphipod)	14.6	0.28
	TOTAL OF 15 SPECIES		5,049.8	98.38
	REMAINING IDENTIFIED FAUNA - 47 SPECIES		83.8	1.62
	TOTAL IDENTIFIED FAUNA - 62 SPECIES		5,133.6	100.00
RP	1	*Mytilus edulis* (Bivalve)	2,628.2	60.82
	2	*Jassa falcata* (Amphipod)	431.8	10.00
	3	*Corophium acutum* (Amphipod)	260.4	6.03
	4	*Lacuna vincta* (Gastropod)	225.6	5.22
	5	*Molgula* sp. (Tunicate)	75.8	1.75
	6	*Margarites umbilicalis* (Gastropod)	75.4	1.75
	7	*Corophium bonelli* (Amphipod)	73.4	1.70
	8	*Mitrella lunata* (Gastropod)	69.2	1.60
	9	*Onoba aculea* (Gastropod)	55.2	1.28
	10	*Pontogeneia inermis* (Amphipod)	54.6	1.26
	11	*Ischyrocerus anguipes* (Amphipod)	53.0	1.23
	12	*Strongylocentrotus droebachiensis* (Echinoderm)	49.4	1.14
	13	*Dexamine thea* (Amphipod)	39.6	0.92
	14	*Caprella penantis* (Caprellid)	29.2	0.68
	15	*Idotea phosphorea* (Isopod)	23.8	0.55
	TOTAL OF 15 SPECIES		4,144.6	95.93
	REMAINING IDENTIFIED FAUNA - 63 SPECIES		176.6	4.07
	TOTAL IDENTIFIED FAUNA - 78 SPECIES		4,321.2	100.00

3.2.5 Species Diversity

Species diversity was measured using the Shannon-Wiener Information index (H') and the Hurlbert rarefaction method. Results of species diversity calculations both with and without the mussels are shown in Table 5 and Figure 7. The mussel population affected the species diversity values, as is typical for the study area, although not as strongly as in the previous spring; H' values without mussels were about 1.5 times higher than with mussels, whereas in spring 1990 that factor was 2 to 3. Generally, diversity was lower in spring 1991 than it had been in spring and fall 1990. This very low diversity is in part the result of high mussel counts (e.g., at the Effluent station), but also of high abundances of the amphipods *Jassa falcata* and two species of *Corophium*.

Diversity was lowest at the Effluent station (H'=1.34), intermediate at the Manomet Point station (H'=1.82), and highest at the Rocky Point station (H'= 2.49); if the mussels were excluded, the stations ranked the same, but the range for H' was higher, between 2.04 and 3.88. Evenness values (J') were also lowest at the Effluent station and highest at Rocky Point, indicating a more patchy distribution of organisms at the Effluent station.

Hurlbert's rarefaction method produced essentially the same patterns as the Shannon-Wiener index, with the lowest diversity present at the Effluent station when mussels are included (35 expected species per 5000 individuals), and the highest diversity value calculated for Rocky Point when mussels are excluded (70 expected species per 5000 individuals). One exception is the second highest diversity, which was present at Manomet Point (without mussels) according to Shannon-Wiener, whereas it occurred at Rocky Point (with mussels) according to Hurlbert. The results of Hurlbert's rarefaction are probably more accurate because they seem to reflect more strongly the effect of low mussel counts at Rocky Point than does Shannon-Wiener.

Table 5. Community Parameters for the Effluent, Manomet Point, and Rocky Point Stations in April 1991.

Station	Density (m^2)	Total No. Species	Species per 100 Indiv.	Species per 500 Indiv.	Species per 1000 Indiv.	Species per 2500 Indiv.	Species per 5000 Indiv.	Shannon-Wiener (H')	Evenness (J')
Effluent	517,631	72	6.3	12.0	16.7	25.9	34.5	1.34	0.217
Without *Mytilus*	132,271	71	9.7	22.2	30.4	42.4	51.9	2.04	0.332
Manomet Point	188,660	62	10.3	20.0	25.2	33.3	41.6	1.82	0.306
Without *Mytilus*	60,821	61	15.7	27.8	34.7	46.6	55.7	2.85	0.480
Rocky Point	158,804	78	15.3	28.5	35.8	47.7	57.9	2.49	0.395
Without *Mytilus*	62,218	77	21.6	37.7	47.0	60.4	69.9	3.88	0.619

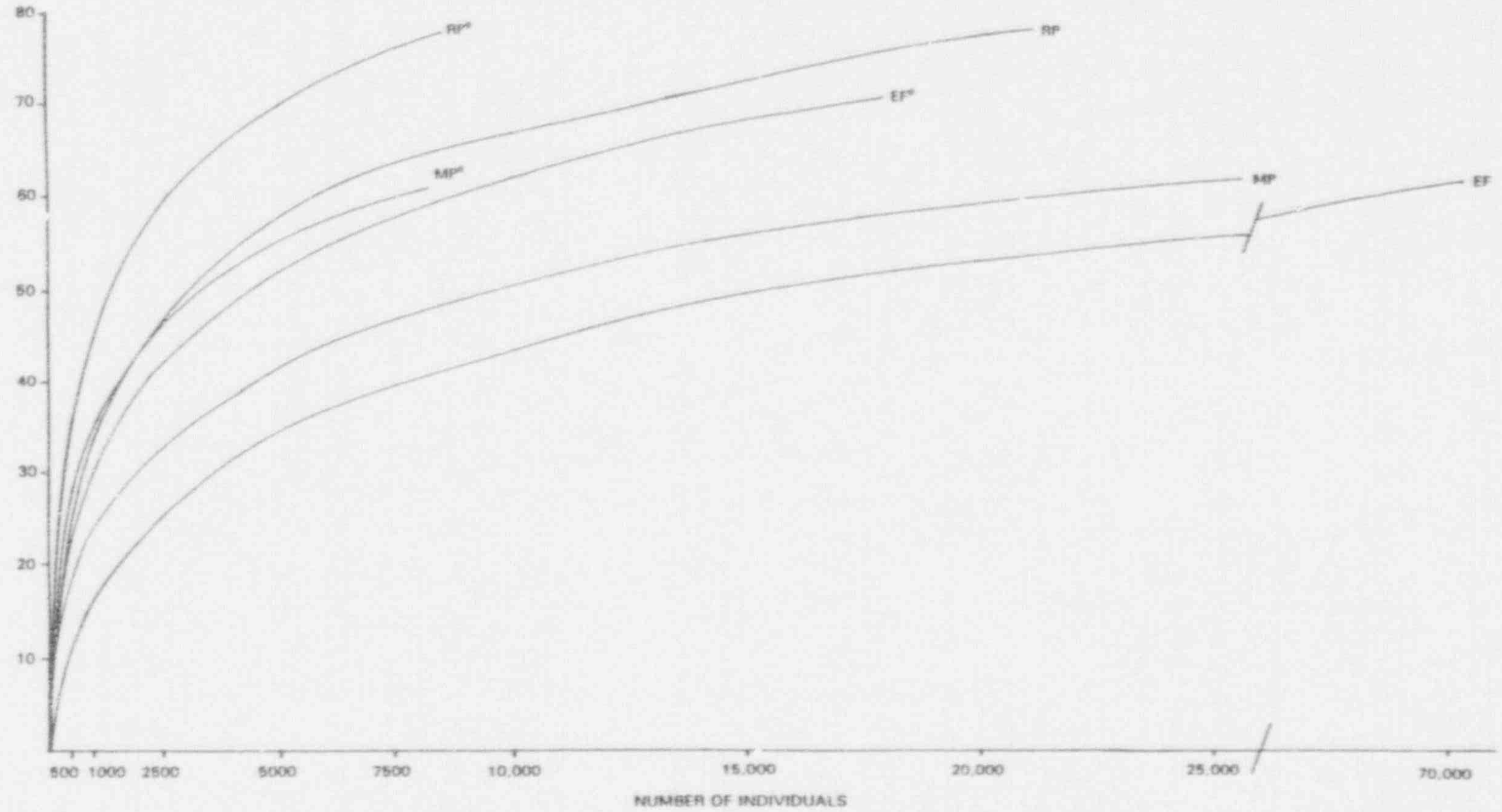

Figure 7. Hurlbert Rarefaction Curves for Total Fauna at the Effluent, Manomet Point, and Rocky Point Stations, March 1991. EF°, MP°, RP° *Mytilus* Excluded.

3.2.6 Community Analysis

Similarity among the samples taken in spring 1991 was measured using Bray-Curtis and NESS; the results are shown in Figures 8 and 9. The dendrogram resulting from the analysis using the Bray-Curtis similarity measure shows three clusters, containing a mixture of Manomet Point and Rocky Point samples, three samples from Rocky Point, and all Effluent samples, respectively. The two clusters consisting of the samples from the two reference stations join at the 0.52 level, and the Effluent cluster joins at the 0.44 level. The small cluster of Rocky Point replicates is characterized by relatively few *Mytilus edulis*, but also low abundances of other dominant species such as the amphipods *Jassa* and *Corophium*, the snails *Margarites*, *Lacuna*, and *Onoba*, and the sea urchin *Strongylocentrotus*. The clear separation of the Effluent station from the reference stations, usually not seen with Bray-Curtis, is mostly the result of the much higher *Mytilus* counts at the Effluent station, but also the shift in species of the amphipod *Corophium* between the Effluent and reference stations (see Section 3.2.4). The Effluent samples are slightly more similar (0.77) than the samples comprising the other two clusters (0.69 to 0.71).

If NESS is used, each of the stations cluster out separately (Figure 9). The individual Effluent replicates join at a high level of similarity (0.96), followed by the Manomet Point replicates (0.90) and the Rocky Point replicates (0.85). The two reference stations join at 0.82, whereas the Effluent station joins the other two stations at the relatively low level of 0.58. As the *Mytilus* counts are not as overwhelming for the analysis with NESS as they are with Bray-Curtis, the replicates of each station are grouped somewhat differently due to the abundances of lower ranking species.

In comparison to the previous year, there is a clear tendency for a separation of the Effluent station from the reference stations. This separation was already seen in fall 1990, although the replicates of the Effluent station were more dissimilar than they were in spring 1991. To detect any temporal patterns in the development of benthic communities in the study area after the end of the prolonged power outage at the PNPS, the combined data of all three seasons since spring 1990 were analyzed with NESS (Figure 10). The dendrogram shows two important developments: (1) There is a seasonal pattern, causing the samples of the two spring seasons to join at a higher similarity level (0.75) than the spring and fall samples combined (0.71). (2) Since the fall of 1990, the Effluent station has been clearly different from the reference stations. While in spring 1990 there were two clusters containing a mixture of samples from the Effluent and at least one reference station (left side of the dendrogram), the fall samples fell into two clusters, one consisting of the Effluent replicates and the other consisting of the two reference stations. In the spring of 1991, the replicates of each station formed a distinct cluster, and the Effluent replicates of the last two seasons combined (right side of the dendrogram) join the other samples at the relatively low 0.55 level.

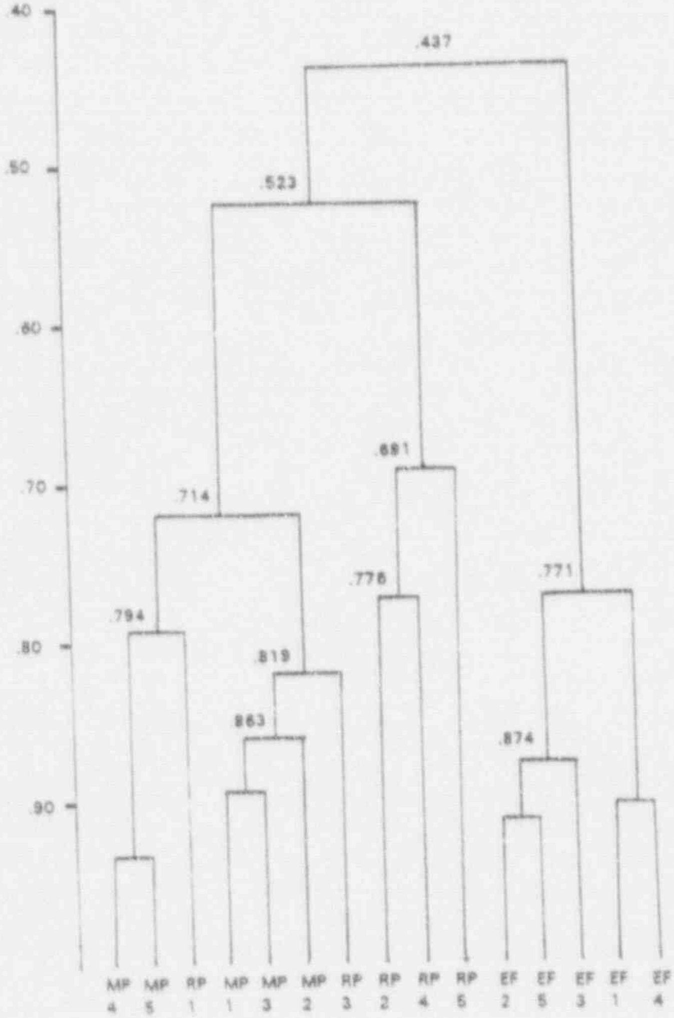

Figure 8. Similarity Analysis Based on Bray-Curtis an Group Average Sorting for March 1991.

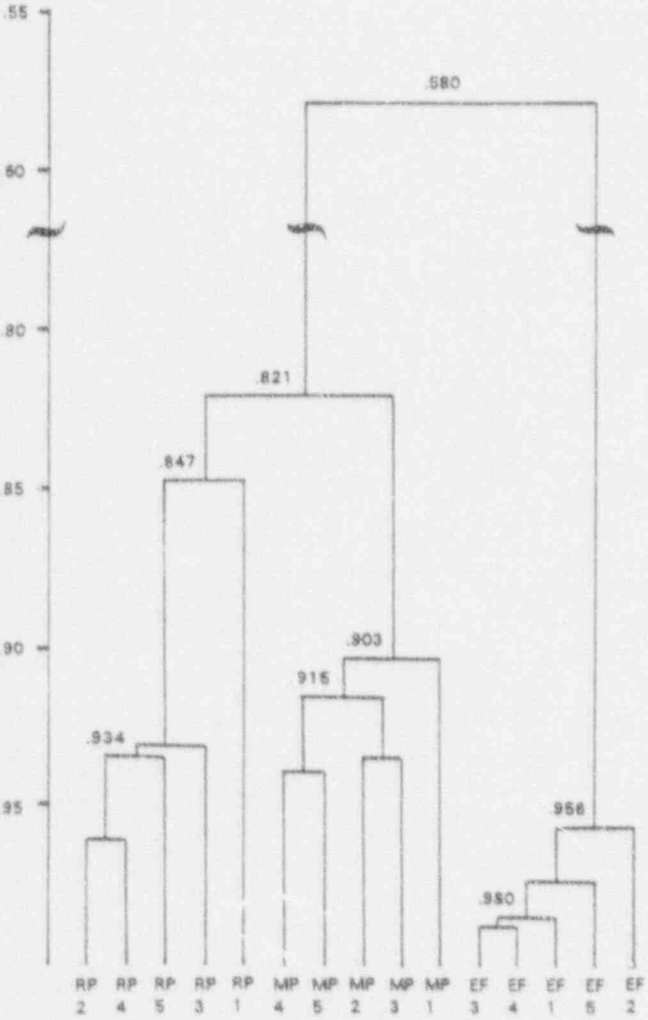

Figure 9 Similarity Analysis Based on NESS and Group Average Sorting for March 1991.

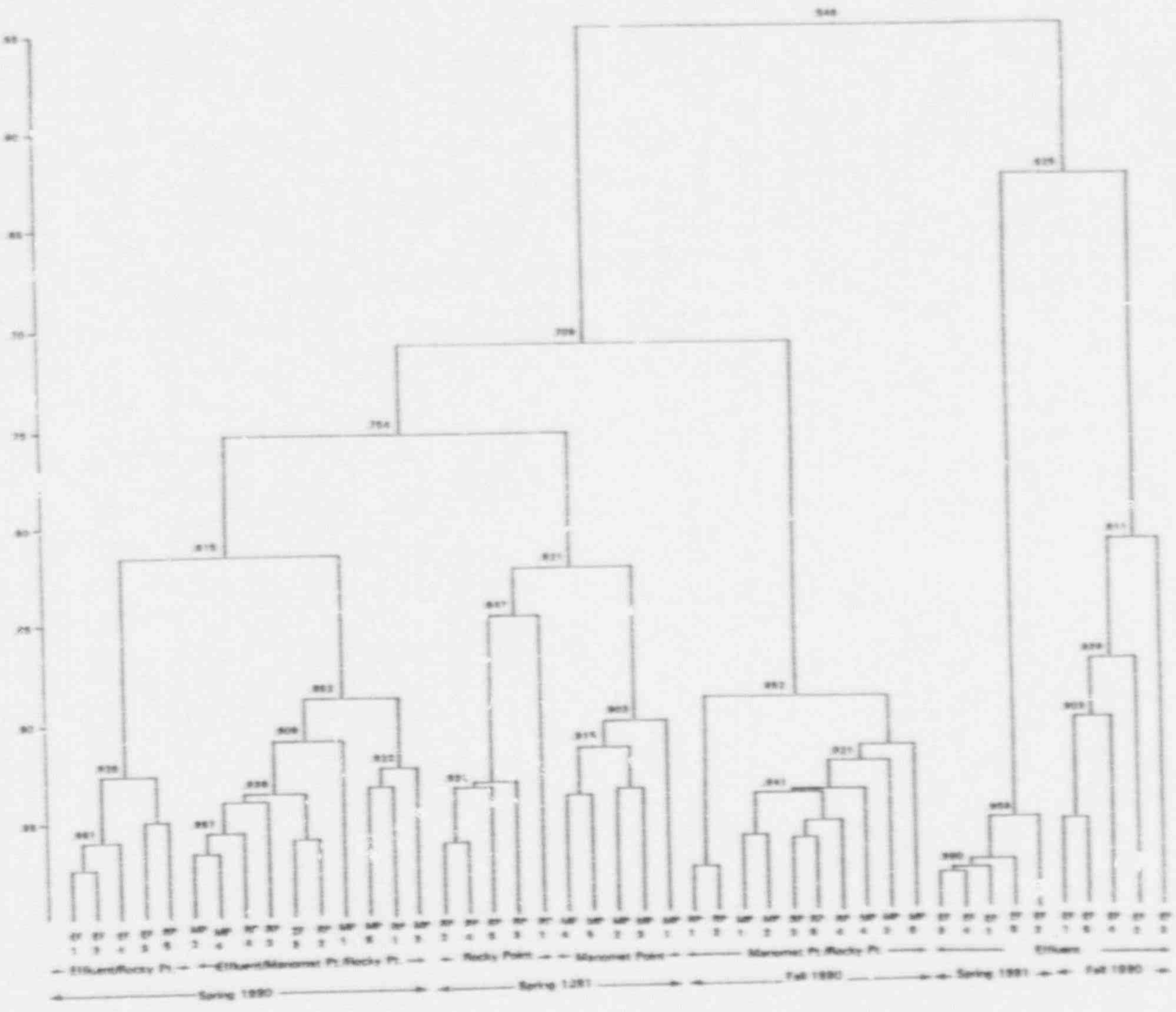

Figure 10. Similarity Analysis of the Combined Data for Spring and Fall, 1990, and Spring 1991 Using Ness and Group Average Sorting.

3.3. QUANTITATIVE ALGAL MONITORING

3.3.1 Systematics

No addition to the cumulative algal species list present in Semi-Annual Report No. 16 (BECO, 1980) were made as a result of analysis of the March 1991 samples. The 27 species present are indicated in Table 1.

3.3.2 Algal Community Description

The rock and cobble substrata found at the Effluent, Manomet Point, and Rocky Point stations were heavily colonized by red macroalgae during the March 1991 survey. Two-thirds of the species collected belonged to the Rhodophyta (red algae). In addition to the dominant species *Chondrus crispus* and *Phyllophora* spp., other benthic rhodophytes included *Ahnfeltia plicata*, *Corallina officinalis*, and *Polyides rotundus*. Epiphytic rhodophytes found in all replicate samples were *Ceramium rubrum*, *Cystoclonium purpureum*, and *Spermothamnion repens*. Other species collected in all samples were the chlorophytes (green algae) *Chaetomorpha linum*, *C. melagonium*, and *Rhizoclonium riparium* and the phaeophyte (brown alga) *Desmarestia aculeata*.

Biomass of *Chondrus crispus*, epiphytic species, and total algae was highest at Manomet Point and lowest at the Effluent station. Biomass of *Phyllophora* spp. and the remaining benthic species was highest at Rocky Point and lowest at Manomet Point.

Gracilaria tikvahiae, an indicator of warm water, was not collected in any of the replicate samples in March 1991. However, *Gracilaria* was observed by the divers within the discharge canal and within the denuded zone out to 40 m on the transect line in March. In June, a short-bladed alga, tentatively identified as *Gracilaria* by the divers, was observed within the discharge canal; no *Laminaria*, a cold water indicator, was seen.

3.3.3 Algal Community Overlap

Community overlap was calculated for the March 1991 data using Jaccard's coefficient that provides a mathematical evaluation of the similarity between two replicates or stations using only species occurrence. Species occurrence records of all 27 species that were found were used for community overlap calculations.

Results of community overlap comparisons between replicate samples for each station for the March 1991 collecting period are presented in matrix form in Figure 11. Ranges of percent overlap were 66.7 to 86.4 at the Effluent station, 75.0 to 100.0 at Manomet Point, and 69.6 to 91.3 at Rocky Point. Replicate percent overlap range was lower at the Effluent station (19.7) than at Manomet Point (25.0) or Rocky Point (21.7), indicating that the replicates at the Effluent station were more similar to each other than replicates at the other two stations.

	1	2	3	4	5
1		21	25	21	21
2	84.0		21	19	19
3	100.0	84.0		21	21
4	84.0	82.6	84.0		18
5	84.0	82.6	84.0	75.0	

Number of Species Shared

Percent Overlap

A

	1	2	3	4	5
1		17	18	19	17
2	73.9		17	16	15
3	78.3	77.3		19	17
4	82.6	66	86.4		17
5	81.0	71.4	85.0	81.0	

Number of Species Shared

Percent Overlap

C

	1	2	3	4	5
1		19	16	21	19
2	82.6		17	21	19
3	69.6	77.3		17	18
4	91.3	91.3	70.8		20
5	82.6	82.6	85.7	83.3	

Number of Species Shared

Percent Overlap

B

	MP	RP	EFF
MP		22	23
RP	81.5		22
EFF	88.5	84.6	

Number of Species Shared

Percent Overlap

D

Figure 11. Algal Community Overlap (Jaccard's Coefficient of Community) and Number of Species Shared Between Replicate Pairs, March 1991. A, Manomet Point Station; B, Rocky Point Station; C, Effluent Station; D, Station Overlap.

Community overlap between stations was high for all three pairs of stations, indicating a high degree of homogeneity in terms of species present at all three stations. Community overlap was higher between the Effluent and Manomet Point stations (88.5%) than between the Effluent and Rocky Point stations (84.6%) or between the Manomet Point and Rocky Point stations (81.5%). This indicates that the algal communities at the Effluent and Manomet Point staions were more similar to each other than either was to the Rocky Point station.

3.3.4 Algal Biomass

Chondrus crispus

Chondrus crispus biomass values recorded for the Effluent, Manomet Point, and Rocky Point stations for March 1991 are presented in Table 6. In March 1991, the range of individual biomass values was highest at Rocky Point (2.75 to 277.33 g/m^2), followed by the Effluent station (0.46 to 146.24 g/m^2), and Manomet Point (82.44 to 217.75 g/m^2). At the Effluent, Manomet Point, and Rocky Point stations, mean *Chondrus* biomass was 21%, 46%, and 35% of the total algal biomass, respectively.

The Manomet Point station had the highest mean biomass value for *Chondrus* (161.75 g/m^2), followed by Rocky Point (112.75 g/m^2), and the Effluent station (52.22 g/m^2). An ANOVA showed no significant differences between any of the stations when mean *Chondrus* biomass values were compared (at $p=0.05$).

Phyllophora spp.

Phyllophora spp. biomass values for the March 1991 collecting period are given in Table 6. The range of individual biomass was greatest at the Rocky Point station (13.31 to 210.96 g/m^2), followed by the Effluent station (19.19 to 214.53 g/m^2), and Manomet Point (57.74 to 159.55 g/m^2). *Phyllophora* spp. were 51% of the total algal biomass at the Effluent station, 30% at Manomet Point, and 41% at Rocky Point.

The Rocky Point station had the highest mean biomass value for *Phyllophora* spp. (131.07 g/m^2), followed by the Effluent station (127.82 g/m^2), and Manomet Point (105.77 g/m^2). No significant differences existed between the stations in March 1991 when comparing *Phyllophora* spp. biomass (at $p=0.05$).

Biomass of Remaining Benthic Species

The remaining benthic species exclude *Chondrus crispus*, *Phyllophora* spp., *Laminaria* spp., and algal epiphytes. Biomass data for the remaining benthic species for March 1991 are presented in Table 6. The Rocky Point station had the highest range of biomass values (22.40 to 102.27 g/m^2), followed by the Effluent station (35.43 to 69.86 g/m^2), and Manomet Point (12.76 to 43.70 g/m^2). The percentage that

Table 6. Dry Weight Biomass (g/m²) for *Chondrus crispus*, *Phyllophora* spp., The Remaining Benthic Species, Epiphytes, and Total Algal Biomass at the Effluent, Manomet Point, and Rocky Point Stations in March 1991.

Station/ Replicate	*Chondrus crispus*		*Phyllophora* spp.		Remaining Benthic Species		Epiphytic Species (Total)		All Algae
	Biomass	Percent	Biomass	Percent	Biomass	Percent	Biomass	Percent	Biomass
EFF 1	7.99	2.81	214.63	75.35	46.63	16.37	15.61	5.48	284.86
EFF 2	49.57	31.09	19.19	12.02	69.86	43.81	20.84	13.07	159.46
EFF 3	146.24	48.88	87.49	29.24	57.65	19.27	7.80	2.61	299.18
EFF 4	0.46	0.22	161.11	78.32	35.43	17.22	8.72	4.24	205.72
EFF 5	56.82	19.22	156.70	52.99	63.80	21.58	18.36	6.21	295.69
$\bar{x}$ EFF	**52.22**	**20.97**	**127.82**	**51.34**	**54.67**	**21.96**	**14.27**	**5.73**	**248.98**
MP 1	183.97	40.99	159.55	35.55	43.70	9.74	61.60	13.72	448.82
MP 2	217.75	60.65	103.00	28.69	12.76	3.55	25.52	7.11	359.03
MP 3	82.44	27.23	144.13	47.61	17.99	5.94	58.20	19.22	302.76
MP 4	176.62	53.91	57.74	17.62	23.32	7.12	69.95	21.35	327.63
MP 5	147.98	43.89	64.44	19.11	41.22	12.22	83.54	24.78	337.18
$\bar{x}$ MP	**161.75**	**45.55**	**105.77**	**29.79**	**27.80**	**7.83**	**59.76**	**16.83**	**355.08**
RP 1	277.33	84.46	13.31	4.05	22.40	6.82	15.33	4.67	328.37
RP 2	63.34	19.83	181.30	56.75	59.39	18.59	15.42	4.83	319.46
RP 3	173.59	61.10	45.53	16.02	46.08	16.22	18.91	6.66	284.12
RP 4	2.75	0.80	204.26	59.56	102.27	29.82	33.69	9.82	342.96
RP 5	46.73	13.90	210.96	62.74	60.13	17.88	18.45	5.49	336.26
$\bar{x}$ RP	**112.75**	**34.99**	**131.07**	**40.68**	**58.05**	**18.02**	**20.36**	**6.32**	**322.23**

EFF: Effluent; MP: Manomet Point; RP: Rocky Point; $\bar{x}$: Mean biomass the remaining benthic species contributed to the total algal biomass was greatest at the Effluent station (22%), followed by Rocky Point (18%) and Manomet Point (8%).

The highest mean biomass values occurred at the Rocky Point station (58.05 g/m^2), followed by 54.67 g/m^2 at the Effluent station, and 27.8 g/m^2 at Manomet Point. To avoid statistical redundancy and permit a meaningful ANOVA for the total algal biomass an ANOVA for biomass of the remaining benthic species is not presented here.

Epiphytic Algal Biomass

Epiphytic algal biomass values for March 1991 are given in Table 6. In March 1991, mean epiphytic biomass values were highest at Manomet Point (59.76 g/m^2), followed by the Rocky Point station (20.36 g/m^2), and the Effluent station (14.27 g/m^2). An ANOVA showed a significant difference between the three stations in epiphytic algal biomass ($F_s = 16.52$; $F_{.05[2,12]} = 3.89$). Scheffé's multiple comparison test (Sokal and Rohlf (1981) p. 256) showed that epiphytic algal biomass at the Effluent station was significantly different from the mean biomass at the control stations and from the biomass at Manomet Point but was not significantly different from the Rocky Point station biomass. In addition, epiphytic algal biomass at the two control stations were different from each other.

Total Algal Biomass

Total mean algal biomass for March 1991 is given in Table 6. The Manomet Point station had the highest biomass value (355.08 g/m^2), the Rocky Point station ranked second (322.23 g/m^2), and the Effluent station ranked third (248.98 g/m^2). Individual replicate ranges for total algal biomass in March 1991 at the Effluent, Manomet Point, and Rocky Point stations were 159.46 to 299.18 g/m^2, 302.76 to 448.82 g/m^2, and 284.12 to 342.96 g/m^2, respectively. An ANOVA showed a significant difference between the three stations in total algal biomass ($F_s = 5.78$; $F_{.05[2,12]} = 3.89$). Scheffé's multiple comparison test showed that total algal biomass at the Effluent station was significantly different from the mean biomass at the control stations and from the biomass at Manomet Point but was not significantly different from the Rocky Point station biomass. For total algal biomass the two control stations were not significantly different from each other.

4.0 DISCUSSION

The pattern of stunted and denuded zones in the discharge canal is readily apparent to divers and is easily mapped and measured as part of the diver surveys. Less obvious, however, is the farfield effect on the benthic communities at the three established benthic stations. As expected, there are no observed changes on the benthic community structure at the two reference stations at Rocky Point and Manomet Point following the return to full plant operation. At the Effluent Station, in contrast, there has been considerable change. Cluster analysis clearly indicates that the station has a different community structure from the reference locations. This pattern was evident in earlier periods of high plant operation. Near the end of the 2-½ year outage, the Effluent Station was indistinguishable from the reference locations. It is likely that the thermal discharge has a farfield effect on the algal canopy and this in turn affects the composition of the resident fauna.

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APPENDIX A

APPENDIX A. LIST OF SPECIES IDENTIFIED AT THE EFFLUENT, MANOMET POINT, AND ROCKY POINT STATIONS IN 1990/1991 (*: PRESENT IN SPRING 1991)

Smaller Phyla

- CNIDARIA
  - _Metridium senile_
  - *Anemone
- PLATYHELMINTHES
  - *Turbellaria
- NEMERTEA
  - *_Cerebratulus lacteus_
  - *Nemertea
  - *_Tetrastemma vittatum_
- SIPUNCULOIDEA

Annelida

- *OLIGOCHAETA
- POLYCHAETA
  - Ampharetidae
    - *_Asabellides oculata_
  - Arenicolidae
    - *_Arenicola marina_
  - Capitellidae
    - *_Capitella capitata_
    - _Mediomastus californiensis_
    - _Mediomastus_ spp. indet.
  - Cirratulidae
    - _Caulleriella bioculata_
    - _Chaetozone setosa_
    - *_Chaetozone_ sp. 1
    - _Chaetozone_ spp. juv.
    - *_Cirratulus cirratus_
    - *_Dodecaceria corallii_
  - Nephtyidae
    - *_Nephtys caeca_
    - *_Nephtys longosetosa_
    - *_Nephtys picta_
  - Nereididae
    - *_Nereis pelagica_
    - *_Nereis succinea_
    - _Nereis zonata_
    - *_Nereis_ spp. juv.
  - Orbiniidae
    - *_Naineris quadricuspida_
  - Pectinariidae
    - _Pectinaria granulata_
  - Pholoidae
    - *_Pholoe minuta_
  - Phyllodocidae
    - *_Eteone longa_
    - *_Eulalia viridis_
    - _Eumida sanguinea_
    - *_Phyllodoce (Anaitides) maculata_
  - Polygordiidae
    - *_Polygordius_ sp. 1
  - Polynoidae
    - _Harmothoe extenuata_
    - *_Harmothoe imbricata_
    - _Harmothoe_ spp. juv.
    - _Harmothoe_ spp. indet.
    - *_Lepidonotus squamatus_
  - Sabellariidae
    - _Sabellaria vulgaris_
  - Sabellidae
    - *_Fabricia sabella_
    - *_Potamilla neglecta_
    - _Potamilla reniformis_
    - Sabellidae spp. indet.
  - Sigalionidae
    - _Sthenelais boa_

- Spionidae
    - **Polydora cornuta*
    - **Polydora giardi*
    - **Polydora socialis*
    - **Polydora websteri*
    - *Polydora* spp. indet.
    - *Prionospio steenstrupi*
    - *Spio filicornis*
    - *Spio thulini*
    - Spionidae spp. juv.

- Syllidae
    - **Autolytus alexandri*
    - *Autolytus fasciatus*
    - *Autolytus prismaticus*
    - *Autolytus* spp. juv.
    - **Exogone hebes*
    - **Syllis (Typosyllis)* cf. *hyalina*

- Terebellidae
    - Amphitritinae spp. juv.
    - *Nicolea venustula*
    - **Nicolea zostericola*
    - **Polycirrus eximius*
    - **Polycirrus phosphoreus*
    - *Polycirrus* spp. indet.
    - *Polycirrus* spp. juv.

Crustacea

- ISOPODA
    - Idoteidae
        - **Idotea phosphorea*
        - **Idotea balthica*
    - Janiridae
        - **Jaera marina*
    - Limnoridae
        - **Limnoria lignorum*

- AMPHIPODA
    - Ampithoidae
        - **Ampithoe rubricata*
    - Aoridae
        - **Unciola irrorata*
    - Calliopidae
        - **Calliopius laeviusculus*
    - Corophiidae
        - **Corophium acutum*
        - **Corophium bonelli*
        - **Corophium insidiosum*
        - *Corophium tuberculatum*
        - *Corophium* spp. indet.
        - *Corophium* spp. juv.
    - Dexaminidae
        - **Dexamine thea*
    - Gammaridae
        - *Gamarellus angulosus*
        - *Gammarus oceanicus*
        - *Gammarus* sp.
        - **Marinogammarus stoerensis*
        - Gammaridae spp. indet.
    - Ischyroceridae
        - **Ischyrocerus anguipes*
        - **Jassa falcata*
    - Phoxocephalidae
        - **Phoxocephalus holbolli*
    - Pleustidae
        - **Pleusymtes glaber*
    - Pontogeneiidae
        - **Pontogeneia inermis*
    - Stenothoidae
        - *Metopella angusta*
        - **Proboloides holmesi*

- CAPRELLIDEA
    - Caprellidae
        - **Caprella linearis*
        - **Caprella penantis*
        - *Caprella* nr. *septentrionalis*
        - **Caprella unica*
        - Caprellidae spp. juv.

- CUMACEA
    - **Diastylis sculpta*

DECAPODA
*_Cancer borealis_
Cancer irroratus
*_Carcinus maenas_
*_Eualus pusiolus_
*_Pagurus acadianus_
Pagurus sp.

Mollusca

GASTROPODA
Acmaeidae
Acmaea testudinalis

Aeolidiidae
Aeolidia papillosa
Doto coronata

Calyptraeidae
Crepidula fornicata
*_Crepidula plana_

Cerithiidae
Bittium alternatum

Columbellidae
*_Anachis translirata_
*_Mitrella lunata_

Coryphellidae
*_Coryphella rufibranchiata_
*_Coryphella salmonacea_

Cratenidae
Cratena pilata

Diaphanidae
*_Diaphana minuta_

Facelinidae
Facelina bostoniensis

Lacunidae
*_Lacuna vincta_

Lamellidorididae
*_Lamellidoris aspera_

Littorinidae
*_Littorina littorea_
Littorina saxatilis

Nassariidae
*_Nassarius trivittatus_

Naticidae
*_Lunatia heros_

Omalogyridae
*_Omalogyra atomus_

Pyramidellidae
*_Odostomia dealbata_
Odostomia gibbosa
*_Turbonilla elegantula_

Rissoidae
*_Alvania pseudoareolata_
*_Onoba aculea_

Trochidae
Margarites helicinus
*_Margarites umbilicalis_

Gastropoda spp. indet.
Gastropoda spp. juv.
Nudibranch spp. indet.

BIVALVIA

Anomiidae
*_Anomia simplex_
*_Anomia squamula_

Cardiidae
*_Cerastoderma pinnulatum_

Hiatellidae
*_Hiatella arctica_
*_Hiatella striata_

Lyonsiidae
*_Lyonsia hyalina_

Mactridae
Spisula solidissima

Myidae
Mya arenaria

Mytilidae
Modiolus modiolus
**Mytilus edulis*

Petricolidae
**Petricola pholadiformis*

Tellinidae
**Macoma balthica*
**Macoma tenta*
**Tellina agilis*

Thraciidae
Thracia septentrionalis

Veneridae
Gemma gemma
**Mercenaria mercenaria*

Bivalvia spp. indet.

POLYPLACOPHORA
Lepidochiton ruber
**Ischnochiton ruber*

Echinodermata

ASTEROIDEA
**Asterias forbesi*
**Henricia sanguinolenta*

ECHINOIDEA
**Strongylocentrotus droebachiensis*

OPHIUROIDEA
**Amphipholis squamata*
**Ophiopholis aculeata*

Tunicata

POLYCLINIDAE
Amaroucium constellatum

MOLGULIDAE
**Molgula* sp.

ICHTHYOPLANKTON ENTRAINMENT MONITORING
AT PILGRIM NUCLEAR POWER STATION
JANUARY - JUNE 1991

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Boston Edison Company
Boston, Massachusetts

by
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Falmouth, Massachusetts

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*Available upon request.

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SECTION I

SUMMARY

Entrainment sampling at PNPS was completed twice per month during January and February, weekly during March through May. Sampling was possible on only two occasions in June due to circulating water system shutdown.

During the first six months of 1991, 28 species were represented in the entrainment samples at PNPS, 16 species by eggs, 24 species by larvae. Samples from the winter-early spring spawning period (January-April) contained small numbers of Atlantic cod, American plaice, and winter flounder eggs. Rock gunnel, grubby, and sand lance were numerically dominant among the larvae. May and June collections reflected the late spring-summer spawners. Atlantic mackerel and the labrids were dominant among the eggs and radiated shanny, Atlantic mackerel, winter flounder, and cunner were dominant among the larvae.

Comparison of January-June 1991 egg and larval densities with those observed from 1975-1990 suggested that Atlantic cod eggs were absent in February for the fourth consecutive year. Fourbeard rockling and labrid eggs were uncommon in June 1991 ranking below all other years for that month. Eggs and larvae found to be relatively abundant during the first half of 1991 were Atlantic mackerel eggs in June, rock gunnel and sculpin larvae in February.

No densities meeting the unusually high criterion established under the contingency sampling plan were noted from January-June 1991 and no larval lobsters were obtained.

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 1991 by Marine Research, Inc. (MRI) for Boston Edison Company (BECo) under Purchase Order No. 68006. A more detailed annual report covering all 1991 data will be prepared following the July-December collection periods.

SECTION III

METHODS AND MATERIALS

Entrainment sampling at PNPS was completed twice per month during January and February, weekly during March through May. Although weekly sampling was scheduled for June, PNPS began a refueling outage in May which resulted in both circulating water system (CWS) pumps being out of service for much of June; samples were obtained on two occasions. From January through April sampling was completed with both CWS pumps in service. During May and June only one CWS pump was available on sampling days. All samples were collected in triplicate from rigging mounted approximately 30 meters from the headwall of the discharge canal (Figure 1) at low tide during daylight hours. A 0.333-mm mesh, 60-cm diameter plankton net affixed to this rigging was streamed in the canal for 8 to 12 minutes depending on the abundance of plankton and detritus. In each case, a minimum of 100 m^3 of water was sampled. Exact filtration volumes were calculated using a General Oceanics Model 2030R digital flowmeter mounted in the mouth of the net.

All samples were preserved in 10% Formalin-seawater solutions and returned to the laboratory for microscopic examination. A detailed description of the analytical procedures appears in MRI (1988) [1].

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[1] Marine Research, Inc. 1988. Ichthyoplankton Entrainment Monitoring at Pilgrim Nuclear Power Station, January-December 1987. III.C.1-6-10. IN: Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-Annual Report No. 31. Boston Edison Company.

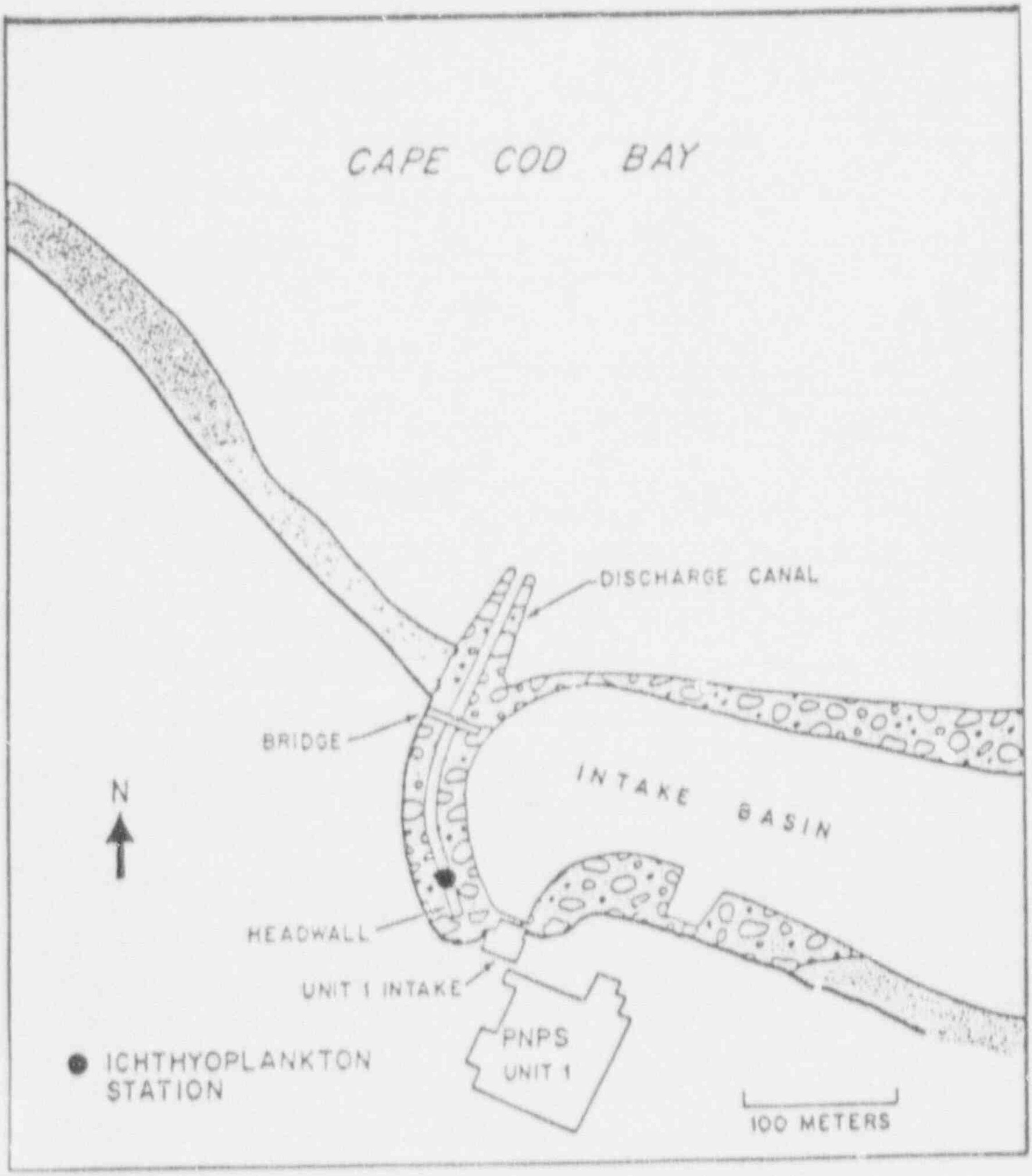

Figure 1. Entrainment sampling station in PNPS discharge canal.

When the Cape Cod Bay ichthyoplankton study was completed in 1976, a contingency sampling plan was added to the entrainment monitoring program. This plan was designed to be implemented if eggs or larvae of any dominant species proved to be "unusually abundant" in the PNPS discharge samples. The goal of this sampling plan was to determine whether circumstances in the vicinity of Rocky Point, attributable to PNPS operation, were causing an abnormally large percentage of ichthyoplankton populations there to be entrained or, alternatively, whether high entrainment levels simply were a reflection of unusually high population levels in Cape Cod Bay. "Unusually abundant" was defined as any mean density, calculated over three replicates, which was found to be 50% greater than the highest mean density observed during the same month from 1975 through 1990.

The contingency sampling plan consists 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.[2] The offshore contingency program consists 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 requires authorization from Boston Edison Company.

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[2] The impact of any large entraiment density would be greater if ichthyoplankton densities were particularly high only close to shore near PNPS.

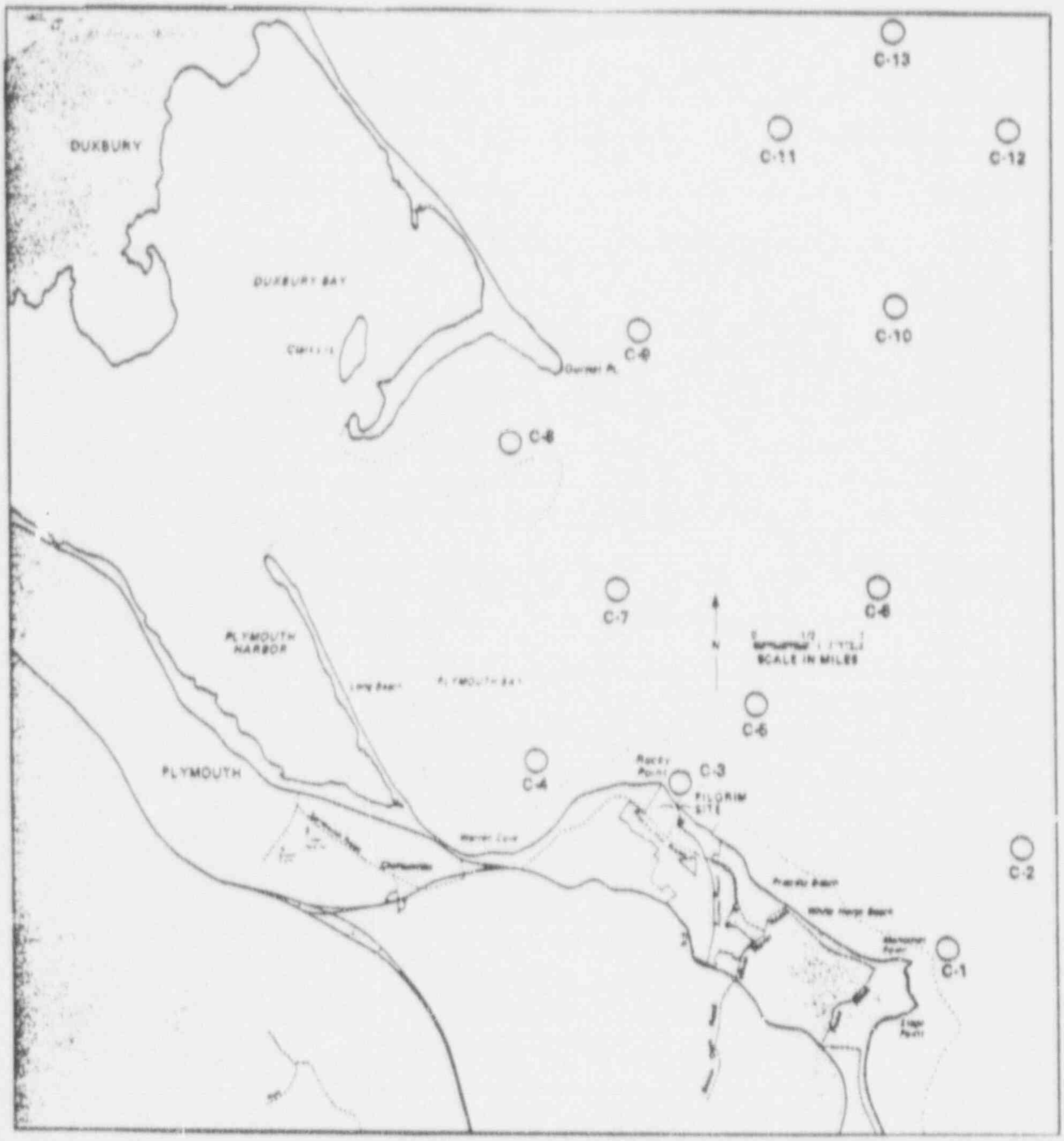

Figure 2. Location of entrainment contingency plan sampling stations, C-1 through C-13.

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 1991 period 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 represented in the discharge collections was five in January, increasing to eight in February, twelve in March, and fifteen in April. Eggs were relatively uncommon since species contributing most to entrainment during this period spawn demersal, adhesive eggs which are not generally subject to entrainment. They were in fact absent from the January and February collections. March samples contained small numbers of Atlantic cod (*Gadus morhua*), American plaice (*Hippoglossoides platessoides*), and winter flounder (*Pleuronectes americanus*) eggs. Monthly mean densities amounted to 0.3 per 100 m^3 for both cod and plaice, 0.1 per 100 m^3 for flounder. Since they are demersal and adhesive, winter flounder eggs are not typically entrained at PNPS. Their numbers in PNPS samples are therefore not considered representative of numbers in the surrounding area. Those that were taken were probably dislodged from the bottom by currents or perhaps other fish.

Table 1. Species of fish eggs (E) and larvae (L) obtained in ichthyoplankton collections from the Pilgrim Nuclear Power Station discharge canal, January-June, 1991.

Species		Jan	Feb	Mar	Apr	May	June
Atlantic menhaden	*Brevoortia tyrannus*					E	E/L
Atlantic herring	*Clupea harengus*	L	L	L	L	L	
Fourbeard rockling	*Enchelyopus cimbrius*				E	E/L	E/L
Atlantic cod	*Gadus morhua*			E	E/L	E/L	L
Silver hake	*Merluccius bilinearis*						E
Pollock	*Pollachius virens*	L	L			L	
Hake	*Urophycis* spp.						E
Goosefish	*Lophius americanus*				E	E	E
Silversides	*Menidia* spp.					L	E/L
Northern pipefish	*Syngnathus fuscus*						L
Searobins	*Prionotus* spp.						E
Grubby	*Myoxocephalus aenaeus*		L	L	E/L	L	
Longhorn sculpin	*M. octodecemspinosus*	L	L		L		
Shorthorn sculpin	*M. scorpius*	L	L	L	L		
Seasnail	*Liparis atlanticus*			L	L	L	L
Gulf snailfish	*L. coheni*		L	L			
Wrasses	Labridae					E	E
Tautog	*Tautoga onitis*					L	L
Cunner	*Tautogolabrus adspersus*					L	L
Radiated shanny	*Ulvaria subbifurcata*			L	L	L	L
Rock gunnel	*Pholis gunnellus*		L	L	L	L	

Table 1 (continued).

Species		Jan	Feb	Mar	Apr	May	June
Wrymouth	*Cryptacanthodes maculatus*			L			
Sand lance	*Ammodytes* sp.	L	L	L	L	L	
Atlantic mackerel	*Scomber scombrus*					E/L	E/L
Windowpane	*Scophthalmus aquosus*				E	E	E/L
Witch flounder	*Glyptocephalus cynoglossus*					E	E/L
American plaice	*Hippoglossoides platessoides*			E	E/L	E/L	L
Yellowtail flounder	*Pleuronectes ferrugineus*				E	E	E/L
Winter flounder	*P. americanus*			E/L	E/L	E/L	L

The number of species represented by larvae generally increased with time during the winter-early spring period; five species were taken in January, eight were taken in February, ten were taken in March, followed by eleven in April. Numerical dominants included the rock gunnel (*Pholis gunnellus*), grubby (*Myoxocephalus aenaeus*), and sand lance (*Ammodytes* sp.). Rock gunnel represented 63% of the January total, 60% of the February total, 30% of the March total, and 8% of the April total with monthly mean densities of 2, 46, 20, and 6 per 100 m^3 of water, respectively. Grubby did not appear in the collections until February when they accounted for 12% of the catch with a monthly mean density of 9 per 100 m^3. Grubby densities peaked in March with a mean density of 39 larvae per 100 m^3 accounting for 59% of the month's catch. They declined to 13 per 100 m^3 in April with a percent contribution of 19. Larval sand lance accounted for 2% of all larvae in January, 1% in February, 8% in March, and 55% in April; monthly mean densities were 0.1, 0.7, 5, and 38 per 100 m^3, respectively.

May and June collections (along with July) consist of late spring-summer spawning species. May collections contained 20 species, June collections 19. Among these, 11 and 12 species were represented by eggs during the two respective months. Numerical dominants were Atlantic mackerel (*Scomber scombrus*) and the labrids. Mackerel eggs accounted for 56% of the May total and 42% of the June total with monthly mean densities of 538 and 473 per 100 m^3, respectively. Labrid eggs, along with the labrid-

Pleuronectes group, which they dominate during late-spring and summer contributed an additional 33% of the eggs in May and 54% in June. Monthly mean densities were 321 per 100 m^3 in May, 607 per 100 m^3 in June.

May and June larval collections contained 15 species each with radiated shanny (*Ulvaria subbifurcata*), Atlantic mackerel, winter flounder, and cunner (*Tautogolabrus adspersus*) being numerically dominant. Radiated shanny contributed 33% of the larvae in May dropping to 1% in June; monthly mean densities were 19 and 2 per 100 m^3, respectively. Mackerel larvae accounted for an additional 12% of the May total with a monthly mean of 7 per 100 m^3, jumping to 86% in June with a monthly mean of 200 per 100 m^3. Larval winter flounder contributed 30% of total in May with a monthly mean of 16 per 100 m^3, declining to 1% in June with a mean of 2 per 100 m^3. Cunner first appeared the last week in May accounting for 0.5% of the month's total with a mean density of 0.3 per 100 m^3. In June they contributed 7% of total with a monthly mean of 17 per 100 m^3.

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 1991 suggests that month by month egg and larval densities were within the range of monthly mean densities observed over the past 16 years. However the following exceptions were noted:

1. Atlantic cod eggs were absent in February for the fourth consecutive year. Prior to 1988 they were taken every year in February although not in high numbers.
2. Atlantic mackerel eggs have been abundant in June during the previous three seasons. In June 1991 (473 per 100 m^3) their numbers declined compared with 1988 (2220 per 100 m^3), 1989 (1013 per 100 m^3), and 1990 (2081 per 100 m^3); however densities continued to rank well ahead of 1975-1987 when means ranged from 5 (1976) to 277 (1986) per 100 m^3. Mackerel larvae were also relatively common in May (6.6 per 100 m^3) and June (200 per 100 m^3) 1991. May's mean density surpassed all previous May values, 1979 being the previous high with 6.1 larvae per 100 m^3. June's density ranked second, exceeded only by the 1981 value of 318 per 100 m^3.
3. In contrast fourbeard rockling eggs (combined with the Enchelyopus-Urophycis-Peprilus group), and labrid eggs were uncommon in June 1991. With a mean density of 9 per 100 m^3 and 607 per 100 m^3 for rockling and the labrids respectively, 1991 values ranked below all previous years. The previous low for rockling was 16 per 100 m^3 in 1982 and for labrids it was 733 per 100 m^3 in 1980.
4. Rock gunnel and sculpin larvae were abundant in February. For rock gunnel February 1991 (46 per 100 m^3) ranked ahead of all previous February values, 1985 showing the previous high with a mean density of 25 per 100 m^3. For sculpin a mean density of 30 per 100 m^3 February 1991 exceeded all previous February

periods except 1988 with 41 per 100 m^3. Interestingly, in both those years shorthorn sculpin (*Myoxocephalus scorpius*) accounted for most of the sculpin larvae taken during February. In all other years they were uncommon or absent.

Although several of the above monthly mean densities exceeded all other monthly means, no densities meeting the unusually high definition of the contingency sampling program were encountered during the January through June period of 1991.

No larval lobsters were found through June.

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 1991.

*Available upon request.

Appendix B

Mean monthly densities and range per 100 m^3 of
water for the dominant species of fish eggs
and larvae entrained at PNPS, January-June
1975-1991.

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.
11. Shaded columns for certain months in 1984 and 1987 delineate periods when sampling was conducted with only salt service water pumps in operation.

Table format: <u>Mean</u>
Range

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[*] 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.

January									
EGGS	1975	1976+	1977+	1978	1979	1980	1981	1982	1983
Brevoortia tyrannus	0			0	0	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
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
Labridae-*Pleuronectes*	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.
+No sampling.

January EGGS	1984	1985	1986	1987	1988	1989	1990	1991
Brevoortia tyrannus	0	0	0	0	0	0	0	0
Enchelyopus-Urophycis-Peprilus	-	-	-	-	-	-	-	-
Enchelyopus cimbrius**	0	0	0	0	0	0	0	0
Urophycis spp.	0	0	0	0	0	0	0	0
Gadidae-Glyptocephalus	-	-	-	-	-	-	-	-
Gadidae*	(0.4) 0-2	0	(0.6) 0.6-2	(0.1) 0-1	0	0	(0.5) 0-2	0
Gadus morhua	0.4 0-2	0	0.6 0.6-2	0.1 0-1	0	0	0.5 0-2	0
Pollachius virens	0	0	0	0	0	0	0	0
Labridae-Pleuronectes	0	0	0	0	0	0	0	0
Labridae	0	0	0	0	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	0	0	0	0	0	0	0
Hippoglossoides platessoides	0	0	0	0	0	0	0	0
Total	0.4 0-2	0	0.6 0.6-2	0.2 0-1	0.1 0-1	0	0.5 0-2	0

*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
Enchelyopus-*Urophycis*-*Peprilus*	-			-	-	-	-	-	-
*Enchelyopus cimbrius***	0			0	0	0	0	0	0
Urophycis spp.	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
Labridae-*Pleuronectes*	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.

+No sampling.

February EGGS	1984	1985	1986	1987	1988	1989	1990	1991
Brevoortia tyrannus	0	0	0	0	0	0	0	0
Enchelyopus-Urophycis-Peprilus	-	-	-	-	-	-	-	-
Enchelyopus cimbrius**	0	0	0	0	0	0	0	0
Urophycis spp.	0	0	0	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	0	0	0
Gadus morhua	1.5 0-3	0.6 0-3	0.4 0-1	0.1 0-1	0	0	0	0
Pollachius virens	0	0	0	0	0	0	0	0
Labridae-Pleuronectes	0	0	0	0	0	0	0	0
Labridae	0	0	0	0	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	0	0	0	0	0	0	0
Hippoglossoides platessoides	0.4 0-2	9	0	0	0.1 0-1	0	0	0
Total	2.0 0-4	1.0 0-3	0.4 0-1	0.1 0-1	0.1 0-1	0.1 0-1	0	0

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*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 t	0			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
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
Labridae-Pleuronectes	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	0	7.7 0.5-17
Total	0.7 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.

+No sampling.

++One sampling period only.

March EGGS	1984	1985	1986	1987	1988	1989	1990	1991
Brevoortia tyrannus	0	0	0	0	0	0	0	0
Enchelyopus-Urophycis-Peprilus	-	-	-	-	-	-	-	-
Enchelyopus cimbrius**	0	0	0	0	0.1 0-1	0	0	0
Urophycis spp.	0	0	0	0	0	0	0	0
Gadidae-Glyptocephalus	0.1 0-2	0	0	0.5 0-2	0.2 0-2	0.1 0-1	0	0.1 0-1
Gadidae*	(2.6) 0-11	(0.3) 0-2	(0.4) 0-2	(0.4) 0-2	(0.2) 0-1	(0.1) 0-1	0	(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	0.1 0-1	0	0.2 0-1
Pollachius virens	0	0	0	0	0	0	0	0
Labridae-Pleuronectes	0	0	0	0	0	0	0	0
Labridae	0	0	0	0	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	0	0	0	0	0	0	0
Hippoglossoides platessoides	4.5 0-22	0.3 0-1	0	0	0.1 0-1	0	0	0.3 0-2
Total	7.9 0.7-30	2.4 0-9	6.6 0-34	48.9 1-219	9.4 0-81	0.4 0-2	0	0.6 0-3

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

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

April EGGS	1975	1976+	1977	1978	1979	1980	1981	1982	1983
Brevoortia tyrannus	0		0	0	0	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
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
Labridae-Pleuronectes	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.

+ One sampling period only.

April EGGS	1984	1985	1986	1987+	1988	1989	1990	1991
Brevoortia tyrannus	0	0	0		0	0	0	0
Enchelyopus-Urophycis-Peprilus	-	-	-		-	-	-	-
Enchelyopus cimbrius**	0.2 0-2	1.0 0-6	4.3 0-14		3.3 0-10	0.9 0-6	4.4 0-28	1.7 0-16
Urophycis spp.	0	0	0		0	0	0	0
Gadidae-Glyptocephalus	0.7 0-3	0	0		0.1 0-1	0.1 0-1	0	0.1 0-1
Gadidae*	(2.0) 0-5	(1.6) 0-4	(0.2) 0-3		(2.2) 0-7	(0.6) 0-3	(0.1) 0-1	(1.1) 0-5
Gadus morhua	2.0 0-5	1.5 0-4	0.2 0-3		2.2 0-7	0.6 0-3	0.1 0-1	1.1 0-5
Pollachius virens	0	0.6 0-0.7	0		0	0	0	0
Labridae-Pleuronectes	0	0	0		0	0.8 0-10	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	0.3 0-2		0	0	0	0
Hippoglossoides platessoides	6.2 1.5-11	1.9 0-12	0.2 0-1		3.7 0-14	1.5 0-9	1.4 0-7	3.9 0-16
Total	11.0 5-16	10.1 0-25	7.6 0-21		14.1 3-29	6.7 0-27	6.7 1-28	10.7 2-51

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

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

+Pumps down - no sampling.

May EGGS	1975	1976	1977	1978	1979	1980	1981	1982	1983
Brevoortia tyrannus	0	0	0	0	0	0.1 0-1	0	0	0
Enchelyopus-Urophycis-Peprilus	8.3 0-30	13.3 0-72	12.5 5-22	2.8 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
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
Labridae-Pleuronectes	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	185.0 10-524

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

**Includes Brosme-Scomber, 1975-1983.

May EGGS	1984	1985	1986	1987	1988	1989	1990	1991
Brevoortia tyrannus	0	0	0	0	0	0.1 0-1	0	0.6 0-4
Enchelyopus-Urophycis-Peprilus	8.5 0-41	14.9 0-98	46.0 3-189	19.8 1-66	27.5 0-131	147.6 2-894	60.4 4-271	50.5 1-186
Enchelyopus cimbrius	8.4 0-44	9.8 1-22	22.5 0-52	17.5 0-57	39.2 1-91	20.7 0-95	13.8 2-27	33.4 4-132
Urophycis spp.	0	0.9 0-9	0.1 0-1	0.1 0-1	0	1.1 0-12	0	0
Gadidae-Glyptocephalus	2.0 0-8	1.0 0-3	0.6 0-5	2.0 0-13	0.2 0-2	0.9 0-4	0.7 0-3	3.2 0-17
Gadidae*	(1.0) 0-5	(0.5) 0-2	(0.2) 0-2	(0.4) 0-3	(0.004) 0-1	(0.4) 0-2	(0.7) 0-3	(1.3) 0-4
Gadus morhua	1.0 0-5	0.5 0-2	0.2 0-2	0.4 0-3	0.004 0-1	0.4 0-2	0.7 0-3	1.3 0-4
Pollachius virens	0	0	0	0	0	0	0	0
Labridae-Pleuronectes	9.5 0-40	1464.5 0-4622	54.0 2-225	20.2 0-141	108.8 3-424	1289.8 0-11376	92.2 1-426	301.8 1-1214
Labridae	0.4 0-5	2.6 0-16	2.4 0-13	0.8 0-5	7.5 0-23	5.1 0-19	1.7 0-16	19.0 0-88
Scomber scombrus**	17.9 0-44	2485.5 5-20871	116.1 30-236	36.1 0-125	1723.7 0-11981	5584.1 0-22910	1477.1 1-11023	537.9 1-1781
Prionotus spp.	0	0.3 0-1	0	0.1 0-1	0	0	0	0
Paralichthys-Scophthalmus	7.5 0-23	25.0 3-85	27.4 2-92	9.9 0-28	74.3 0-392	32.7 0-132	16.4 0-92	13.9 3-35
Hippoglossoides platessoides	2.4 0-6	1.4 0-7	0.5 0-2	0.8 0-4	0.08 0	2.5 0-14	1.7 0-4	2.2 0-6
Total	59.5 19-123	4051.5 38-21505	275.8 75-513	111.2 21-407	1989.1 17-12625	7492.0 32-35350	1666.5 22-11593	967.5 30-3108

*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
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
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
Labridae-Pleuronectes	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	1.6 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.

June EGGS	1984	1985	1986	1987	1988	1989	1990	1991
Brevoortia tyrannus	9.7 0-51	1.0 0-8	2.1 0-9	0.6 0-4	11.0 0-56	23.0 9-36	0.7 0-3	1.0 0-4
Enchelyopus-Urophycis-Peprilus	12.3 1-44	19.1 3-50	45.0 0-204	20.2 0-80	39.2 2-137	30.5 15-52	27.2 2-114	5.0 1-15
Enchelyopus cimbrius	3.1 0-12	8.6 0-19	74.5 1-223	23.3 3-52	51.0 4-196	34.0 11-93	19.3 0-66	3.8 0-8
Urophycis spp.	1.0 0-6	3.6 0-9	4.8 0-19	6.0 0-24	3.1 0-10	29.1 12-51	6.3 0-32	0.8 0-2
Gadidae-Glyptocephalus	2.4 0-14	0.9 0-3	1.0 0-4	0.4 0-4	1.7 0-5	0.3 0-2	1.2 0-3	0.1 0-1
Gadidae*	(0.8) 0-3	(0.2) 0-1	(0.1) 0-1	(0.8) 0-5	(0.3) 0-2	0	(0.5) 0-2	0
Gadus morhua	0.8 0-3	0.2 0-1	0.1 0-1	0.8 0-5	0.3 0-2	0	0.5 0-2	0
Pollachius virens	0	0	0	0	0	0	0	0
Labridae-Pleuronectes	1489.9 47-5983	639.9 52-1126	1826.0 332-6515	5166.2 177-14223	1100.8 238-3907	3801.7 968-9011	987.6 205-1973	456.5 357-570
Labridae	2.0 0-6	94.9 12-241	62.6 0-119	110.7 2-359	163.8 67-338	776.9 239-1516	66.5 0-287	150.1 2-361
Scomber scombrus**	33.4 1-88	109.8 3-349	276.7 0-990	122.6 12-411	2220.3 27-6243	1012.9 11-4440	2080.7 1-8742	473.4 1-1078
Prionotus spp.	0.5 0-4	5.4 0-15	3.3 1-9	77.0 0-225	2.3 0-20	2.9 0-9	0.3 0-2	2.5 0-8
Paralichthys-Scophthalmus	9.9 0-31	43.9 2-95	25.9 7-42	51.7 9-119	49.9 3-97	137.3 29-251	37.2 2-75	25.5 4-57
Hippoglossoides platessoides	0.1 0-1	0	0	1.5 0-13	0.1 0-2	0	1.4 0-8	0
Total	1581.1 93-6074	936.7 79-1798	2326.7 499-6712	5589.8 313-14910	3654.5 474-7879	5867.2 1330-10308	3229.9 333-10774	1126.6 364-2113

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

**Includes Brosme-Scomber, 1975-1983.

January LARVAE	1975	1976*	1977*	1978	1979	1980	1981	1982	1983
Clupea harengus	0.2 0-0.6			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
Tautoga onitis	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	2.2 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
Pleuronectes 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

*No sampling.

January LARVAL	1984	1985	1986	1987	1988	1989	1990	1991
Clupea harengus	0	0	0.1 0-0.6	1.0 0-3	0	0	0.2 0-1	0.6 0-2
Enchelyopus cimbrius	0	0	0	0	0	0	0	0
Tautoga onitis	0	0	0	0	0	0	0	0
Tautogolabrus adspersus	0	0	0	0	0	0	0	0
Ulvaria subbifurcata	0	0	0	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	0.1 0-1	0.2 0-1	2.2 0-5
Ammodytes sp.	0	44.1 0-111	1.3 0-3	0	0	0	0.1 0-1	0.1 0-1
Scomber scombrus	0	0	0	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	0	0	0.5 0-1
M. aenaeus	0	0.2 0-1	0	0.1 0-1	0.1 0-1	0	0	0
M. octodecemspinosus	0.2 0-0.8	1.5 0-4	0.6 0-2	0.2 0-1	0.3 0-1	0	0	0.3 0-1
M. scorpius	0	0	0	0	0	0	0	0.2 0-1
Liparis spp.	0	(0.1) 0-0.5	0	(0.1) 0-1	0	0	0	0
L. atlanticus	0	0	0	0	0	0	0	0
J. coheni	0	0.1 0-0.5	0	0.1 0-1	0	0	0	0
Pleuronectes americanus	0	0	0	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	0.3 0-1	0.6 0-1	3.4 1-7

February LARVAE	1975	1976*	1977*	1978	1979	1980	1981	1982	1983
Clupea 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
Tautoga onitis	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			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
Pleuronectes 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

*No sampling.

February LARVAE	1984	1985	1986	1987	1988	1989	1990	1991
Clupea harengus	0.1 0-1	0.4 0-0.9	0.5 0-1	0.1 0-1	0	0	0	0.1 0-1
Enchelyopus cimbrius	0	0	0	0	0	0	0	0
Tautoga onitis	0	0	0	0	0	0	0	0
Tautogolabrus adspersus	0	0	0	0	0	0	0	0
Ulvaria subbifurcata	0	0	0	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	11.6 4-37	1.9 0-5	46.3 39-59
Ammodytes sp.	1.0 0-3	35.4 0-132	0.1 0-0.6	0	0.4 0-2	0	1.1 0-5	0.7 0-1
Scomber scombrus	0	0	0	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	(2.0) 0-5	(0.1) 0-1	(29.9) 10-53
M. aenaeus	0.7 0-2	7.7 0-24	0.9 0-2	8.5 5-10	7.3 0-17	0.4 0-2	0.1 0-1	8.9 6-15
M. octodecemspinosus	0.4 0-1	1.0 0-3	0.5 0-2	0.3 0-1	0.5 0-1	0	0	0.2 0-1
M. scorpius	0	6.2 0-20	0	3.4 0-7	33.1 1-75	1.6 0-3	0	20.6 2-44
Liparis spp.	0	(0.5) 0-1	0	0	(0.1) 0-1	(1.2) 0-3	0	0.1 0-1
L. atlanticus	0	0	0	0	0	0	0	0
L. coheni	0	0.5 0-1	0	0	0.1 0-1	1.2 0-3	0	0.1 0-1
Pleuronectes americanus	0	0	0	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	14.8 5-45	3.1 0-11	77.4 51-104

March LARVAE	1975	1976*	1977**	1978	1979	1980	1981	1982	1983
Clupea harengus	0.8 0-2			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
Tautoga onitis	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
Pleuronectes 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

*No sampling.
**One sampling period only.

March LARVAE	1984	1985	1986	1987	1988	1989	1990	1991
Clupea harengus	0.5 0-5	1.2 0-4	0.2 0-1	0	1.7 0-18	0.2 0-1	0	0.7 0-3
Enchelyopus cimbrius	0	0	0	0	0	0	0	0
Tautoga onitis	0	0	0	0	0	0	0	0
Tautogolabrus adspersus	0	0	0	0	0	0	0	0
Ulvaria subbifurcata	0.03 0-0.6	0	0.3 0-2	0	0	0	0	0.1 0-1
Pholis gunnellus	108.9 0-482	45.7 0-96	58.4 2-159	3.4 0-11	117.8 4-375	61.0 0-126	3.7 0-8	19.9 2-48
Ammodytes sp.	1.0 0-3	10.4 0-47	9.2 0-30	0.1 0-1	2.4 0-9	3.8 0-11	1.2 0-4	5.1 1-19
Scomber scombrus	0	0	0	0	0	0	0	0
Myoxocephalus spp.	(37.6) 0-228	(23.3) 0-61	(65.6) 8-218	(4.1) 0-10	(114.6) 32-356	(60.6) 0-183	(12.1) 2-22	(41.0) 14-87
M. aenaeus	26.3 0-156	21.3 0-58	60.0 5-213	3.7 0-10	102.9 12-347	34.2 0-65	2.5 2-8	39.4 13-85
M. octodecemspinosus	0	0.7 0-2	1.0 0-3	0.2 0-1	0.3 0-2	1.5 0-6	0	0
M. scorpius	11.3 0.7-72	1.3 0-3	4.6 0-12	0.2 0-1	11.2 0-26	24.8 0-119	9.6 0-20	1.6 0-4
Liparis spp.	(0.04) 0-0.8	(0.6) 0-2	(0.8) 0-5	(0.1) 0-1	(0.5) 0-1	(0.8) 0-4	(0.1) 0-1	(0.2) 0-1
L. atlanticus	0	0.06 0-0.7	0.4 0-4	0	0.1 0-1	0.1 0-1	0	0.1 0-1
L. coheni	0.04 0-0.8	0.5 0-2	0.4 0-2	0.1 0-1	0.4 0-2	0.8 0-4	0.1 0-1	0.1 0-1
Pleuronectes americanus	0.1 0-0.9	0.3 0-3	1.5 0-7	0	0	0	0	0.1 0-1
Total	148.7 0-172	82.5 2-179	136.5 14-346	8.0 1-19	237.8 19-736	128.4 2-286	17.5 4-30	67.2 21-127

April LARVAE	1975	1976*	1977	1978	1979	1980	1981	1982	1983
Clupea harengus	1.3 0-12		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
Tautoga onitis	0		0	0	0	0	0	0	0
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	-		0-3						
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	0	15.3 1-69
L. coheni	-		-	-	-	-	0	0.9 0-4	0
Pleuronectes 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 55-154	458.2 21-1324	120.5 57-238	86.0 8-266	66.5 29-142	185.4 4-732	51.7 3-135

*One sampling period only.

April LARVAE	1984	1985	1986	1987*	1988	1989	1990	1991
Clupea harengus	0	0.1 0-0.9	0.4 0-2		0.9 0-3	0.3 0-2	0.3 0-2	0.3 0-1
Enchelyopus cimbrius	0	0	0		0.1 0-1	0	0.1 0-1	0
Tautoga onitis	0	0	0		0	0	0	0
Tautogolabrus adspersus	0	0	0		0	0	0	0
Ulvaria subbifurcata	0	4.8 0-21	2.2 0-8		0.8 0-3	0.4 0-2	0.8 0-3	5.5 0-26
Pholis gunnellus	2.9 0-11	29.1 0-77	8.4 0-27		3.5 0-8	11.1 0-44	17.1 0-41	5.7 0-20
Ammodytes sp.	0	22.4 1-89	35.7 0-156		11.0 0-64	3.3 0-14	89.7 4-344	38.0 1-71
Scomber scombrus	0	0	0		0	0	0	0
Myoxocephalus spp.	(2.9) 0-11	(121.1) 18-442	(72.6) 1-295		(43.0) 3-111	(26.8) 6-73	(32.5) 2-72	(13.1) 4-23
M. aenaeus	2.9 0-11	121.0 18-442	71.9 1-292		38.9 3-111	26.4 6-71	31.5 2-71	12.8 4-23
M. octodecemspinosus	0	0	0.5 0-4		0	0	0.3 0-1	0.1 0-1
M. scorpius	0	0.1 0-0.8	0.3 0-2		0.3 0-2	0.5 0-2	0.7 0-3	0.2 0-2
Liparis spp.	0	(6.5) 1-26	(8.2) 0-27		(17.4) 0-99	(7.5) 0-33	(3.6) 1-8	(2.7) 0-14
L. atlanticus	0	6.1 0-26	8.0 0-27		17.3 0-99	7.5 0-33	3.5 1-8	2.7 0-14
L. coheni	0	0.4 0-2	0.2 0-1		0.1 0-1	0	0.1 0-1	0
Pleuronectes americanus	0	4.2 0-11	10.7 0-33		2.9 2-17	3.8 0-20	1.3 0-6	1.6 0-10
Total	6.7 0-17	189.5 54-524	139.4 12-358		68.3 9-307	53.5 6-120	146.6 30-366	68.5 8-115

*Pumps down - no sampling

May LARVAE	1975	1976	1977	1978	1979	1980	1981	1982	1983
Clupea 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
Tautoga onitis	0	0	0	0	0.1	7.0 0-1	0 0-39	0	0
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
Pleuronectes americanus	13.9 2-36	7.4 2-18	16.3 4-29	38.0 0-129	18.4 13-40	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	1989	1990	1991
Clupea harengus	0.1 0-1	0	0.1 0-1	0	0.08 0-1	0.3 0-2	3.0 0-10	0.3 0-2
Enchelyopus cimbrius	0	4.4 0-6	5.5 0-27	1.3 0-3	5.3 0-31	2.2 0-17	0	2.4 0-6
Tautoga onitis	0	0.04 0-1	0	0	0	0	0	0.1 0-1
Tautogolabrus adspersus	0	0	0.2 0-1	0	0	0.1 0-1	0	0.3 0-4
Ulvaria subbifurcata	0.9 0-4	15.6 0-75	5.8 1-16	2.0 0-5	3.3 0-15	20.3 1-88	25.3 0-63	18.9 1-58
Pholis gunnellus	0.9 0-4	0.1 0-0.6	0.1 0-1	0	0.9 0-3	0.7 0-5	0.5 0-3	0.2 0-1
Ammodytes sp.	16.6 0-57	0.6 0-3	1.2 0-5	0.2 0-1	2.5 0-14	4.9 0-17	22.8 2-47	0.8 0-4
Scomber scombrus	0	0.5 0-6	0.2 0-1	0.1 0-1	0	0.5 0-4	0.1 0-1	6.6 0-43
Myoxocephalus spp.	(1.9) 0-10	(2.1) 0-11	(0.5) 0-2	(0.2) 0-1	(2.0) 0-10	(2.5) 0-11	(4.3) 0-20	(0.9) 0-6
M. aenaeus	1.9 0-10	2.1 0-11	0.5 0-2	0.2 0-1	2.0 0-10	2.5 0-11	4.3 0-20	0.9 0-6
M. octodecemspinosus	0	0	0	0	0	0	0	0
M. scorpius	0	0	0	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	(13.8) 0-59	(7.3) 1-17	(5.2) 1-8
L. atlanticus	3.3 0-11	15.7 0-30	2.2 0-6	16.0 0-101	28.3 1-146	13.8 0-59	7.3 1-17	5.2 1-8
L. coheni	0	0	0	0	0	0	0	0
Pleuronectes americanus	9.6 0-27	14.1 0-27	7.4 2-13	10.2 0-52	23.6 0-105	7.5 0-30	12.2 0-47	16.4 0-46
Total	33.7 0-64	55.4 8-79	24.1 15-41	27.5 0-158	67.6 10-291	54.7 20-108	77.3 26-125	56.5 23-105

June LARVAE	1975	1976	1977	1978	1979	1980	1981	1982	1983
Clupea harengus	0	0	0	0	0	0	0	0	0
Enchelyopus cimbrius	50.1 0-137	[illegible] 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
Tautoga onitis	0.7 0-1	0.4 0-5	6.7 0-27	6.2 0-37	4.3 0-11	7.0 0-20	12.5 0-162	3.0 0-27	0.5 0-2
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	35.5 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
Pleuronectes americanus	5.5 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	297.2 125-6	176.7 51-343	82.6 27-154	145.8 49-377	710.7 5-5423	35.8 0-136	102.5 2-383

June LARVAE	1984	1985	1986	1987	1988	1989	1990	1991
Clupea harengus	0	0.07 0-1	0	0	0	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	32.4 3-137	29.3 0-120	1.8 0-4
Tautoga onitis	0	5.2 0-41	1.1 0-5	2.3 0-12	0.3 0-2	10.2 0-35	2.6 0-10	1.6 0-4
Tautogolabrus adspersus	0	50.7 0-208	40.4 0-157	0.8 0-6	1.0 0-5	70.2 4-196	7.2 0-30	17.2 0-37
Ulvaria subbifurcata	1.0 0-4	3.4 1-5	2.4 0-6	0.2 0-2	1.5 0-12	3.6 0-13	3.5 0-9	1.6 0-4
Pholis gunnellus	0.1 0-1	0	0	0	0	0	0	0
Ammodytes sp.	0.1 0-1	0	0	0	0	0.2 0-2	0.6 0-2	0
Scomber scombrus	0.1 0-1	86.5 0-376	113.2 0-393	0.4 0-2	5.6 0-52	137.2 0-434	5.6 0-23	199.7 0-422
Myoxocephalus spp.	0	0	0	0	0	0	(0.1) 0-2	0
M. aenaeus	0	0	0	0	0	0	0.1 0-2	0
M. octodecemspinosus	0	0	0	0	0	0	0	0
M. scorpius	0	0	0	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	(1.4) [illegible]	(3.7) 0-13	(5.5) 0-14
L. atlanticus	4.4 0-13	1.6 0-3	2.6 0-11	1.5 0-13	6.9 1-32	1.4 0-7	3.7 0-13	5.5 0-14
L. coheni	0	0	0	0	0	0	0	0
Pleuronectes americanus	4.7 0-24	2.2 0-7	1.3 0-6	0.3 0-4	0.6 0-4	0.7 0-2	0.1 0-2	1.8 0-5
Total	11.3 0-41	201.6 4-681	198.6 17-663	15.2 0-61	19.6 5-69	274.3 57-771	[illegible] [illegible]-198	232.3 0-478

IMPINGEMENT OF ORGANISMS AT
PILGRIM NUCLEAR POWER STATION

(January - June 1991)

Prepared by: Robert D. Anderson

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Senior Marine Fisheries

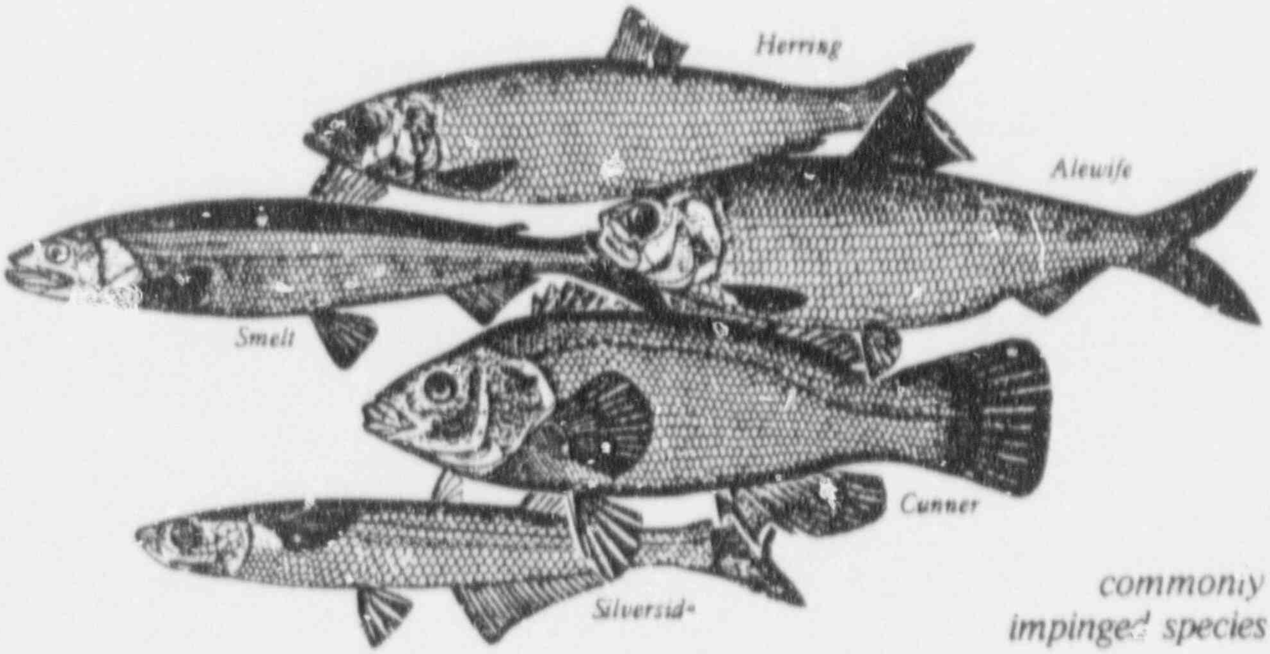
Biologist

Regulatory Affairs Department

Licensing Division

Boston Edison Company

October 1991



commonly
impinged species

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SECTION I

SUMMARY

Fish impingement averaged 1.31 fish/hour during the period January-June 1991. Atlantic silverside (Menidia menidia), Atlantic herring (Clupea harengus harengus), grubby (Myoxocephalus aenaeus) and winter flounder (Pseudopleuronectes americanus) accounted for 80% of the fishes collected. Initial impingement survival for all fishes from static screen wash collections was approximately 23% and from continuous screen washes 77%.

The collection rate (no./hr.) for all invertebrates captured from January-June 1991 was 0.86+. Sevenspine bay shrimp (Crangon septemspinosa) and common starfish (Asterias forbesi) accounted for 60% of the enumerated invertebrates impinged. Mixed species of algae collected on intake screens amounted to 1,494 pounds.

The relatively high fish impingement rates from January-June 1989 (0.55), 1990 (0.52) and 1991 (1.31), compared to the same period in 1988, reflect circulating water pumps operating during these entire periods. The invertebrate impingement was not as reflective of increased intake flow.

The Pilgrim Nuclear Power Station capacity factor was 60% from January - June 1991.

SECTION 2

INTRODUCTION

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

This document is a report pursuant to operational environmental monitoring and reporting requirements of NPDES Permit No. 0003557 (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 1991.

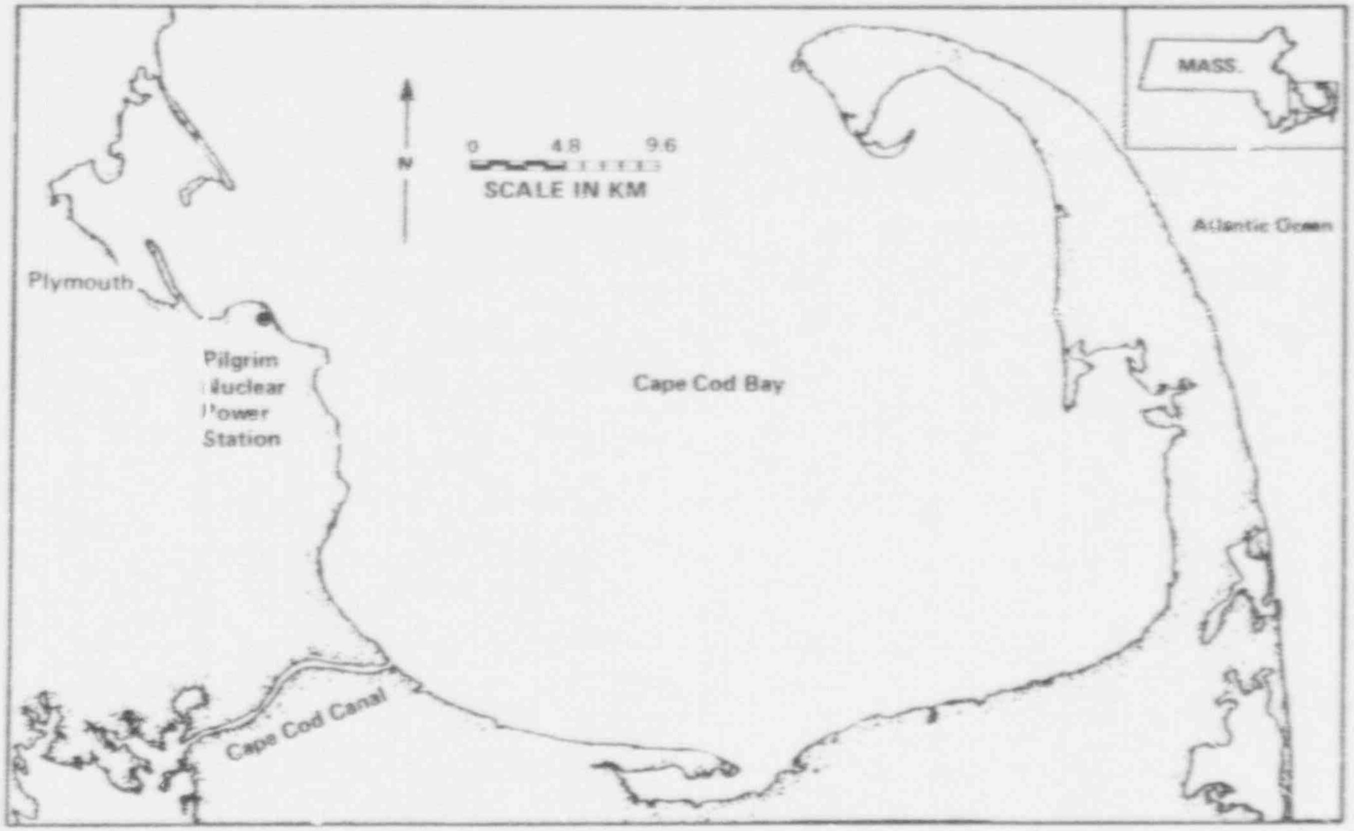

Figure 1. Location of Pilgrim Nuclear Power Station.

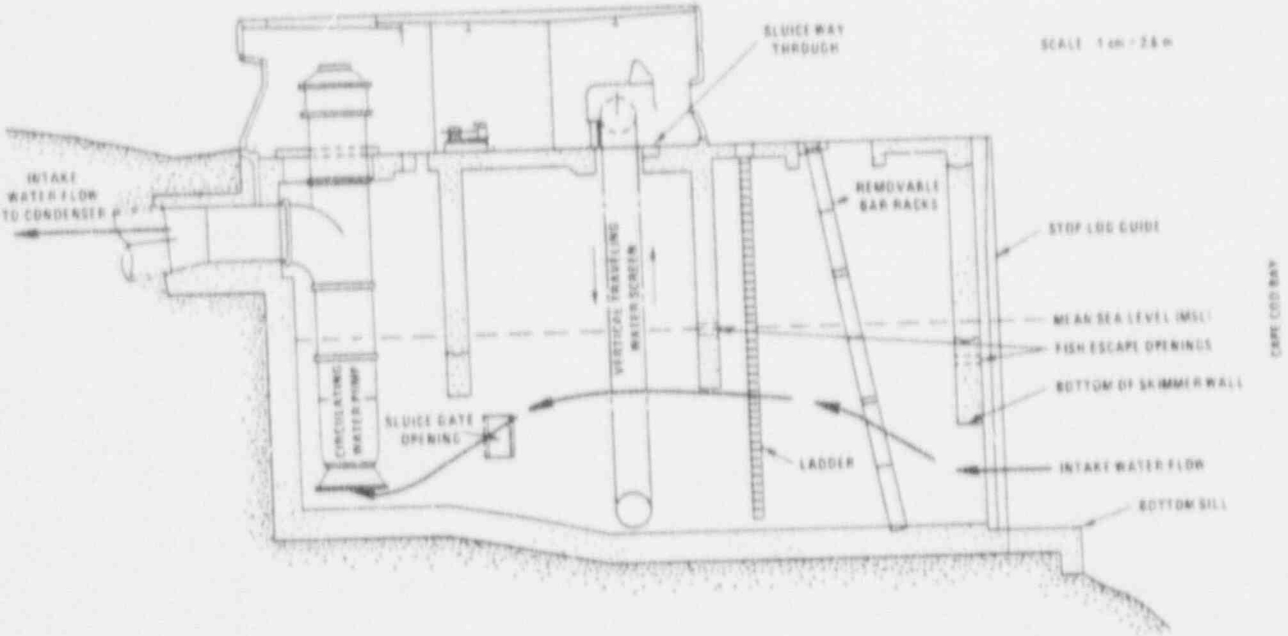

Figure 2: Cross-section of intake structure of Pilgrim Nuclear Power Station.

SECTION 3

METHODS AND MATERIALS

Three screen washings each week were performed from January-June 1991 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 light periods and one dark period on a weekly basis.

Water nozzles directed at the screens washed impinged organisms and debris into a sluiceway that flowed into a trap. The original trap 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.

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 (1988, 1989 and 1991).

SECTION 4

RESULTS AND DISCUSSION

4.1 Fishes

In 429+ collection hours, 560 fishes of twenty-five species (Table 1) were collected from Pilgrim Nuclear Power Station intake screens during January-June 1991. The collection rate was 1.31 fish/hour. Atlantic silverside (Menidia menidia) was the most abundant species accounting for 36.6% of all fishes collected (Table 2). Atlantic herring (Clupea harengus harengus), grubby (Myoxocephalus aenaeus) and winter flounder (Pseudopleuronectes americanus) accounted for 33.6, 5.2 and 4.1% of the total number of fishes collected. Atlantic silverside were impinged in highest numbers during March and April. These were primarily adult fish that averaged 107 mm total length. Winter flounder were mostly impinged in March, Atlantic herring in June and grubby during January-March. The January-June 1991 fish impingement rate was much greater than the same period in 1989 (0.55) and 1990 (0.52). Rates increased the past three years compared to the 1988 rate (0.30) and this is possibly attributable to greater circulating water pump operating capacity from 1989-1991.

4.2 Invertebrates

In 429+ collection hours, 368+ invertebrates of 15 species (Table 3) were collected from Pilgrim Station intake screens between January-June 1991. The collection rate was 0.86+ invertebrates/hour. Sevenspine bay shrimp (Crangon septemspinosa) and common starfish (Asterias forbesi) accounted for 37.2 and 23.4%, respectively, of the total number of enumerated invertebrates collected. An undetermined number of blue mussels (Mytilus edulis) were impinged in May.

Table 1. Monthly Impingement For All Fishes Collected From Pilgrim Station Intake Screens, January-June 1991

Species	Jan.	Feb.	March	April	May	June	Totals
Atlantic silverside	9	24	55	114	1	2	205
Atlantic herring			12	7	2	167	188
Grubby	9	8	8	3	1		29
Winter flounder	3	4	11	2	3		23
Cunner	4	1		2	10		17
Blueback herring			8	5			13
Alewife	4		2	6			12
Windowpane	2		6	1	2		11
Rainbow smelt	2	1		4	3		10
Atlantic tomcod	5			1	1		7
Little skate					6	1	7
Red hake	1			3	2		6
Rock gunnel			4	2			6
Northern searobin					4		4
Pollock					4		4
Lumpfish	3						3
Northern pipefish			3				3
Striped searobin			3				3
Fourspot flounder						2	2
Sand lance sp.							2
Radiated skanny				1			1
Silver hake					1		1
Smooth dogfish	1						1
Tautog				1			1
Threespine stickleback			1				1
TOTALS	43	38	113	152	42	172	560
Collection Time (hrs.)	74	67	74	65	128	21+	429+
Collection Rate (#/hr.)	0.58	0.57	1.53	2.34	0.33	8.19	1.31

Table 2. Species, Number, Total Length(mm), Weight(gms) and Percentage For All Fishes Collected From Pilgrim Station Impingement Sampling, January-December 1991

Species	Number	Length Range	Mean Length	Weight Range	Mean Weight	Percent of Total Fish
Atlantic silverside	205	72-143	107	2-13	6	36.6
Atlantic herring	188	38-302	79	0.1-157	5	33.6
Grubby	29	40-110	79	1-16	5	5.2
Winter flounder	23	58-335	120	2-152	19	4.1
Cunner	17	45-176	126	2-92	46	3.0
Blueback herring	13	75-105	87	2-6	4	2.3
Alewife	12	73-138	101	3-18	8	2.1
Windowpane	11	40-104	77	1-13	5	2.0
Rainbow smelt	10	68-185	101	1-36	8	1.8
Atlantic tomcod	7	121-174	157	13-85	34	1.3
Little skate	7	470-511	495	650-900	753	1.3
Red hake	6	89-181	140	4-34	18	1.1
Rock gunnel	6	70-196	124	1-21	7	1.1
Northern searobin	4	240-255	248	139-149	144	0.7
Pollock	4	51-70	60	1-3	2	0.7
Lumpfish	3	50-83	67	3-11	6	0.5
Northern pipefish	3	140-141	140	1	1	0.5
Striped searobin	3	96	96	8	8	0.5
Fourspot flounder	2	318	318	-	-	0.4
Sand lance sp.	2	140	140	10	10	0.4
Radiated shanny	1	85	85	5	5	0.2
Silver hake	1	93	93	6	6	0.2
Smooth dogfish	1	781	781	-	-	0.2
Tautog	1	160	160	63	63	0.2
Threespine stickleback	1	63	63	2	2	0.2

Table 3. Monthy Impingement For All Invertebrates Collected From Pilgrim Station Intake Screens, January-June 1991

Species	Jan.	Feb.	March	April	May	June	Totals
Sevenspine bay shrimp	29	42	43	21	2		137
Common starfish	25	3	30	14	7	7	86
Rock crab	6	4	6	13	3	4	36
Blue mussel	3		2	6	*	16	27+
American lobster			3	11	2	5	21
Horseshoe crab				1	10	10	21
Green crab		1		7	4	1	13
Isopoda	1	1			7		9
Nereis sp.		2	5				7
Green seaurchin		1	1			1	3
Lady crab			2	1			3
Longwrist hermit				2			2
Cirripedia		1					1
Nemertea		1					1
Pagurus sp.			1				1
TOTALS	64	56	93	76	35+	44	368+
Collection Time (hrs.)	74	67	74	65	128	21+	429+
Collection Rate (#/hr.)	0.86	0.84	1.26	1.17	0.27+	2.09	0.86+

* Undetermined numbers

The collections of sevenspine bay shrimp occurred primarily in February and March, and common starfish during March. In 1989 from January - June, blue mussels and mussel predators dominated possibly due to the lack of effective macrofouling controls then. Twenty-one specimens of the commercially important American lobster (Homarus americanus) were captured which is high compared with previous years, although 16 were recorded for the same time frame in 1990.

Approximately 1,494 pounds of mixed algae species were recorded during impingement sampling, or 3.5 pounds/hour. Like the January-June 1989, 1990 and 1991 fish impingement rates, the algal impingement rate for these years was notably higher than recorded for the same period in 1988.

4.3 Fish Survival

Fish survival data collected while impingement monitoring are shown in Table 4. Static screen wash collections provided high numbers of fishes and revealed relatively low impingement survival rates for most species. Continuous screen wash collections had higher survival rates, although so few fishes were sampled that they are not a good indicator of continuous wash survival. After 1-hour and 56-hour holding periods data were limited because of survival pump freezing problems in the winter, or fishes being lost or collected in the screenhouse where no survival facilities are located.

Table 4. Survival Summary for the Fishes Collected During Pilgrim Station Impingement Sampling, January-June 1991. 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		Mean	Range
			Static	Cont.	Static	Cont.	Static	Cont.		
Atlantic silverside	198	7	63	5	2	4	0	2	107	72-143
Atlantic herrring	188	0	0	-	0	-	0	-	79	38-302
Grubby	21	8	16	8	3	1	2	0	79	40-110
Winter flounder	15	8	11	7	3	0	2	0	120	58-335
Cunner	15	2	2	1	0	1	0	1	126	45-176
Blueback herring	13	0	2	-	0	-	0	-	87	75-105
Alewife	11	1	2	0	0	0	0	0	101	75-13[illegible]
Windowpane	7	4	5	4	1	0	1	0	77	40-104
Rainbow smelt	10	0	0	-	0	-	0	-	101	68-185
Atlantic tomcod	7	0	4	-	0	-	0	-	157	121-174
Little skate	7	0	3	-	0	-	0	-	495	470-511
Red Hake	6	0	1	-	1	-	0	-	140	89-181
Rock gunnel	3	3	3	1	1	0	1	0	124	70-196
Northern searobin	4	0	2	-	0	-	0	-	248	240-255
Pollock	4	0	0	-	0	-	0	-	60	51-70
Lumpfish	3	0	0	-	0	-	0	-	67	50-83
Northern pipefish	2	1	0	0	0	0	0	0	140	140-141
Striped searobin	3	0	0	-	0	-	0	-	96	96
Fourspot flounder	2	0	2	-	0	-	0	-	318	318
Sand lance sp.	2	0	2	-	0	-	0	-	140	140
Radiated skanny	1	0	1	-	0	-	0	-	85	85
Silver hake	1	0	0	-	0	-	0	-	93	93
Smooth dogfish	1	0	1	-	1	-	0	-	781	781
Tautog	0	1	-	1	-	1	-	1	160	160
Threespine stickleback	1	0	0	-	0	-	0	-	63	63
All Species:										
Number	525	35	120	27	12	7	6	4		
(% Surviving)			(22.9)	(77.1)	(2.3)	(20.0)	(1.1)	(11.4)		

* Limited data for species because survival pool was frozen, or fishes were lost or sampled in the screenhouse.

SECTION 5

CONCLUSIONS

1. The average Pilgrim impingement rate for the period January-June 1991 was 1.31 fish/hour. The collection rate was comparatively lower in 1988, than in 1989, 1990 and 1991, possibly due to more circulating water pump capacity during the latter years.

2. Twenty-five species of fish were recorded in 429+ impingement collection hours.

3. The major species collected and their relative percentages of the total collections were Atlantic silverside, 36.6%; Atlantic herring, 33.6%; grubby, 5.2%; and winter flounder, 4.1%.

4. The hourly collection rate for invertebrates was 0.86+ with sevenspine bay shrimp 37.2% and common starfish 23.4% of the enumerated catch. Twenty-one American lobsters were caught. Impingement rates for invertebrates were higher and algae lower for this period in 1988 than in 1989, 1990 and 1991.

5. Impinged fish survival was relatively low for species during static screen washes, compared to continuous washes.

SECTION 6

LITERATURE CITED

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The Commonwealth of Massachusetts

Division of Marine Fisheries
18 Route 6A
Sandwich, Massachusetts 02563

PHILIP G. COATES
DIRECTOR

888-1155

MEMORANDUM

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

FROM: Brian Kelly, Recording Secretary, Massachusetts Division of Marine Fisheries

SUBJECT: Minutes of the 75th meeting of the Pilgrim Administrative-Technical Committee

DATE: July 15, 1991

The 75th meeting of the Pilgrim Administrative-Technical (A-T) Committee was called to order by Chairman Szal (DWPC) on June 18, 1991 at 10:05 a.m. at the Richard Cronin Building, Massachusetts Division Fisheries and Wildlife Field Headquarters, Westboro, Massachusetts. Eight agenda items were addressed.

I. Minutes of the 74th Meeting

There were no additional comments on the minutes of the previous A-T meeting.

II. Pilgrim Station 1990/1991 Operational Review

Bob Anderson reviewed 1990 Pilgrim Station operation, wherein the plant ran at 72% capacity with two pumps operating for most of the year. Pilgrim ran at 90% capacity through April 1991, and since early May has been in a planned refueling outage which will continue into late July. Only one or no circulating pumps will be on during the majority of this outage. Pilgrim will not need to refuel again until early 1993. Thus, 1992 should be a high operational year, with only a 30 day mid-cycle outage planned for spring.

Bob Anderson noted that Pilgrim received a new NPDES permit from EPA on April 29, 1991, wherein the A-T Committee is cited as an official entity for the first time.

Richard Dorfman mentioned that the location of the potential ocean sewage outfall off Rocky Point will be decided on in mid-1992, with construction planned for completion in 1995. Located in 60 feet of water, this outfall would complicate any environmental monitoring efforts concerning Pilgrim Station.

III. 1990 Impingement/Overflight Results

Bob Anderson stated that fish impingement in 1990 at Pilgrim Station was projected at approximately 15,000 fish, the highest figure since 1981 but not atypical when compared with the 1973-1990 datasets. The number of fish impinged in any given year is correlated to circulating water pump operation for that time period. Impinged fish survival (which varies depending on the species involved) in 1990 averaged 10% on static screen washes and 27% on continuous screen washes. Further discussion on either eliminating or resuming 56-hr survival studies of impinged fish will ensue at the upcoming Fisheries Subcommittee meeting in July. Overflight monitoring in 1990 showed two large schools of Atlantic herring in the general vicinity of Pilgrim Station in October, but no large fish schools were reported within a half mile of the Plant.

IV. 1990 Marine Fisheries Monitoring Results

Bob Lawton prefaced that in the 1990 annual report the Marine Fisheries impact section (Volume 2) was done by a species rather than gear type approach in order to zero in on potential indicator organisms. Brian Kelly mentioned that the trawl monitoring study continued to show depressed abundance indices of the dominant groundfish in the area.

The first operational year for the research lobster study was 1990. Analysis of 1990 research lobster data revealed no measurable impact of plant operation on legal lobster catch rate; however, sublegal catch rates at the Discharge site were lowest at the two stations closest to the discharge canal, and a correlation existed at these stations between average plant operational levels and sublegal catch rates. Current is hypothesized to be the factor influencing sublegal abundance/distribution near the discharge.

The Atlantic silverside, the dominant fish obtained in the haul seine study, is impinged primarily from November through April, when adult silversides are overwintering in low abundance within the Intake embayment. Low water temperatures in winter may make these silversides lethargic and hence more subject to impingement.

Bob Lawton outlined the recent expanded effort of studying cunner. Cunner is a structure fish that resides in the discharge area most of the year, feeding on mussels and even small organisms in the water column (an underwater videotape of the discharge was presented by Division of Marine Fisheries), and hence subject to potential low-level radiological or other contamination. Bob reviewed the cunner tagging program to date, with fish 12 cm and larger being tagged in the discharge and a control area. Otoliths are being used to age fish in order to characterize the present structure of the cunner population in the Pilgrim area. Cunner abundance at Pilgrim has been declining for the past eight years based on gillnet catches. It is one of the dominant fish impinged and its eggs and larvae are entrained at Pilgrim, while several thousand are caught annually by anglers along the Station's breakwater.

V. 1990 Benthic Monitoring Results

Jim Blake noted that the June qualitative dive survey data show a return to the denuded impacted zone as seen in 1985-1986. SAIC looked at the 1985-1990 quantitative benthic data to investigate certain individual species distribution between sampling sites, and found for the amphipod Jassa falcata that its relative distribution in 1990 at the control and impact sites corresponded to the return of a previously noted "impact signature" at the effluent site. Jim discussed the problem of large variability of replicates for algal biomass in the discharge area. He explained the NESS and Bray-Curtis similarity indices' strengths and weaknesses. Using similarity analyses on the 1985-1990 quantitative data, a two year lag period appeared to exist at the effluent site for reversion to control conditions when the plant was off-line from 1986-early 1989. Preliminary analysis of 1991 data shows that the old pattern of the discharge station being somewhat different from the control sites has re-emerged now that Pilgrim Station has been back on-line for a period of time.

VI. Review of 1990 and Update of 1991 Benthic Monitoring Retrospective

Gerald Szal reviewed the minutes of the last two benthic subcommittee meetings. Considerable discussion ensued regarding the future quantitative benthic monitoring effort. Regarding the June subcommittee meeting, Jerry struck the line in section 3 of the minutes "We recommend this work also be conducted by Osman and Whitlatch", thus keeping the 1992 quantitative benthic review award open on a possible competitive bid. Committee members agreed that more time was needed to review recent benthic subcommittee meeting minutes, the Whitlatch and Osman revised benthic monitoring review proposal for 1991, and Jim Blake's comments on it. There was confusion regarding upcoming benthic studies discussed at recent benthic subcommittee meetings and at the A-T Committee meeting. Jerry will summarize and disseminate the required information to Committee members and will arrange a special emergency meeting of the A-T Committee to discuss benthic monitoring issues for the future.

VII. 1991 Marine Fish and Benthic Subcommittees

The fisheries subcommittee will be comprised of Maietta, Griswold, Anderson, Lawton, Finn, and Higgins. Carolyn will check with Jack Finn if he wishes to stay on the subcommittee, and Ted Landry will ask Jack Paar (EPA) if he would become a member both of the main A-T Committee and one of the subcommittees. The next fisheries subcommittee meeting will be Wednesday, July 24 at 10 A.M. at Pilgrim Station. The subcommittee may vote for a new chairman.

The benthic subcommittee will have Miller (Chairman), along with Szal, Pederson, Lawton, and Anderson. Jim Blake was invited to join the subcommittee.

VIII. 1990 Entrainment Results

Mike Scherer noted that few cod eggs have been entrained for the past few years, while mackerel eggs have been very abundant the last three years. Winter flounder larval abundance continues to be down, while cunner and tautog larvae were quite abundant in July and August. Bob Lawton requested the fisheries subcommittee at their next meeting discuss (1) evaluating the contingency baywide sampling plan for entrainment events and (2) ways to equate entrainment and impingement for certain species to adult equivalent estimates.

IX. Adjournment

The meeting adjourned at 3:55 PM.

Pilgrim Administrative-Technical Committee Meeting Attendance

June 18, 1991

Gerald Szal, Chairman	Mass. DWPC, Westboro
Robert Maietta	Mass. DWPC, Westboro
Carolyn Griswold	NMFS, Narragansett
Robert Anderson	BECo, Braintree
Robert Lawton	Mass. DMF, Sandwich
Jim Blake	SAIC, Woods Hole
Brigitte Hilbig	SAIC, Woods Hole
Ted Landry	EPA, Lexington
Mike Scherer	MRI, Falmouth
Richard Dorfman	Mass. DWPC, Westboro
Brian Kelly	Mass. DMF, Sandwich

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PHILIP G. COATES
DIRECTOR

886-1155

MEMORANDUM

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

FROM: Brian Kelly, Recording Secretary, Massachusetts Division of Marine Fisheries

SUBJECT: Minutes of the Emergency Meeting of the Pilgrim Administrative-Technical Committee

DATE: August 26, 1991

An emergency meeting of the Pilgrim Administrative-Technical (A-T) Committee to discuss the benthic monitoring program was called to order by Chairman Szal (DWPC) on August 1, 1991 at 10:07 a.m. at the Richard Cronin Building, Massachusetts Division Fisheries and Wildlife Field Headquarters, Westboro, Massachusetts.

Don Miller referred to his memo of July 19, 1991 regarding benthic monitoring concerns at Pilgrim. Don stated that to date regulators have been content that quantitative benthic monitoring has shown little evidence that much is going on; data from the effluent station, located 120 meters off the discharge jetties, have not shown much plant impact. BECo may be able to monitor for half the cost and still ask the question - "what's going on out there"? Don mentioned this could be addressed by having some biologists (including an algologist) do a reconnaissance dive in the discharge area. If the divers document an impact that is more than trivial, Don feels the A-T Committee should consider a gradient sampling design to replace the present control stations. Two questions to consider are: (1) is there enough of an impact on the benthic community to bother studying it? (2) if there is, what monitoring effort and design should be used?

During the group discussion which ensued, concerns surfaced regarding the temporal component of monitoring, and one of the study questions was rephrased as "For all months of the year, what is the spatial influence of the plume"? Jerry Szal asked if a three dimensional representation of temperature and current over depth could be obtained in the discharge plume to map the area of concern, as the delineation of abiotic factors first is less costly than broad biological monitoring. The Committee decided to ask Robert Whitlatch and Richard Osman, benthic biologists, to monitor plume temperatures using four Ryan temperature monitors in conjunction with their proposed panel studies to commence at the end of August. The money for the temperature monitors will come out of the present benthic budget, which may result in the number of panel stations being reduced by one from the proposed eight. Don believed that the capital expense for the abiotic monitoring effort should not exceed five thousand dollars.

There was concern expressed by some Committee members regarding the use of PVC plastic panels versus cement blocks in regards to benthic community interactions and with the complicating effect of depth on benthic species composition. Don explained that the panel studies to be done from August through October are more feasibility studies, and that data collected from them will be reviewed by a group of benthic ecologists at the 1991 winter workshop.

Judy Pederson motioned and was seconded to accept the 1991 benthic study proposal which includes panel feasibility work, reconnaissance diving, plume temperature monitoring using thermographs, and the benthic ecological workshops for 1991 and 1992. The motion carried unanimously. Jerry then motioned which was seconded to terminate the quantitative three-site benthic monitoring for 1992 as currently done, to re-evaluate the benthic monitoring program design for future years based on a review of the recommendations of the upcoming benthic ecological panel meeting in winter 1991, and to implement by the summer of 1992 any revised benthic proposal accepted at a special full A-T meeting to be held in January 1992. The qualitative diving/plume mapping survey will continue as is. The motion carried, with one dissenting vote. One committee member felt the present quantitative sampling should continue through 1992 until a new benthic monitoring program is accepted by the Committee and in place.

Adjournment

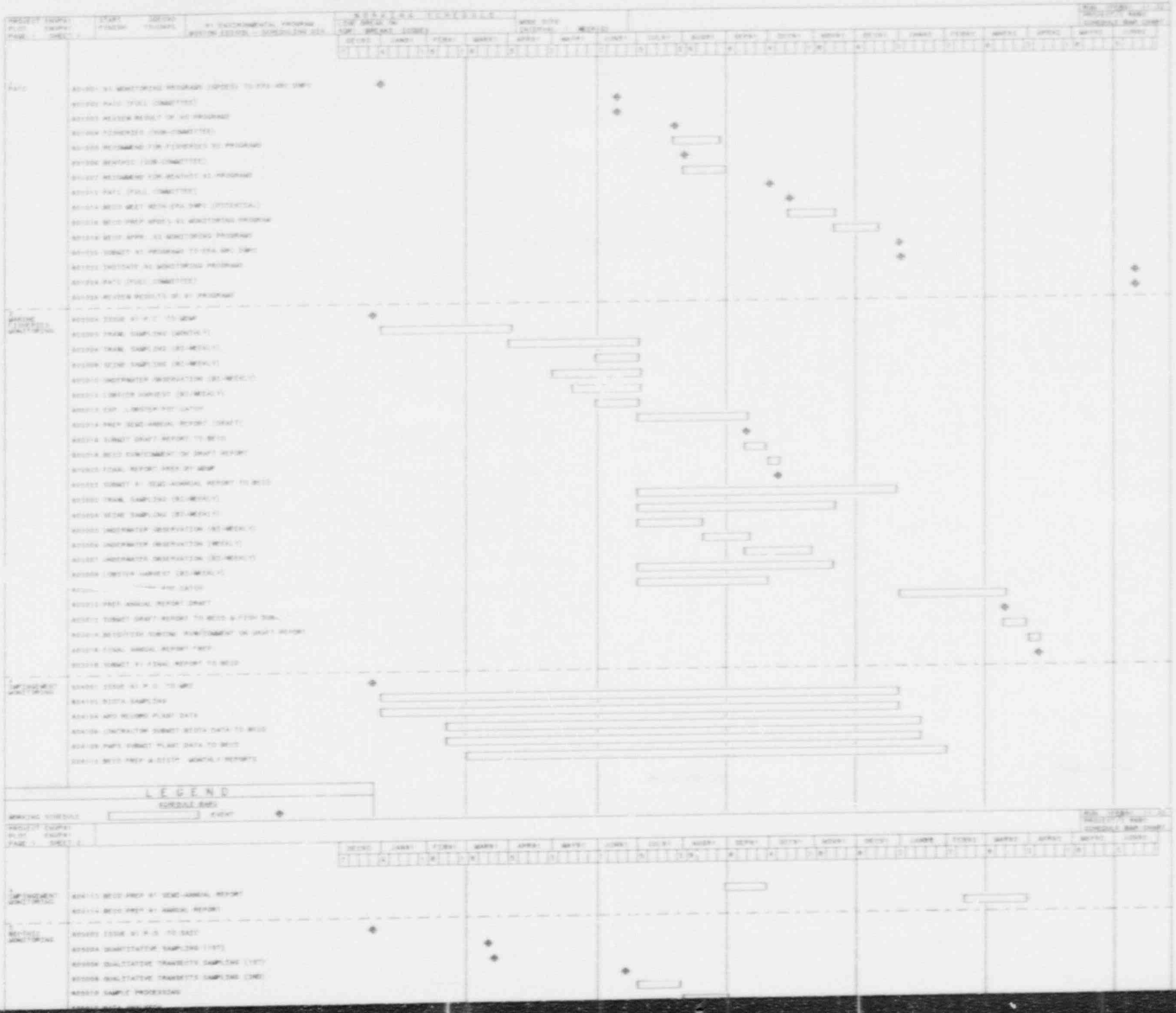
The meeting adjourned at 12:15 PM.

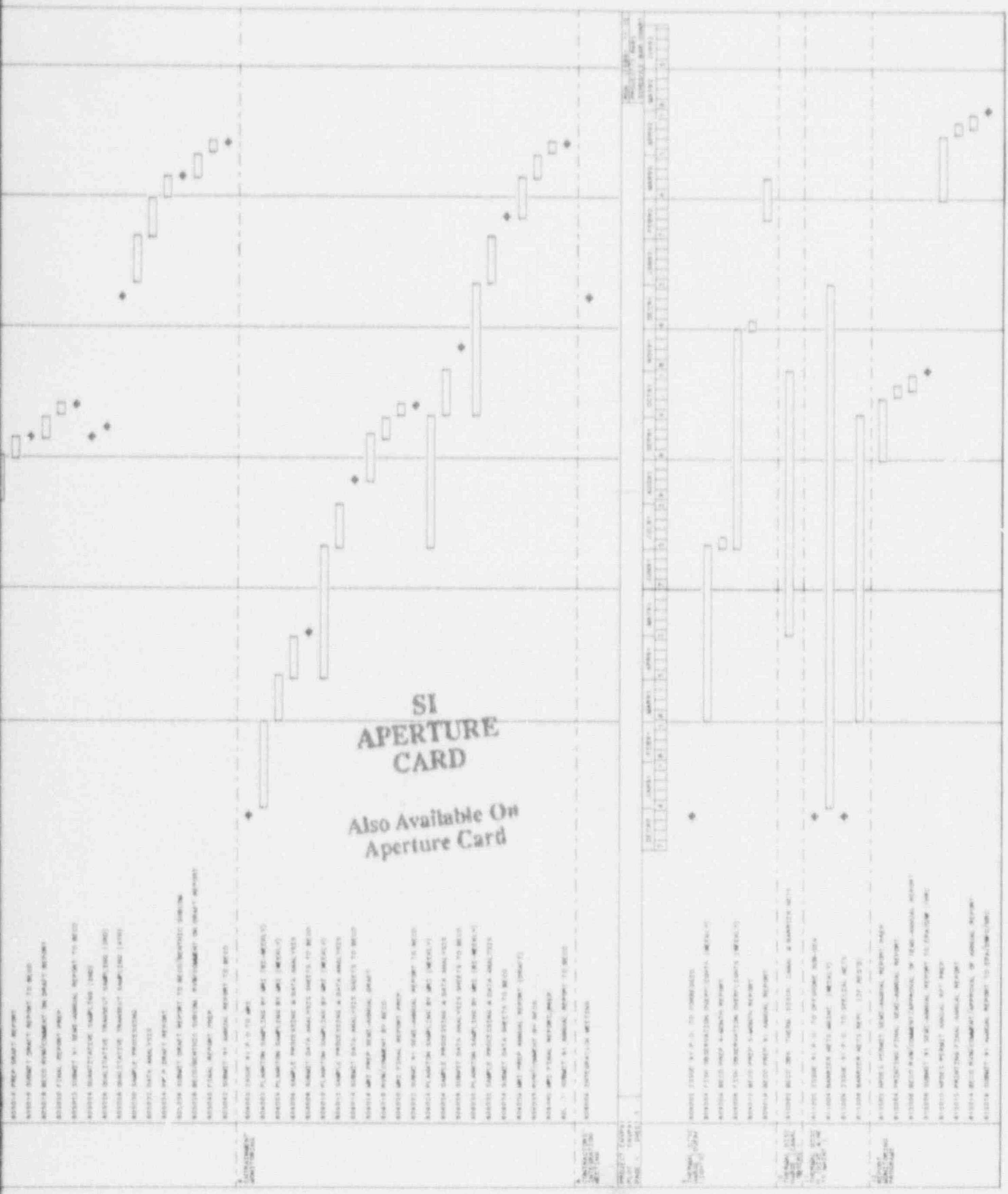
Pilgrim Administrative-Technical Committee Meeting Attendance

August 1, 1991

Gerald Szal, Chairman	DEP, Westboro
Donald C. Miller	EPA, Narragansett
Carolyn Griswold	NMFS, Narragansett
Jack Parr	EPA, Waltham
Leigh Bridges	DMF, Boston
Robert Anderson	BECo, Braintree
Robert Lawton	Mass. DMF, Sandwich
Judith Pederson	MCZM, Boston
Brian Kelly	Mass. DMF, Sandwich (recording secretary)

Figure 7. Schedule for Pilgrim Station 1991 Environmental Monitoring Programs (NPDES permit).





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