BOSTON EDISON

Pilgrim Nuclear Power Station
Rocky Hill Road
Plymouth, Massachusetts 02360

W. C. Rothert
General Manager Technical

April 21, 1994

BECo 94-042

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

NPDES PERMIT MARINE ECOLOGY MONITORING REPORT

Dear Sirs:

In accordance with Part I, Paragraphs A.8.b. & e, and Attachment A, Paragraph I.F, of the Pilgrim Nuclear Power Station NPDES Permit No. MA0003557(Federal) and No. 359 (State), Semi-Annual Marine Ecology Report No. 43 is submitted. This covers the period from January through December, 1993.

W.C. Rothert

Attachment: Semi-Annual Marine Ecology Report No. 43

WCR/RDA/nas/ECOLRPT

BOSTON EDISON

Pilgrim Nuclear Power Station
Rocky Hill Road
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W. C. Rothert
General Manager Technical

April 21, 1994

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NPDES Program Operations Section (WCP)
Environmental Protection Agency
P.O. Box 8127
Boston, MA 02114

NPDES PERMIT MARINE ECOLOGY MONITORING REPORT

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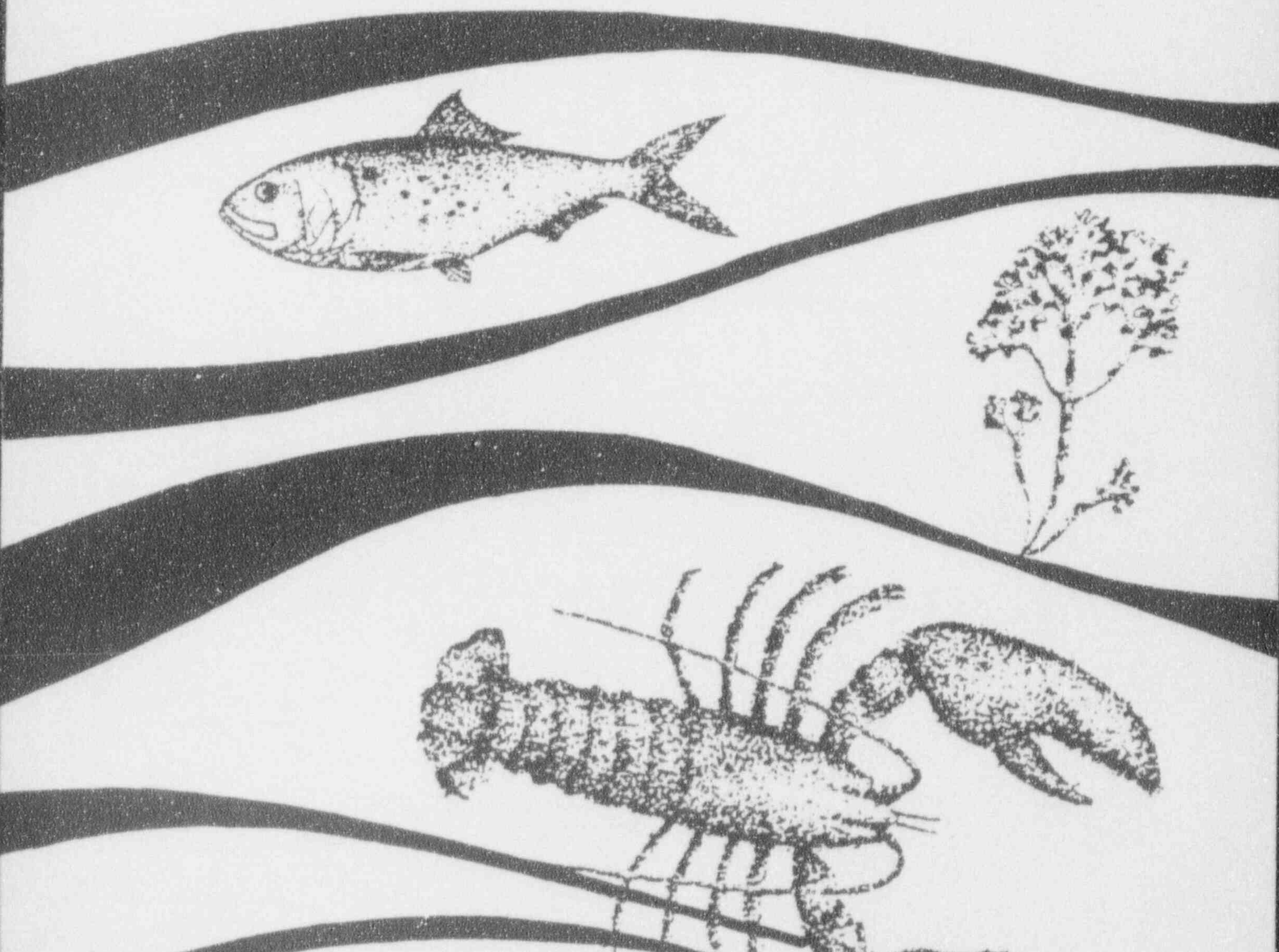
Attachment: Semi-Annual Marine Ecology Report No. 43

WCR/RDA/nas/ECOLRPT

marine ecology studies

Related to Operation of Pilgrim Station

SEMI-ANNUAL REPORT NUMBER 43
JANUARY 1993 – DECEMBER 1993



BOSTON EDISON COMPANY
LICENSING DIVISION

BOSTON EDISON
800 Boylston St. Boston, MA 02199

MARINE ECOLOGY STUDIES
RELATED TO OPERATION OF PILGRIM STATION

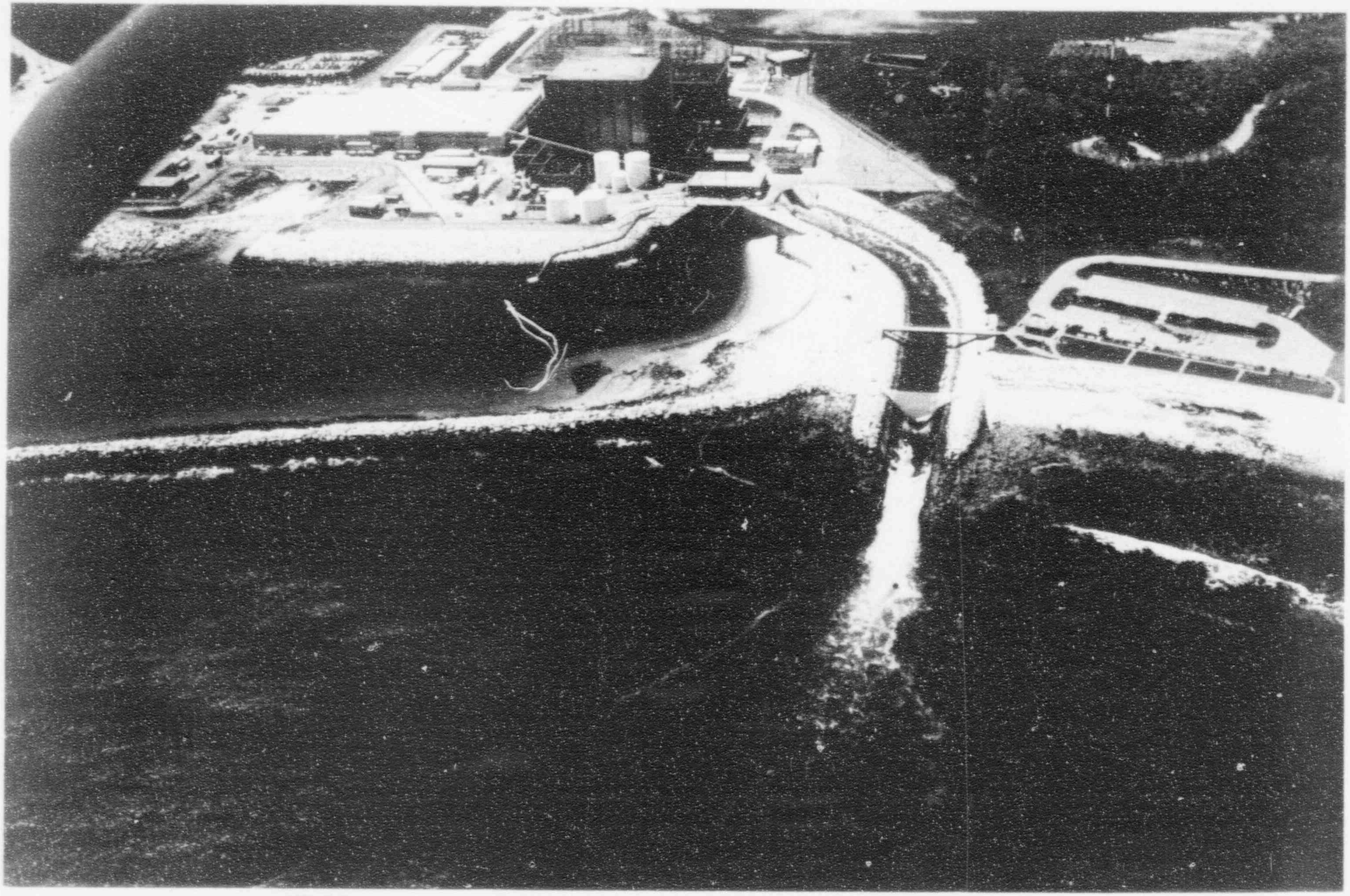
SEMI-ANNUAL REPORT NO. 43

REPORT PERIOD: JANUARY 1993 THROUGH DECEMBER 1993

DATE OF ISSUE: APRIL 30, 1994

Compiled and Reviewed by: Robert D. Anderson
Robert D. Anderson
Principal Marine Biologist

Licensing Division
Boston Edison Company
Pilgrim Nuclear Power Station
Plymouth, Massachusetts 02360



Pilgrim Nuclear Power Station

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SUMMARY

Highlights of the Environmental Surveillance and Monitoring Program results obtained over this reporting period (January - December 1993) are presented below. (Note: PNPS was operating at high power level from January - December 1993 with the exception of a refueling outage (RFO 9) during April and May.)

Marine Fisheries Monitoring:

1. In the late June - mid-October 1993 shorefront sportfish survey at Pilgrim Station, 1,391 angler visits accounted for 461 fishes caught. Bluefish (87%) and striped bass (13%) comprised the sportfish catch. The presence of a strong thermal discharge component during most of 1990-1993 resulted in good sportfishery success compared with outage and low power years covering the shorefront angling season.

2. Shrimp trawl catch for 1993 recorded 24 benthic fish species with little skate (43%), winter flounder (20%) and windowpane (15%) composing 78% of the total. Mean CPUE for all species was lowest (44.8) at the Pilgrim Intake station, highest (66.2) at the Pilgrim Discharge station and 57.5 for all stations pooled in 1993. The presence of a large number of small winter flounder caught in the Pilgrim intake from 1984-1992 indicates this area may serve a nursery function for this species, but this wasn't as apparent from 1993 data; however, 1993 groundfish diving transect results recorded the highest abundance of winter flounder in the intake embayment.

3. The lobster research study, which commenced in 1986, found no consistent relationships between discharge canal proximity and lobster catch rates in 1993. A total of 6,465 lobsters were sample from June - September.

4. In May - October 1993 fish observational dive surveys, 6 species (774 fishes) were observed in the thermal plume area. Cunner (41%), striped bass (33%) and tautog (16%) were the most numerous fishes seen, the latter two species being most abundant in the direct path of the Pilgrim discharge current. Total number of fishes observed was 23% higher than in 1992, primarily because of more striped bass and bluefish seen. Most fishes were in greatest concentrati ns at stations in the discharge zone (80%), followed by the control zone (13%) and the stunted zone (7%). These results were different than 1984/1987/1988 (outage years with reduced discharge current), when most fish were observed relatively evenly divided between discharge and control zones, and similar to 1985/1986/1989-1992 (higher discharge current years) when fish seemed to greatly favor being in the path of the effluent.

5. A total of 2,613 cunner were tagged in 1990-1993 and 517 (20%) recovered in the Pilgrim vicinity. Time at large and locations of recovered fish indicate that movement of this species is local which reflects its residential nature. Initial local population estimates of adult cunner residing in the Pilgrim intake breakwater vicinity were from 4,000-5,000 individuals for 1992. The 1993 estimate is not yet available. Prelimary winter flounder tagging around the Plymouth-Kingston-Duxbury Bay estuary began in 1993 to estimate adult population size and Pilgrim Station impact.

Impingement Monitoring:

1. The mean January - December 1993 impingement collection rate was 2.78 fish/hr. The rate ranged from 0.07 fish/hr (July) to 15.19 fish/hr. (December) with rainbow smelt comprising 39.2% of the catch, followed by Atlantic silverside 38.4%, winter flounder 4.8%, alewife 2.8% and grubby 2.7%. Fish impingement rates in 1985, 1986 and 1989 - 1993 were several times higher than in 1984, 1987

and 1988 when Pilgrim Station outages had both circulating water pumps off for various periods of time.

2. In December 1993, rainbow smelt impingement accounted for 91% of this species annual collection. They have been the most abundant species impinged on an annual basis at Pilgrim Station in only two other years, 1987 and 1978.

3. A large, fish impingement incident was noted from December 15-28 when a rate of 25.38 fish/hour (16.78 smelt/hour) was recorded, resulting in an estimated mortality of approximately 5,100 rainbow smelt (mostly juveniles).

4. The mean January - June 1993 invertebrate collection rate was 0.97+/hr, with ctenophores and sevenspine bay shrimp dominating. Rock crabs (17.1%) and American lobster (13.9%) accounted for 31% of the catch. Ninety-one American lobsters were sampled. The invertebrate impingement rates in 1985, 1986 and 1989 - 1993 were similar to those recorded at Pilgrim Station during the 1987 and 1988 outage years, despite lower circulating water pump availability in these outage years.

5. Impinged fish, initial survival in the Pilgrim Station intake sluiceway was approximately 57% during static screen washes and 88% during continuous washes. Eight of the dominant species showed greater than 50% survival, overall.

Fish Surveillance.

Fish overflights in 1993 spotted all four major species categories: herring, Atlantic menhaden, Atlantic mackerel and baitfish. Sightings in the nearfield Pilgrim vicinity were made of Atlantic herring and menhaden. On August 22 a high of 185,000 pounds of herring, and in May and June smaller quantities of menhaden, were observed within a few miles of Pilgrim Station. None of these occurrences

were reported to regulatory authorities as they were not within 1/2 mile of the discharge canal.

Benthic Monitoring

Four observations of the discharge, near-shore acute impact zones were performed during this reporting period. Denuded and stunted zone boundaries were indistinguishable during September 1987 - June 1989 discharge surveys as a result of the PNPS shutdown. These surveys noted delineated, denuded impact areas in fall 1989 - 1993, primarily because two circulating water pumps were in operation most of the time, resulting in maximum discharge current flow. The area of PNPS-induced scouring impacts varied from 1055 m^2 (June) to 1,648 m^2 (September) in 1993. The total affected area by the thermal plume in December 1993 (2,242.5 m^2) was the largest ever seen during this study, in part due to heavy infestation by encrusting bryozoans on Irish moss.

Entrainment Monitoring

1. A total of 38 species of fish eggs and/or larvae were found in the January - December 1993 entrainment c[illegible]ctions (19-eggs, 37-larvae).

2. Seasonal egg collections for 1993 were dominated by American plaice (winter - early spring); Atlantic mackerel and labrids (late spring - early summer); Atlantic menhaden (late summer - autumn).

3. Seasonal larval collections for 1993 were dominated by grubby and sand lance (winter - early spring); sand lance, radiated shanny and winter flounder (late spring - early summer); cunner, Atlantic menhaden and fourbeard rockling (late summer - autumn).

4. One lobster larva was collected in the entrainment samples for 1993, the first since 1990.

5. In 1993 an estimated 6.442×10^9 fish eggs and 1.973×10^8 fish larvae were entrained at Pilgrim Station, assuming full flow capacity of all seawater pumps. On an annual basis, eggs were dominated b. Atlantic menhaden, Atlantic mackerel and the labrid - Pleuronectes group, and larvae by sand lance sp. and sculpin spp.

6. Total numbers of fish larvae collected for similar volumes of water sampled in spring/summer 1983 - 1992 were noteably different for certain years. These results were shown significant to the fact that Pilgrim Station circulating water withdrawal rate (number of pumps operating) affects number of larvae entrained; however, fish eggs appear relatively unaffected by this variable. Limited comparable data from 1993 support these results.

7. On one occasion in 1993 an "unusually abundant" ichthyoplankton density was recorded involving Atlantic menhaden eggs (September 21), as defined by the entrainment contingency sampling plan, reflecting a strong nearshore autumn spawning for this species.

8. The mean annual losses attributable to PNPS entrainment for the adult stage of three abundant species of fish over the period 1987-1993 were as follows: cunner, 54,763; Atlantic mackerel, 6,617; winter flounder, 466-5,668. None of these losses for the species concerned were found to be significant in the context of population or fishery effects although comprehensive population/impact studies are presently being conducted for cunner and winter flounder.

INTRODUCTION

A. Scope and Objective

This is the forty-third semi-annual report on the status and results of the Environmental Surveillance and Monitoring Program related to the operation of Pilgrim Nuclear Power Station (PNPS). The monitoring programs discussed in this report relate specifically to the Cape Cod Bay ecosystem with particular emphasis on the Rocky Point area. This is the thirty-first 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 the 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 1993, 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 V.

B. Marine Biota Studies

1. Marine Fisheries Monitoring

A modified version of the marine fisheries monitoring, initiated in 1981, was 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 were monitored. In 1981, shrimp trawling was initiated which provides PNPS impact-related sampling of benthic fish. Shrimp trawling was done twice/month (April - December) at 4 stations (Figure 1). Gill net sampling for pelagic fishes was suspended in 1993 after over 20 years of data collection.

Monitoring was terminated in 1993 of local lobster stock catch statistics for areas in the proximity of Pilgrim Station. Catch statistics were collected approximately biweekly throughout the fishing season (May - November) from 1970 - 1992.

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 1) in the PNPS thermal plume area.

In 1986, an experimental, lobster pot trawl monitoring effort was initiated to facilitate the collection of lobster stock catch statistics for determining PNPS effects. Nine 5-pot lobster trawls were fished in the thermal plume and control areas around PNPS during 1993 (Figure 2).

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

2. <u>Benthic Monitoring</u>

The benthic monitoring described in this report was conducted by Scientific Applications International Corporation, Woods Hole, Massachusetts.

Retrospective program and physical thermal plume analysis were conducted or planned to recommend the most applicable future studies to be performed. Qualitative transect sampling off the discharge canal to determine the extent of the denuded and stunted algal zones was continued four times a year (March, June, September and December).

Results of the benthic monitoring and impact analysis during this period are discussed in Section IIIB.

3. <u>Plankton Monitoring</u>

Marine Research, Inc. (MRI) of Falmouth, Massachusetts, has been monitoring entrainment in Pilgrim Station cooling water for fish eggs and larvae, and lobster larvae (from 1973-1975 phytoplankton and zoo-plankton were also studied). Figure 3 shows the entrainment contingency sampling

station locations to be sampled should the number of eggs/larvae entrained greatly exceed recorded historical averages. Information generated through this monitoring has been utilized to make periodic modifications in the sampling program to more efficiently address the question of the effects of entrainment. These modifications have been developed by the contractor, and reviewed and approved by the PATC on the basis of the program results. Plankton monitoring in 1993 emphasized consideration of ichthyoplankton entrainment and selected species adult equivalency analyses. Results of the ichthyoplankton entrainment monitoring and impact analysis for this reporting period are discussed in Section IIIC.1 and IIIC.2.

4. Impingement Monitoring

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

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

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

C. Fish Surveillance Studies

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

An annual summary report for this effort for 1993 is presented in Section IVA.

D. Station Operation History

The daily average reactor thermal power levels from January through December, for 1988-1993 are shown in Figure 4. As can be seen, PNPS was in a high operating stage during most of this reporting period with a 1993 capacity factor (MDC) of 74.0%. Cumulative capacity factor from 1973-1993 is 50.2%.

E. 1993 Environmental Programs

A planning schedule bar chart for 1994 environmental monitoring programs related to the operation of Pilgrim Station, showing task activities and milestones from December 1993 - June 1995, is included after Figure 4.

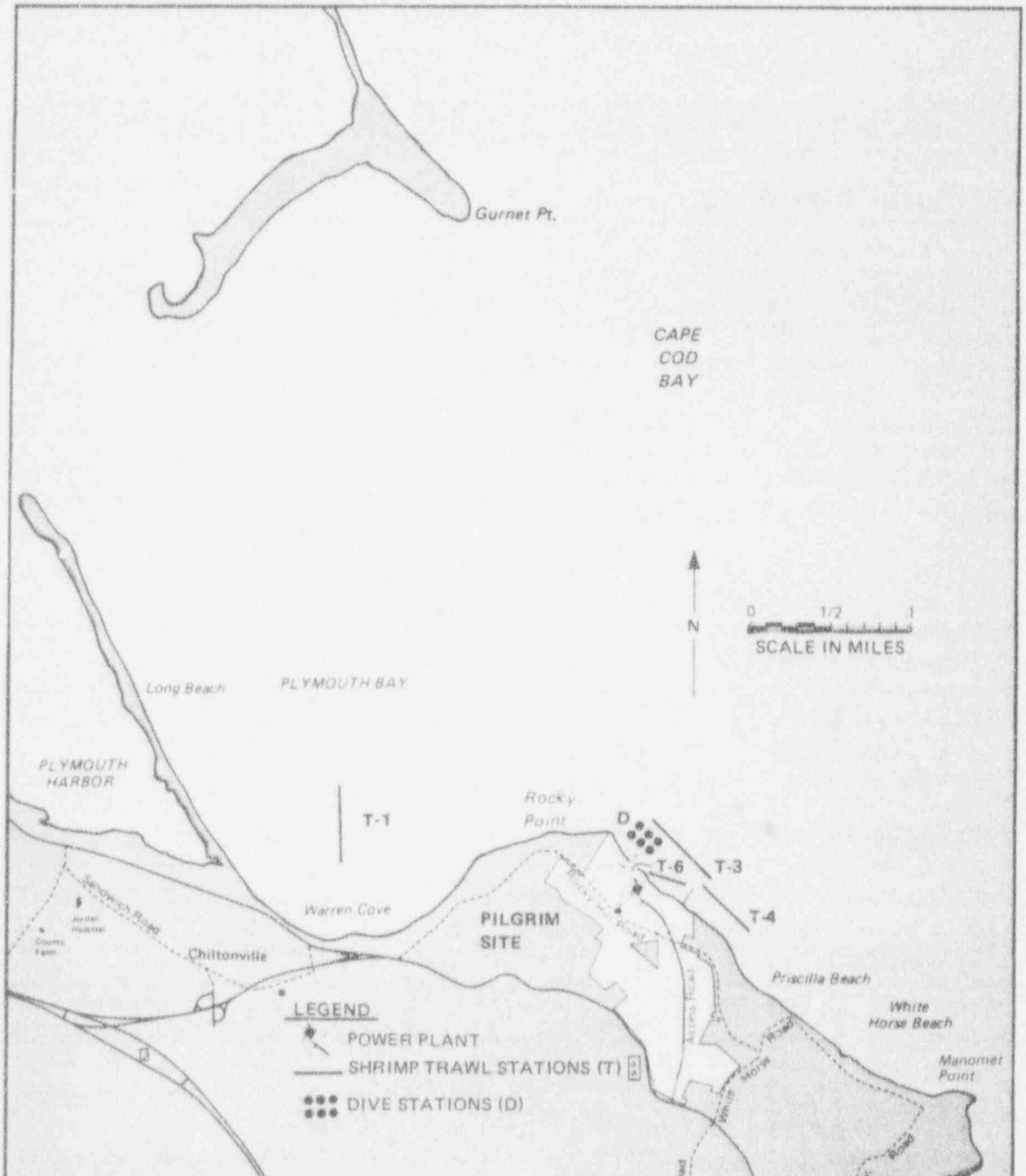

Figure 1. Location of Shrimp Trawl and Dive Sampling Stations for Marine Fisheries Studies

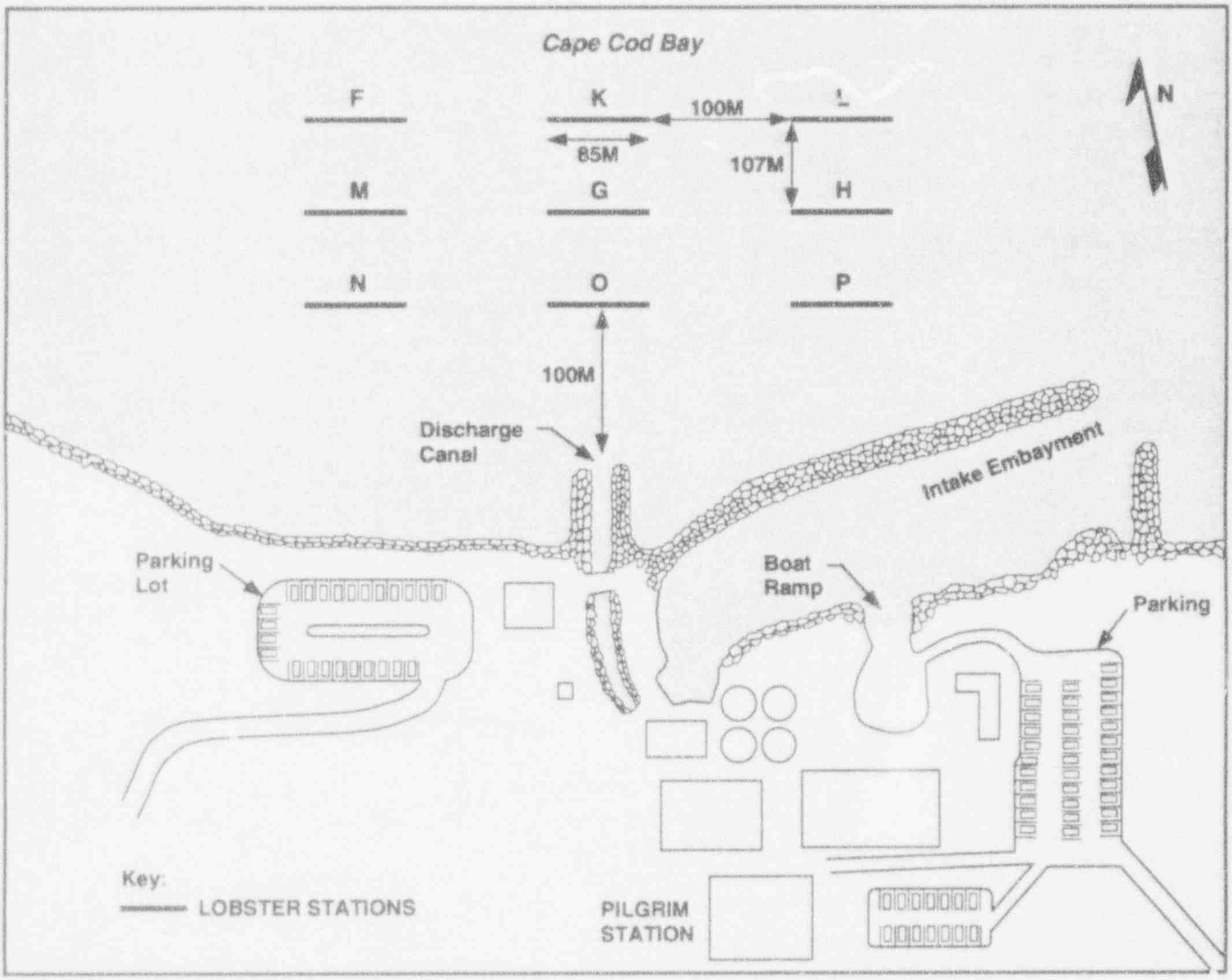

Figure 2. Diagram of Experimental Lobster Stations, 1993 (not drawn to scale).

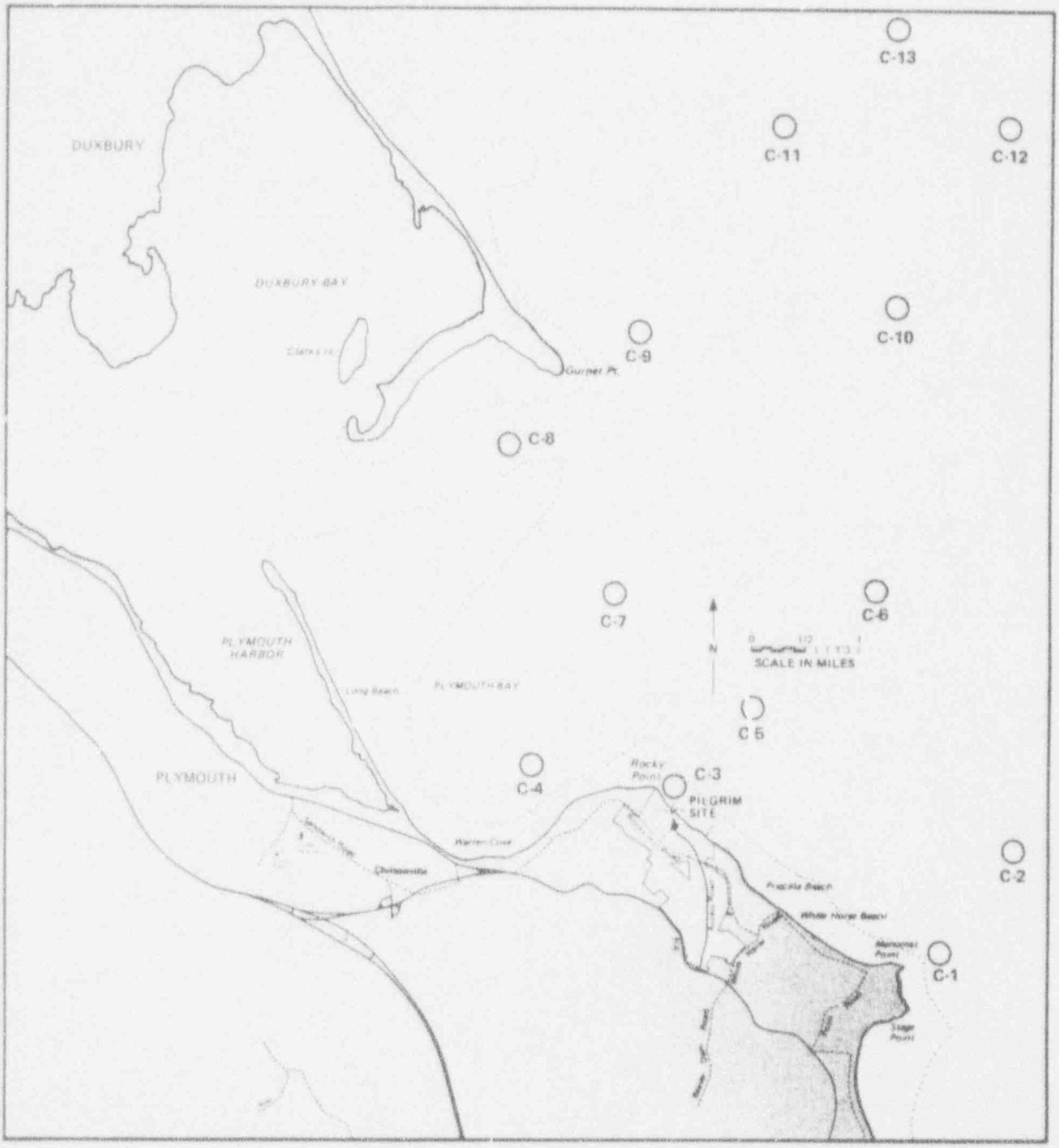

Figure 3. Location of Entrainment Contingency Plan Sampling Stations, C.

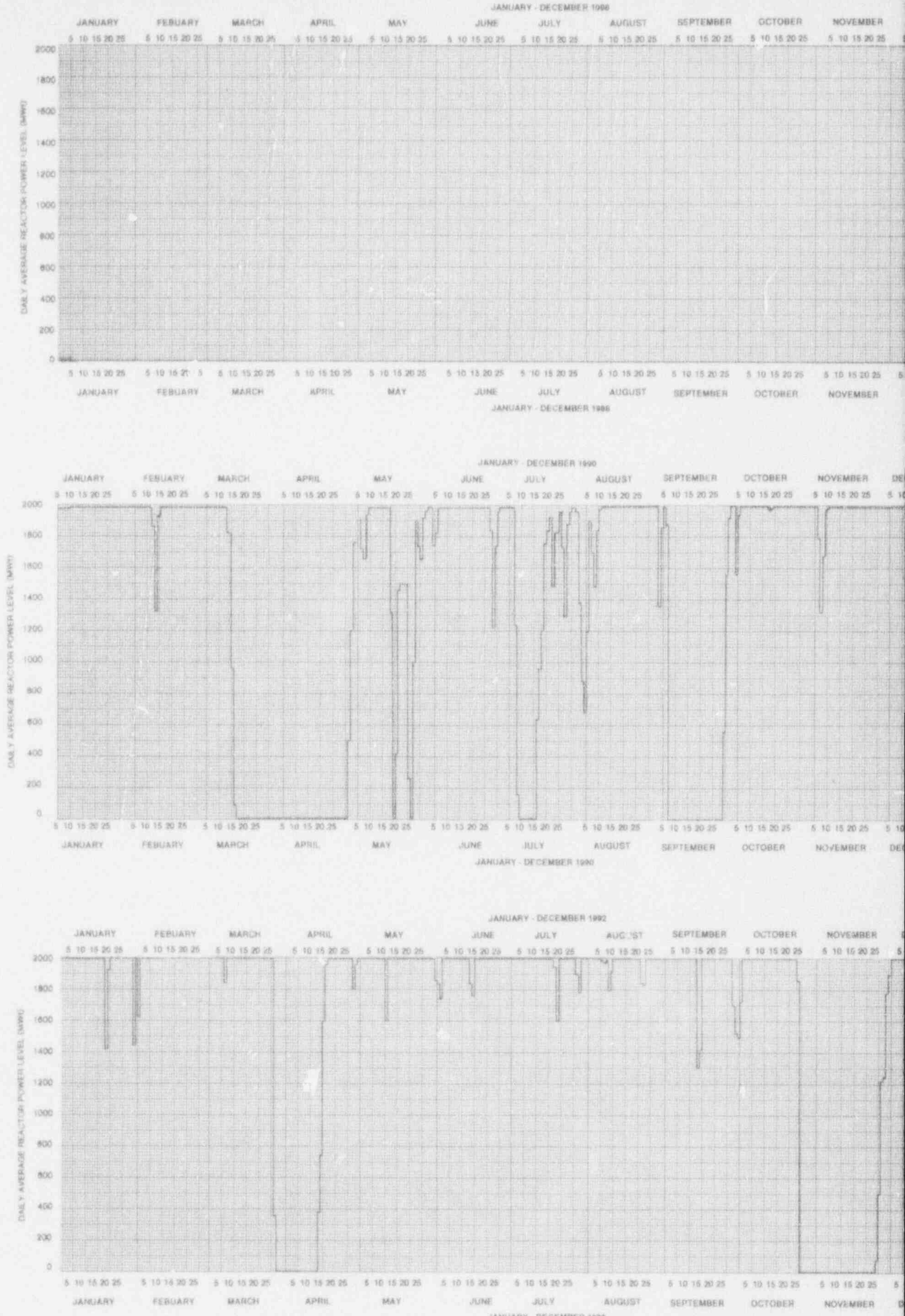

FIGURE 4. Daily Average Reac
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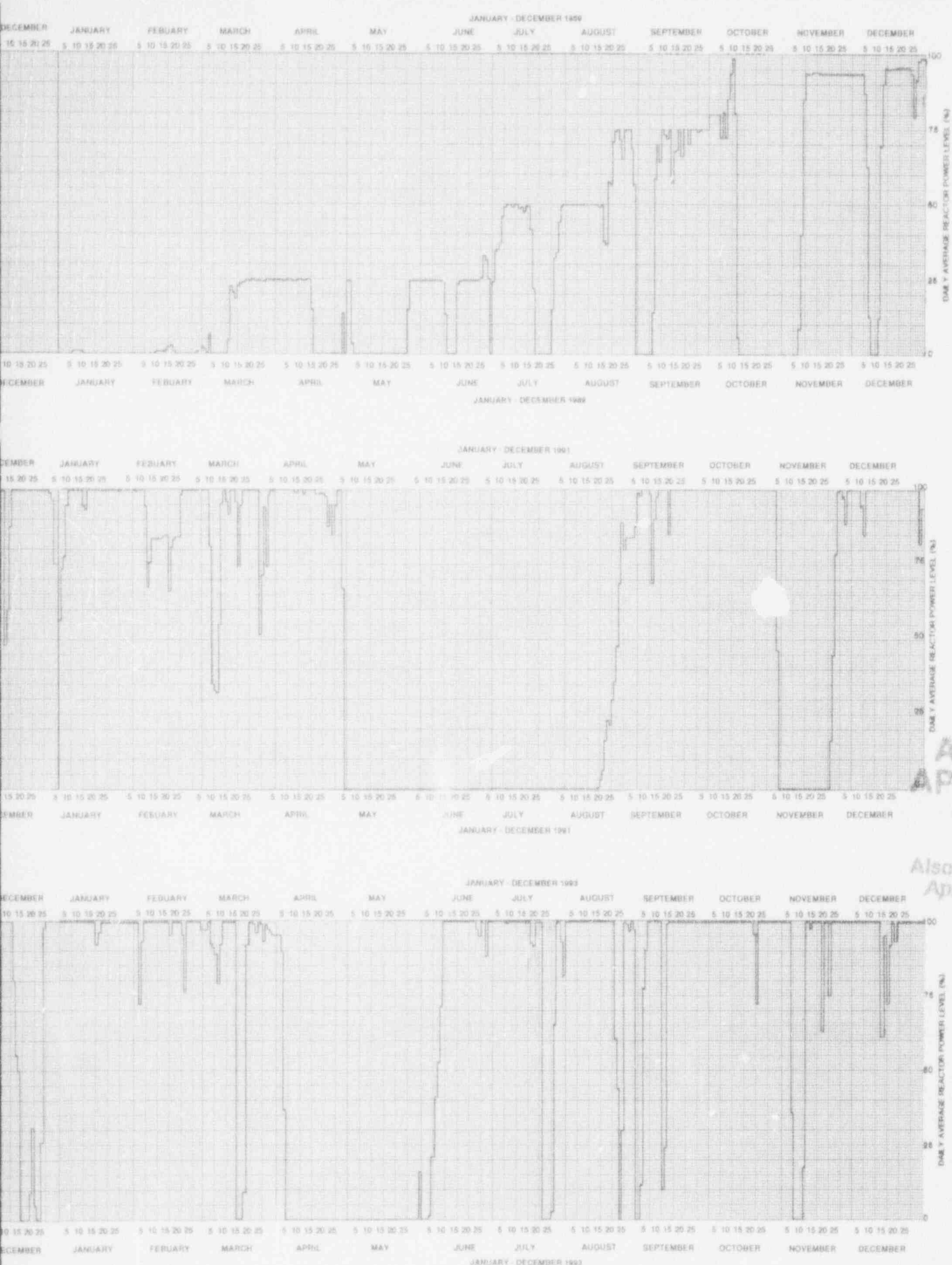

...tor Thermal Power Level (MW_t and %) from
...mber 1993 for Pilgrim Nuclear Power Station.

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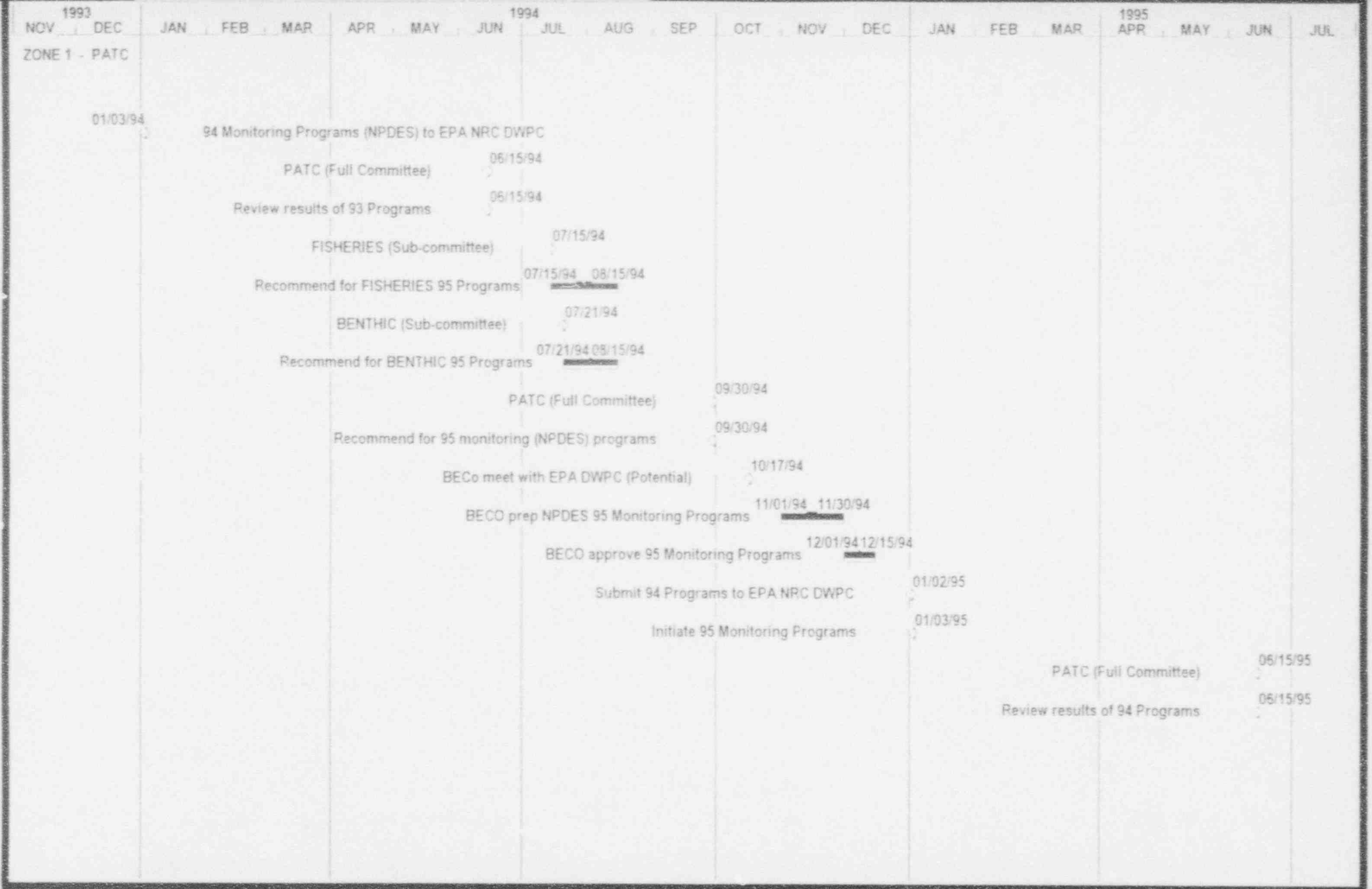
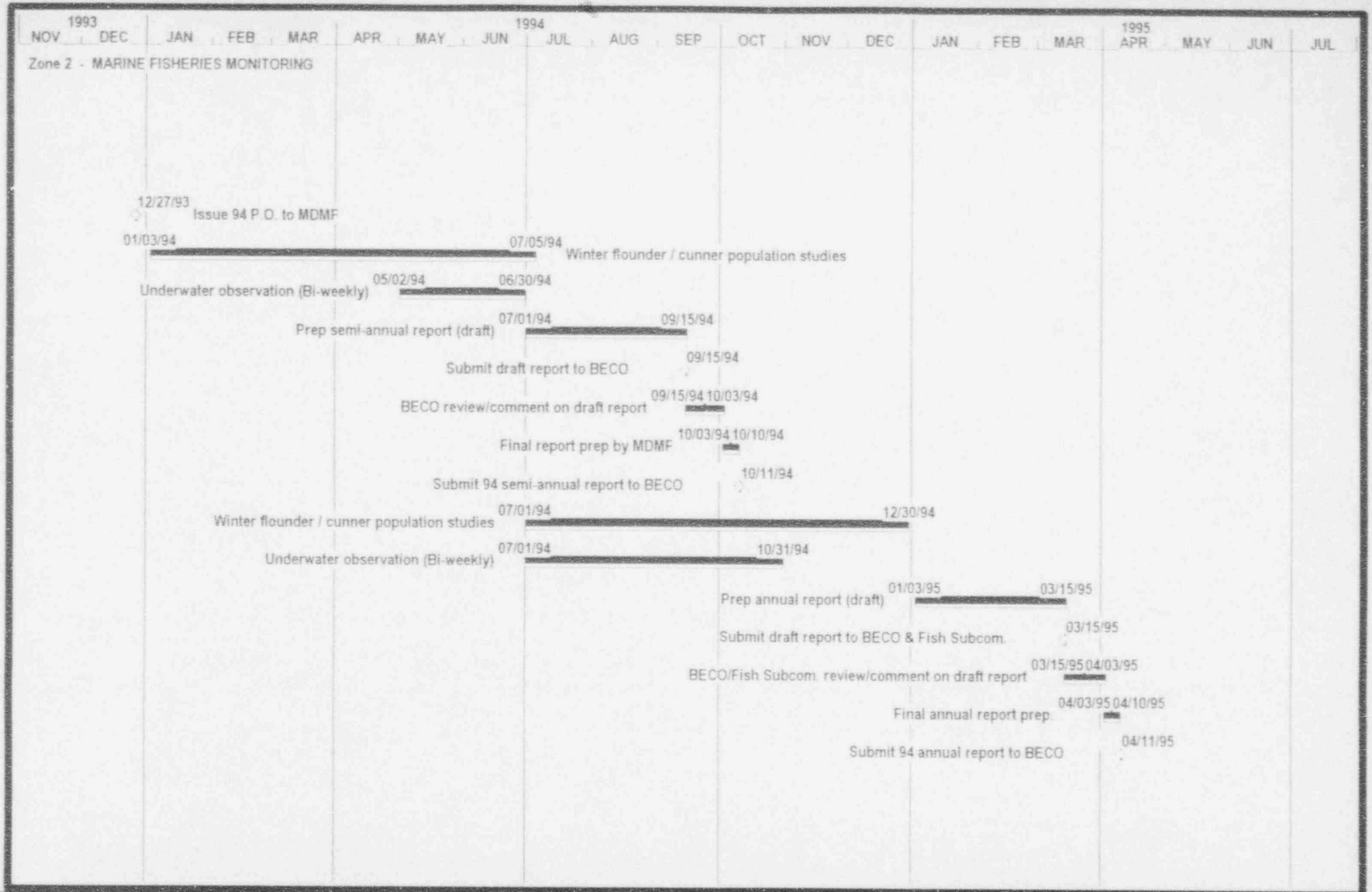


PNPS 1994 ENVIRONMENTAL PROGRAMS

(NPDES PERMIT #MA 0003557)



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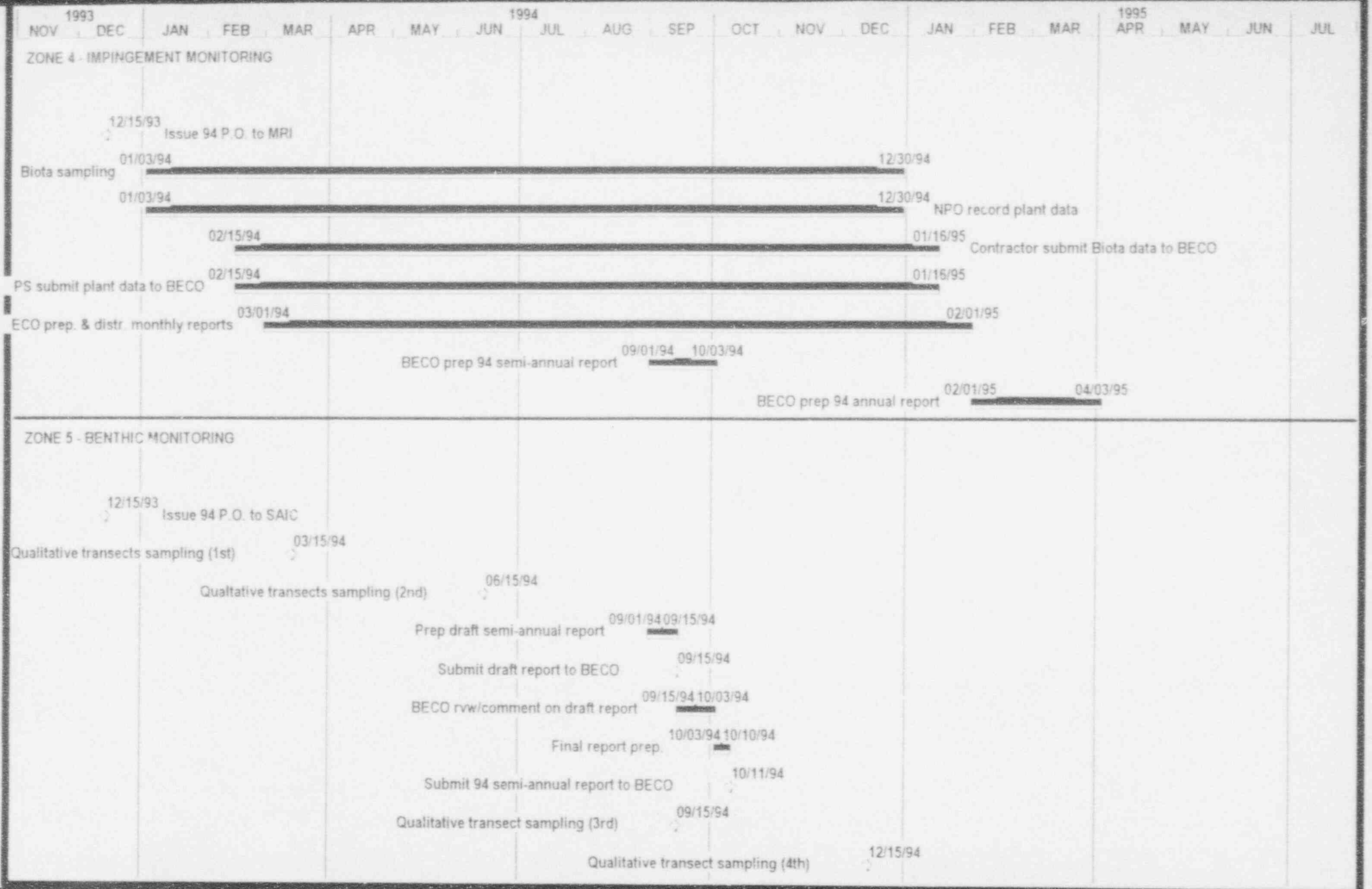


PNPS 1994 ENVIRONMENTAL PROGRAMS

(NPDES PERMIT #MA 0003557)

1993 NOV DEC | 1994 JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC | 1995 JAN FEB MAR APR MAY JUN JUL

prep draft annual report 02/15/95 03/15/95

Submit draft report to BECO/Benthic Subcom. 03/15/95

BECO/Benthic Subcom. rvw/comment on draft report 03/15/95 04/03/95

Final report prep. 04/03/95 04/10/95

Submit 94 annual report to BECO 04/11/95

ZONE 6 - ENTRAINMENT MONITORING

12/15/93 Issue 94 P.O. to MRI

01/03/94 02/28/94 Plankton sampling by MRI (Bi-weekly)

Plankton sampling by MRI (weekly) 03/01/94 03/31/94

Sample processing & data analysis 04/01/94 05/02/94

Submit data analysis sheets to BECO 05/02/94

Plankton sampling by MRI (weekly) 04/01/94 06/30/94

Sample processing & data analysis 07/01/94 08/01/94

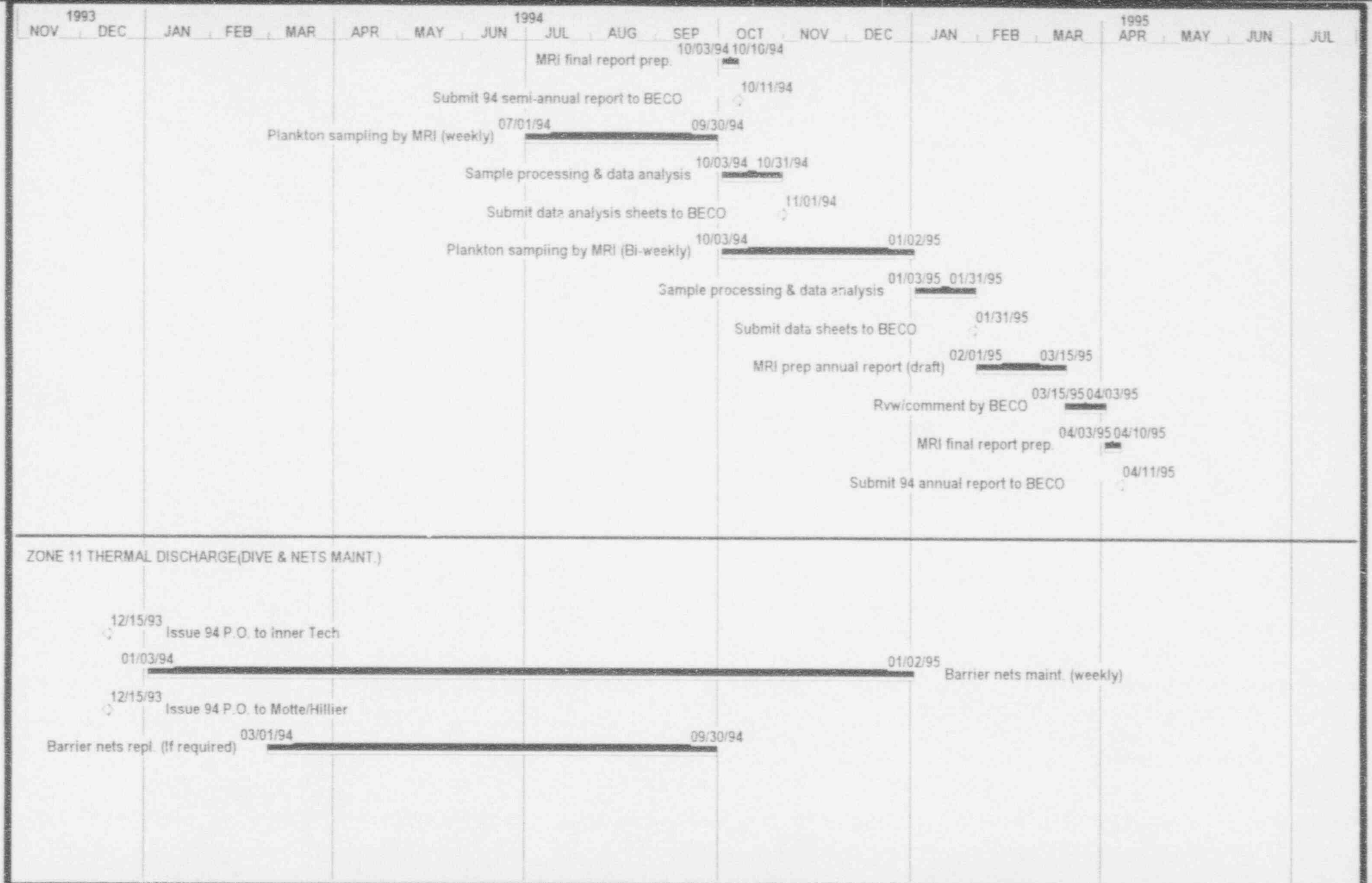
Submit data analysis sheets to BECO 08/02/94

MRI prep semi-annual draft 08/16/94 09/15/94

Rvw/comment by BECO 09/15/94 10/03/94

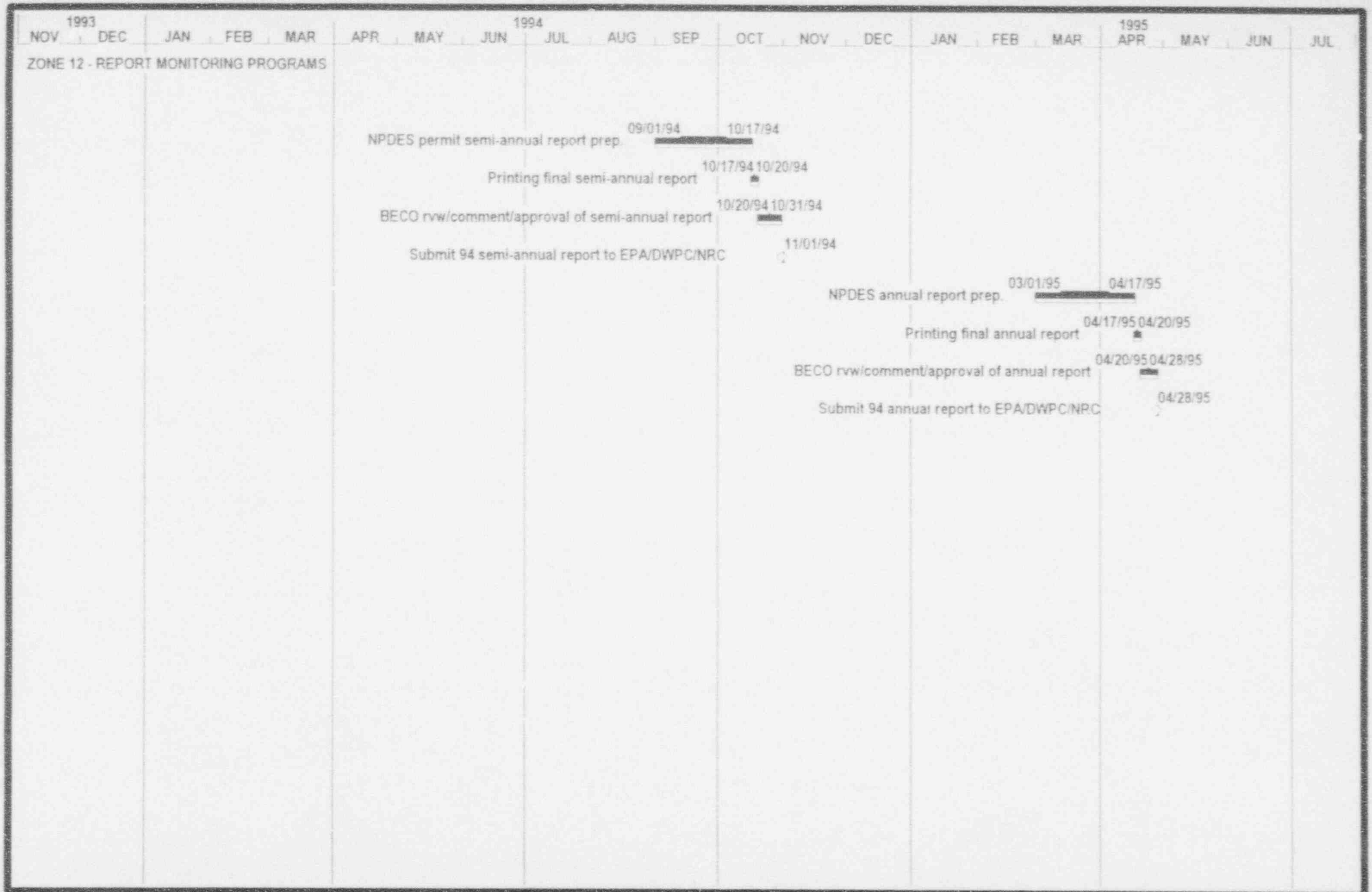
PNPS 1994 ENVIRONMENTAL PROGRAMS

(NPDES PERMIT #MA 0003557)



PNPS 1994 ENVIRONMENTAL PROGRAMS

(NPDES PERMIT #MA 0003557)



PNPS 1994 ENVIRONMENTAL PROGRAMS

(NPDES PERMIT #MA 0003557)

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

(CHARACTERIZATION OF FISHERIES RESOURCES)

Project Report No. 56 (January-December, 1993)

(Volume 1 of 2)

By

Robert P. Lawton, Brian C. Kelly,
Vincent J. Malkoski, John Chisholm,
Paul Nitschke and William O'Brien

April 1, 1994
Massachusetts Department of Fisheries,
Wildlife, and Environmental Law Enforcement
Division of Marine Fisheries
100 Cambridge Street
Boston, Massachusetts 02202

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I. EXECUTIVE SUMMARY

A modified version of marine fisheries monitoring for Pilgrim Nuclear Power Station, initiated in 1981 and refined in 1992, was conducted by the Massachusetts Division of Marine Fisheries in 1993. The occurrence, distribution, and relative abundance of finfish and lobster were monitored according to standardized sampling schemes to identify trends and relationships in the sampling data collected from the study area over time. We focused our efforts on commercially and recreationally important fisheries resources. Nearshore bottom trawling, experimental lobster trapping, diver observations near the discharge canal and also along supplemental diving transects near trawl stations, cunner tagging, and a sportfishing creel survey rounded out investigations.

Three groundfish, winter flounder, little skate, and windowpane, comprised 78% of the total fish captured in the trawl survey. The overall number of fish sighted during the discharge diving study increased, due primarily to a substantial increase in the sightings of bluefish and striped bass. Angling effort at the Shorefront decreased from last year, as did the sportfish catch rate. Tag returns of cunner from three tagging areas near Pilgrim Station indicate that there is very limited summer movement of cunner, with recapture rates reaching 20% in 1993. Lobster catch rates from the research lobster study indicated no trends relative to the Pilgrim Station discharge. A total of 189 adult winter flounder were fin-clipped in the vicinity of Pilgrim Station and

adjacent Plymouth-Kingston-Duxbury Bay in a preliminary effort to determine adult population size.

II. INTRODUCTION

A field sampling program was conducted in 1993 by the Massachusetts Division of Marine Fisheries (DMF) to assess impact of Pilgrim Nuclear Power Station (PNPS) on the marine environment, under Purchase Order No. LBR107003 to Boston Edison Company (BECo). Our sampling employs various gear types and strategies to characterize the lobster and numerous finfish populations present in the Pilgrim area. Data were collected from impact and comparable reference stations. When possible, we have established more than one reference site to address natural variability.

The biological variables of interest are distribution, abundance, and size. We followed a standardized sampling regime and obtained measurements and counts, on which statistical tests were run.

Volume 1 focuses on characterizing the fisheries resources in the Pilgrim area as a whole. Essential findings are presented as our intent is to condense the subject matter but maintain clarity of data reporting and interpretation.

III. METHODS AND MATERIALS

For a comprehensive description of sampling station locations, gear and equipment, and the techniques employed in our monitoring program, the reader is referred to Semi-Annual Report No. 54 (January-December 1992): Section 3: pp 4-9, in the report series entitled Marine Ecology Studies Related to Operation of Pilgrim Station published by Boston Edison Company. The overall study area is depicted in Figure 1. We will address here only those areas of change or modification to the existing program of study. Methods and materials are otherwise the same as those reported for 1992 in the above reference.

In 1993, cunner tagging continued with a focus on obtaining a population estimate with which to compare entrainment at Pilgrim Station. Cunner were tagged this past summer at three sites to obtain information on movement and population size. To identify individual fish, we have employed the Floy FD-68BC T-bar anchor tag, which is 58 mm (2.3 in) long and weighs 0.11 g (3.9×10^{-3} oz). The tags are printed with individual numbers along with the agency phone number. Tags were one of three colors: white at Rocky Point, yellow at the outer breakwater, and blue at White Horse Beach. A mark and recapture protocol was used throughout the sampling season with data to be analyzed by the Jolly-Seber model.

Our underwater operations, both observational surveys and trawl transect dives followed the techniques used last year; Figure 2 pictures the sampling tool used in trawl transect surveys. The format was changed in 1992, and an in-depth explanation of

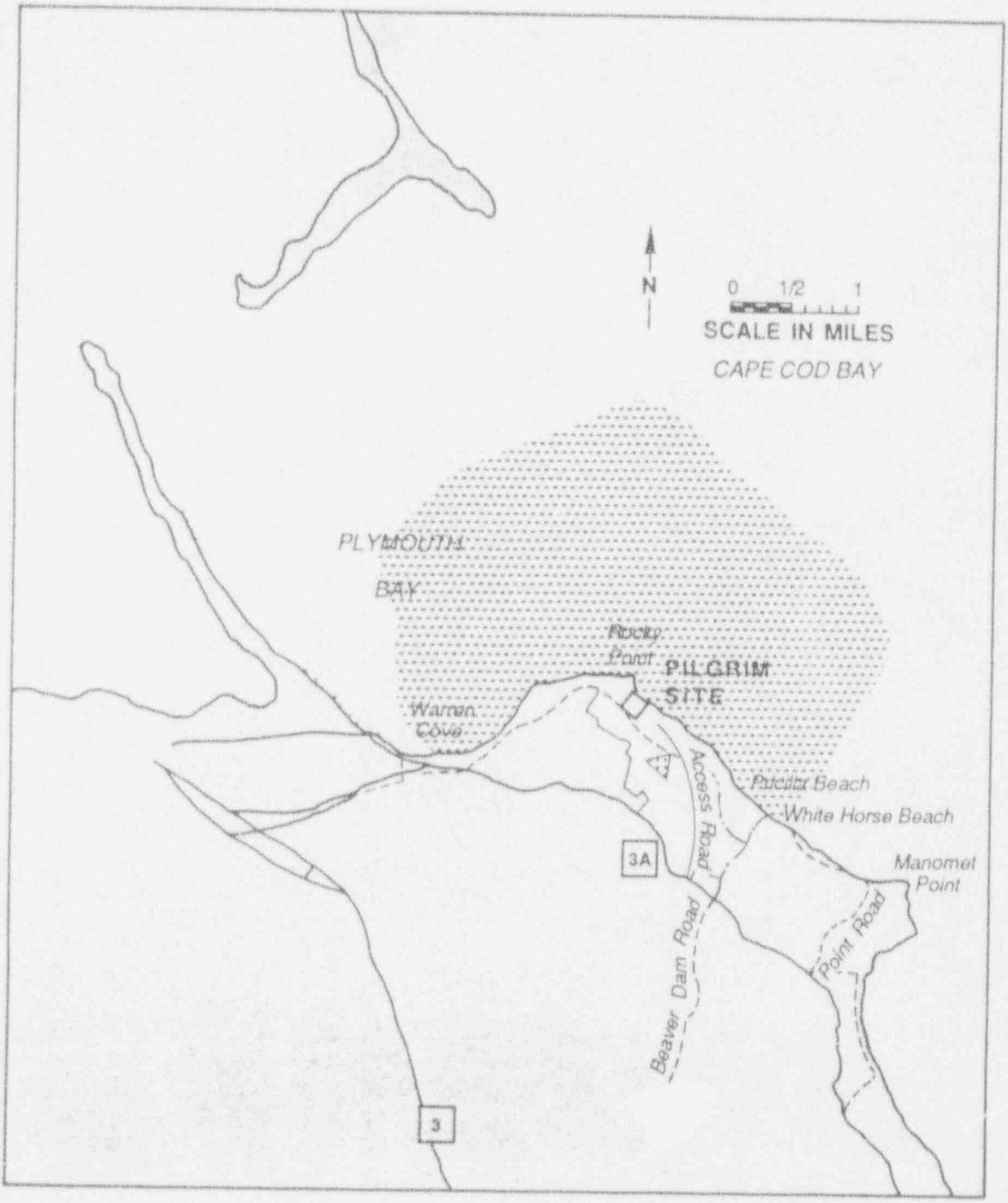

Figure 1. Location of Marine Fisheries study area (hatched) for trawl, cunner mark and recapture, lobster, dive, and sportfish surveys in the Pilgrim area.

procedures is found in Semi-Annual Report No. 54 (January-December 1992): Section 3: pp 4-9, in the report series entitled Marine Ecology Studies Related to Operation of Pilgrim Station. In addition to our fixed-station groundfish trawl survey, we began preliminary sampling that employs different procedures for our upcoming winter flounder population study.

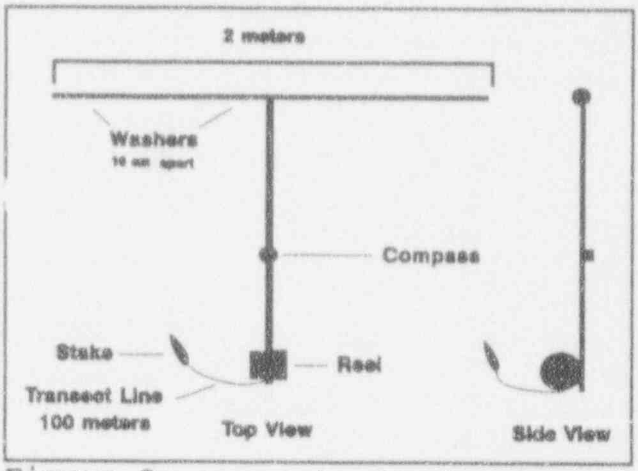

Figure 2. Survey tool used by divers for abundance and size estimation along trawl transects in the Pilgrim Station area.

The objective of our research lobster study was to determine if the thermal effluent causes a spatial shift in the distribution of lobster off Pilgrim Station. We examine for alterations in catch rate and size composition. We altered the configuration of our lobster trawl locations by establishing a gradient of sampling both offshore and alongshore. Baited standardized wire lobster traps were used to sample the nine fixed stations (Figure 3). A standard two-day soak was used between samples. The traps were fished in five-pot trawls set parallel to shore, one trawl set at each station. Stations O, G, and K are located in direct line with the thermal plume and the other six stations (three on each side of the discharge) are controls.

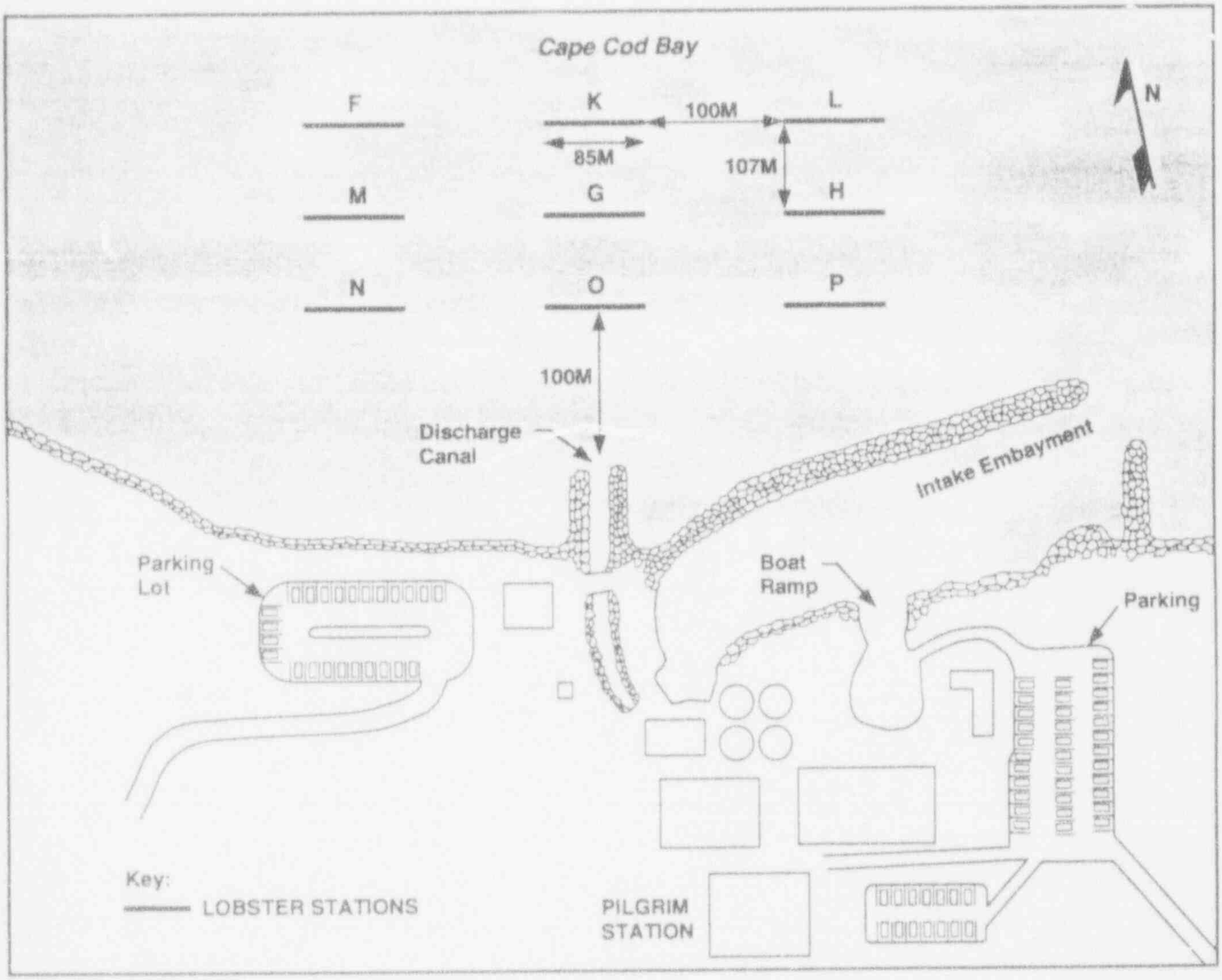

Figure 3. Diagram of Experimental Lobster Stations, 1993 (not drawn to scale).

IV. RESULTS AND DISCUSSION

A. FISHERIES - LOBSTER

1. Research Lobster Trap Fishing

In 1993 the research lobster study sampling stations were relocated. Lobsters were trapped from June through September. Fifty-six sampling trips were completed during this, the eighth year of our study, with a total of 6,465 lobsters captured. The catch rate, i.e., the number of lobster captured per trap haul, ranged from 0 to 12. Numbers of legals and sublegals per trap haul ranged from 0 to 3 and 0 to 12, respectively. In eight percent of the traps hauled, the catch was zero. The overall mean catch per trap haul for the sampling season decreased for the second time in as many years, from 3.3 in 1992 to 2.6 in 1993.

The annual catch ratio of sublegals to legals was 10.8:1 in 1993. Until this year the sublegal to legal ratio had been steadily increasing (5.8:1 in 1988, 6.6:1 in 1989, 8.1:1 in 1990 and 9.0:1 in 1991 and 11.5:1 in 1992). We believe this is a reflection of the gauge increase the fishery underwent back in 1989 which raised the minimum size for legal lobster to 82.55 mm (3.25 in). This change in legal size was not accompanied by an increase in the size of escape vents in our traps, which contributed to the increased catches of sublegal lobster relative to legals.

Fifty-five percent of the lobster captured were males. Of the females, 80 were egg bearing, comprising 2.7% of all females captured. Sixty-seven (84%) of the ovigerous females were sublegal. Culls (lobster with missing or regenerated claw(s))

comprised 23% of the research lobster catch. This is the first decrease in cull rate in years and is the lowest value since 1988. The cull rates were as follows: in 1988 (23%), 1989 (27%), 1990 (28%), and in 1991-92 (29%).

The lobster traps used in this study have 44 mm x 152 mm escape vents. The traps are designed to retain legal-sized lobster (carapace length (CL) ≥ 82.55 mm), however, sublegals are also captured. The size range (CL) of lobster sampled in 1993 was 35 mm to 130 mm. The overall mean size in 1993 (74.5 mm) was similar to the 1992 value of 74.9. The average sublegal size was only 0.6 mm smaller in 1993, while the average legal size increased 1.1 mm from 1992 and was 87.8 mm. A size distribution was plotted for 1993 (Figure 4). The length histogram displays effects of lobster availability, trap vulnerability, and fishing mortality. The graph suggests lobster become increasingly vulnerable to the trap fishery between 51 and 80 mm carapace length. The mode overall was at 81 mm CL. Vent escapement is partly responsible for low catches of smaller

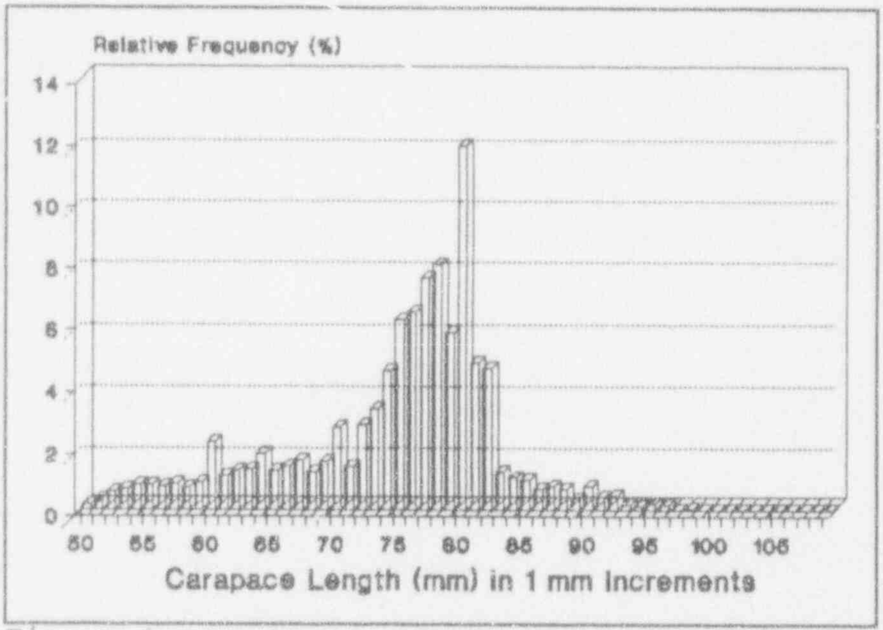

Figure 4. Size distribution of lobster captured in the research trap study off Pilgrim Station June-September 1993.

lobster. Reduced catches of legal-size lobster reflect the high fishing mortality of the lobster fishery in the Pilgrim area.

B. FISHERIES - FINFISH

A species check list of fish observed or collected by all gear types in the Pilgrim area in 1993, complete with scientific names (Robins et al. 1991), is found in Table 1.

Table 1. Taxonomic checklist of finfish species (classification according to Robins et al. 1991) collected or observed in waters adjacent to the Pilgrim Nuclear Power Station in 1993.

Class: Elasmobranchiomorphi

Order: Rajiformes
Family: Rajidae - skates
Raja erinacea (Mitchill) - little skate
Raja ocellata (Mitchill) - winter skate

Class: Osteichthyes
Order: Clupeiformes
Family: Clupeidae - herrings
Alosa aestivalis (Mitchill) - blueback herring
Alosa psuedoharengus (Wilson) - alewife
Clupea harengus Linnaeus - Atlantic herring

Order: Salmoniformes
Family: Osmeridae - smelts
Osmerus mordax (Mitchill) - rainbow smelt

Order: Gadiformes
Family: Gadidae - codfishes
Gadus morhua Linnaeus - Atlantic cod
Urophycis tenuis (Mitchill) - white hake
Urophycis regia (Walbaum) - spotted hake
Urophycis chuss (Walbaum) - red hake
Merluccius bilinearis (Mitchill) - silver hake
Microgadus tomcod (Walbaum) - Atlantic tomcod

Order: Atheriniformes
Family: Atherinidae - silversides
Menidia menidia (Linnaeus) - Atlantic silverside

Order: Gasterosteiformes
Family: Syngnathidae - pipefishes and seahorses
Syngnathus fuscus Storer - northern pipefish

Order Scorpaeniformes
Family: Triglidae - searobins
Prionotus carolinus (Linnaeus) - nothern searobin

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

Family: Cyclopteridae - lumpfishes and snailfishes
Cyclopterus lumpus Linnaeus - lumpfish

Table 1 (continued).

Order: Perciformes
  Family: Sciaenidae - drums
    Leiostomus xanthurus (Lacepede) - spot

  Family: Percichthyidae - temperate basses
    Morone saxatilis (Walbaum) - striped bass

  Family: Pomatomidae - bluefishes
    Pomatomus saltatrix (Linnaeus) - bluefish

  Family: Sparidae - porgies
    Stenotomus chrysops (Linnaeus) - scup

  Family: Labridae - wrasses
    Tautoga onitis (Linnaeus) - tautog
    Tautogolabrus adspersus (Walbaum) - cunner

  Family: Pholidae - gunnels
    Pholis gunnellus (Linnaeus) - rock gunnel

  Family: Zoarcidae - eelpouts
    Macrozoarces americanus (Scheider) - ocean pout

  Family: Stromateidae - butterfishes
    Peprilus triacanthus (Peck) - butterfish

Order: Pleuronectiformes
  Family: Bothidae - lefteye flounders
    Paralichthys dentatus (Linneaus) - summer flounder
    Paralichthys oblongus (Mitchill) - fourspot flounder
    Scophthalmus aquosus (Mitchill) - windowpane

  Family: Pleuronectidae - righteye flounders
    Pleuronectes ferrugineus (Storer) - yellowtail flounder
    Pleuronectes americanus Walbaum - winter flounder

Order: Tetraodontiformes
  Family: Balistidae - leatherjackets
    Aluterus schoepfi (Walbaum) - orange filefish

1. Groundfish - Bottom Trawling

The 1993 groundfish survey began in April and proceeded through December. The sampling consisted of 84 tows made at four fixed stations in the general area shown in Figure 1 of this report. A total of 4,827 finfish was captured (Table 2) in 1993, which almost doubled last year's catch. Of the 34 species captured in 1993, the top three, which comprised 78% of the total, were little skate, winter flounder, and windowpane, in decreasing order of abundance. Catch (number of fish) and species diversity were highest in Warren Cove (Station 1).

Table 2. Expanded bottom trawl catch[1], totals, and percent composition of groundfish captured at fixed stations in the Pilgrim Power Plant area, April to December, 1993.

	Station					
Species	1 Warren Cove	3 Pilgrim Discharge	4 Priscilla Beach	6 Pilgrim Intake	Totals	Percent of total catch
Little skate	678.0	690.1	536.0	150.8	2054.9	42.6
Winter flounder	309.5	357.8	198.6	89.9	955.9	19.8
Windowpane	296.0	212.0	175.7	29.0	712.7	14.8
Atlantic cod	241.5	53.4	22.2	6.3	323.3	6.7
Yellowtail flounder	20.5	88.1	67.9	16.2	192.7	4.0
White hake	20.0	51.0	58.4	5.8	135.2	2.8
Longhorn sculpin	43.0	33.7	13.2	16.4	106.2	2.2
Scup	42.0	28.5	1.0	0.0	71.5	1.5
Rainbow smelt	2.0	11.1	25.0	17.0	55.1	1.1
Red hake	11.0	17.5	4.0	2.3	34.8	0.7
Winter skate	10.0	5.8	14.6	2.3	32.7	0.7
Rock gunnel	7.0	17.8	5.1	2.6	32.5	0.7
Other species[2]	57.5	22.7	19.3	20.0	119.5	2.4
Total fish	1738.0	1589.5	1141.0	358.6	4827.1	
Number of tows	27	24	25	8	84	
Catch per tow	64.4	66.2	45.6	44.8	57.5	
Percent of catch	36.0	32.9	23.6	7.4		
Number of species	27	23	26	16	34	

[1]Catch rates were expanded for tows less than the standard 15-minute duration.
[2]Represents pooled totals from 22 other species of low catch abundance.
Shaded columns are data from surveillance stations.

Little skate

Little skate catches comprised 43% of the trawl totals in 1993. The mean catch per tow for pooled stations was 24.5.

Station catch rates ranged from a high of 28.8 at the Discharge (Station 3) to a low of 18.9 in the Intake embayment (Station 6). The catch rates increased during 1993 over previous levels. The individual numbers of little skate caught this season were almost twice that of last year.

Winter flounder

Winter flounder ranked second in catch, comprising 20% of the overall trawl total. Relative abundance was highest (14.9) in the discharge area and lowest (7.9) off Priscilla Beach (Table 3). The

Table 3. Bottom trawl catch data[1] for dominant groundfish in the vicinity of Pilgrim Station, April to December, 1993.

Station	Little Skate	Winter Flounder	Windowpane
1			
Mean catch per tow	25.1	11.5	11.0
Mean size (cm)	35	27	26
Size range (cm)	15-54	2-45	9-34
3			
Mean catch per tow	28.8	14.9	8.8
Mean size (cm)	43	29	27
Size range (cm)	16-55	6-46	9-34
4			
Mean catch per tow	21.4	7.9	7.0
Mean size (cm)	34	23	22
Size range (cm)	16-53	5-41	6-31
6			
Mean catch per tow	18.9	11.2	3.6
Mean size (cm)	39	25	26
Size range (cm)	4-52	6-39	8-30

[1]Catch rates were expanded for tows less than the standard 15-minute duration.
Shaded rows are data collected at surveillance stations.

overall relative abundance of winter flounder is up slightly from last year (Figure 5). The winter flounder stock north of Cape Cod Bay has been in a state of decline (Northeast Fisheries Center 1991). The length of winter flounder captured ranged from 2 cm to 46 cm and included age cohorts from 0+ to 9+ years old (Witherell

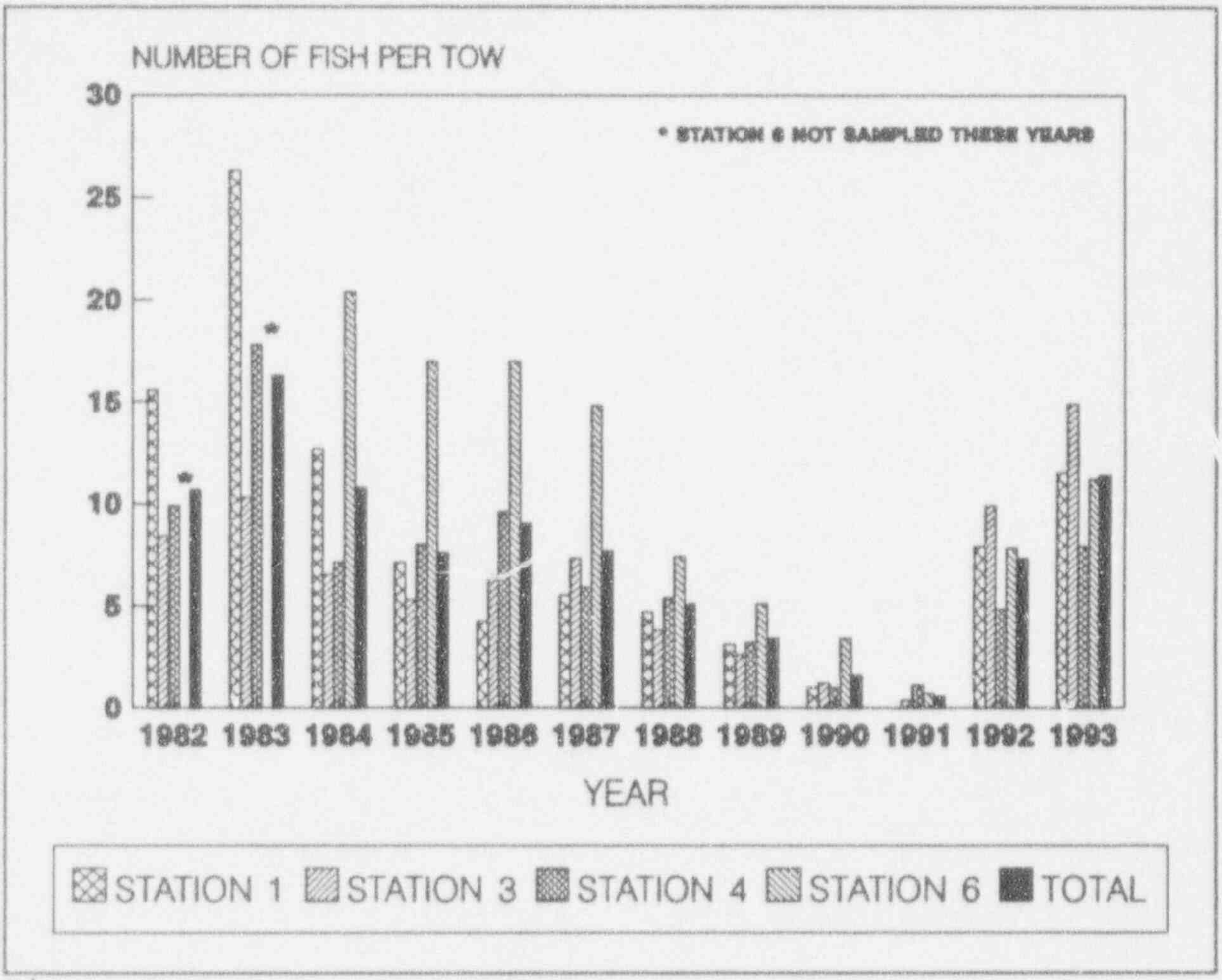

Figure 5. Mean annual catch per tow (number) of winter flounder at four stations and all stations pooled in the Pilgrim Station area, 1982-1993.

et al. 1990). There was a variation in the size of flounder caught throughout the sampling area, with the greatest number of large fish caught at Warren Cove (mode = 31 cm TL versus 25 cm TL at the other stations).

Windowpane

Windowpane ranked third in our trawl catch at 15% of the total for the study area. The relative abundance for windowpane ranged from a high of (11.0) in Warren Cove to a low of (3.6) in the Intake embayment (Table 3). The overall relative abundance of windowpane was similar to that of last year.

Other Groundfish

The remainder of the groundfish catch consisted of 31 species comprising 22% of the catch. These species were caught in relatively low numbers. However, an unusually large number of young-of-the year cod (3-5 cm) were caught in April and May at the three stations proximal to the plant.

2. Groundfish - Diving Transects

From May through October 1993, we conducted nine quantitative diver surveys along 200 m transects selected haphazardly at three of our fixed trawl stations - Discharge, Intake, and Priscilla Beach. Using a T-shaped sampling tool (see Figure 2, in the Methods and Materials section) modified after Walton and Bartoo (1976), the divers recorded information on the relative abundance, size, and distribution of winter flounder, windowpane, and little skate. This technique was introduced in 1992 to provide supplemental data for our nearshore groundfish studies during the summer months when the proliferation of fixed gear prohibited towing an otter trawl. The sampling tool can be maneuvered over obstacles (lobster pots, buoy and trawl lines, and boulders) that would snag a trawl net. This has enabled us to sample in the discharge area to within 60 m of the discharge canal (at mid- to high tide), far closer than we are able to trawl. Additionally, we believe the use of this procedure may reduce sampling variability, as the divers are directly counting fish, rather than relying on a sample catch from the net. The accuracy of trawl data are greatly influenced by the catch efficiency of the gear, which may be less

than 50% with our trawl. Conversely, via third-party observation of our divers during sampling, we estimate the efficiency of diver observations for the species listed above using the sampling tool to be higher.

As in 1992, relative abundance (pooled species density index of fish per m^2) was highest in the Intake embayment (0.08), followed by the Discharge (0.02) and Priscilla Beach sites (0.01). A summary by species of the 1993 sampling data is found in Table 4.

Table 4. Number of fish, number per square meter, and size range of three fish species observed by divers along transects at three trawl stations in the immediate vicinity of Pilgrim Station, May through October 1993.

Station	Number of Dives	Winter flounder	Little skate	Windowpane
Discharge				
Number	9	37	21	6
Number per m^2 sampled		0.01	0.006	0.002
Size range (cm)		3-34	8-66	8-40
Priscilla Beach				
Number	9	7	10	5
Number per m^2 sampled		0.002	0.003	0.001
Size range (cm)		10-30	15-60	20-30
Intake				
Number	9	273	11	7
Number per m^2 sampled		0.08	0.003	0.002
Size range (cm)		2-40	15-45	15-40
Pooled				
Number	27	317	42	18
Number per m^2 sampled		0.09	0.012	0.005
Size range (cm)		2-40	8-66	8-40

Shaded rows are data collected at surveillance stations.

Winter flounder accounted for the majority of fish recorded (84%), with highest abundance in the Intake embayment (Table 4). Little skate comprised 11% of the total and windowpane 5%.

Paired comparisons in the field between the diver transects and trawling could not be completed. We were unable to find enough

clear towable bottom to permit extended side-by-side sampling due to the presence of fixed gear. We did convert annual mean trawl CPUE to fish per m^2 densities, which can be found together with diving observations in Table 5. Although it may not be appropriate to compare the indices statistically, a qualitative examination revealed that the two techniques generally yielded abundance estimates of similar magnitude.

Table 5. Number per square meter and size range of three fish species observed by divers and collected by otter trawl at three trawl stations in the immediate vicinity of Pilgrim Station in 1993.

Station	Winter flounder	Little skate	Windowpane
Diver Densities			
Discharge			
Number per m^2 sampled	0.01	0.006	0.002
Size range (cm)	3-34	8-66	8-40
Priscilla Beach			
Number per m^2 sampled	0.002	0.003	0.001
Size range (cm)	10-30	15-60	20-30
Intake			
Number per m^2 sampled	0.08	0.003	0.002
Size range (cm)	2-40	15-45	15-40
Trawl Densities			
Discharge			
Number per m^2 sampled	0.01	0.013	0.004
Size range (cm)	6-46	16-55	9-34
Priscilla Beach			
Number per m^2 sampled	0.003	0.01	0.003
Size range (cm)	5-41	16-53	6-31
Intake			
Number per m^2 sampled	0.005	0.01	0.002
Size range (cm)	6-39	4-52	8-30

Shaded rows are data collected at surveillance stations.

3. Winter Flounder Preliminary Assessment

Pilgrim Station entrained an estimated 8.2 million winter flounder larvae in 1993. Adult equivalent analysis equates this to approximately 4,820 age-three fish from the local population. This

conditional mortality is an added burden to the local population since fishing mortality is presently too high due to overfishing.

In Cape Cod Bay, winter flounder exist in relatively localized populations (Stone and Webster 1975). Plymouth-Kingston-Duxbury Bay (PKDB) estuary is the site proximal to Pilgrim Station where intensive flounder spawning occurs. Marine Research Inc. (1986) provided evidence of additional flounder spawning outside PKDB, possibly near Brown's Bank outside the mouth of the estuary. Adults disperse from the winter-early spring estuarine spawning grounds (after the late winter-early spring spawn) and migrate into deeper nearshore waters within Cape Cod Bay during late spring and summer (Howe and Coates 1975).

We began preliminary sampling in 1993 to determine where adult winter flounder congregate to spawn in the Pilgrim Station vicinity, in order to estimate adult population size via a tagging program and a density extrapolation technique. The overall objective is to put in perspective the magnitude of the impact of flounder entrainment ongoing at the power plant.

Flounder were sampled utilizing a 9.8 m Wilcox trawl (9.8 m sweep, 7.0 m headrope, of 10.2 cm wing mesh and 13 cm cod-end mesh, and fitted with a 6.4 mm stretch mesh cod-end liner). Sampling occurred outside the estuary in the Pilgrim Station vicinity and within PKDB on both flats (at high tide by necessity) and in channels. Tow locations were haphazardly selected after reviewing navigational charts for towable bottom. Tow times ranged between 8 and 15 minutes.

Flounder were measured, and sex was assessed by external examination for gonadal development, by noting running ripe fish, and by rubbing the blind side of the caudal peduncle for scale roughness. One pectoral fin of each flounder ≥ 25 cm was clipped to half its length; PKDB flounder were clipped on the lower (blind) side, while fish outside PKDB were marked on the upper (eyed) side. All catches of flounder were examined for fin clips.

This study was conducted from January to May and again in November and December. A total of 189 flounder from 77 tows were marked outside the estuary. There were two recaptures in 1993 (one in June and other in July during the course of our routine biweekly trawling program outside the estuary). In the PKDB estuary, 17 fish were marked, with no recaptures. The majority of the flounder taken in the estuary (including fish ≤ 25 cm) were captured during channel tows in May.

Based on preliminary work this year and on discussions with Rhode Island DEM personnel (Chris Powell, personal communication)[1], we will increase our sampling of the deeper channels in 1994 for our work within the estuary. We will use Peterson disc tags to mark flounder ≥ 20 cm within and outside PKDB to estimate population size via mark and recapture. In addition, an independent estimate of population size will be generated using an area-swept approach, with all tow lengths standardized to 400 m.

[1] Chris Powell, Senior Fisheries Biologist, Rhode Island Department of Fish and Wildlife

4. Underwater Finfish Observations

Observational diving at six fixed stations in and around the discharge canal began in early May, with a total of 11 SCUBA dives made through mid-October. A depiction of the station locations can be found in Figure 2 of Semi-Annual Report No. 55 (January to June 1993): Section 3: p 7. Over 750 fish, comprising 6 species (Table 6), were observed at six fixed sampling stations off the discharge canal. Invertebrates also noted were the blue mussel (*Mytilus edulis*), starfish (*Asterias spp.*), and rock crab (*Cancer irroratus*).

Lateral visibility (obtained with a diver-held secchi disk and metered line) was estimated to range from 3-8 m (average 5 m), and was influenced by sea condition and incident light.

Table 6. Numbers, percent composition, and location of greatest abundance of finfish sighted during underwater observations, May to October, 1993.

Species	Number observed by divers	Percent of total	Station where most abundant
Cunner	318	41.1	D_1
Striped bass	255	32.9	D_2
Tautog	126	16.3	D_2
Bluefish	62	8.0	D_1
Other*	13	1.7	
Total 6 species	774		

* Rock gunnel and winter flounder

The number of fish recorded in 1993 (774) was up from that observed in 1992 (631). Striped bass and bluefish, in particular, were sighted in greater numbers than in 1992 (255 vs. 160 and 62 vs. 26, respectively). As in 1992, no pollock were observed in the study area by project divers. A plot of pooled fish sighted per dive (an index of relative abundance) from 1981 through 1993 is

found in Figure 6. In 1993, project divers reported an average of 70 fish per dive, similar to the 1992 index value. Relative abundance for the last two years is similar to the reduced levels found during the extended plant outage at Pilgrim Station (1987-1989). However, testing with regression analysis, revealed no relationship (P > 0.05) between plant output (MDC) and fish per dive indices. As has been the pattern since 1985 (Figure 6), more fish were observed in the denuded area (80.5%) than in the control (12.5%) or stunted (7%) areas. No relationship (P > 0.05) was found between fish distribution and MDC.

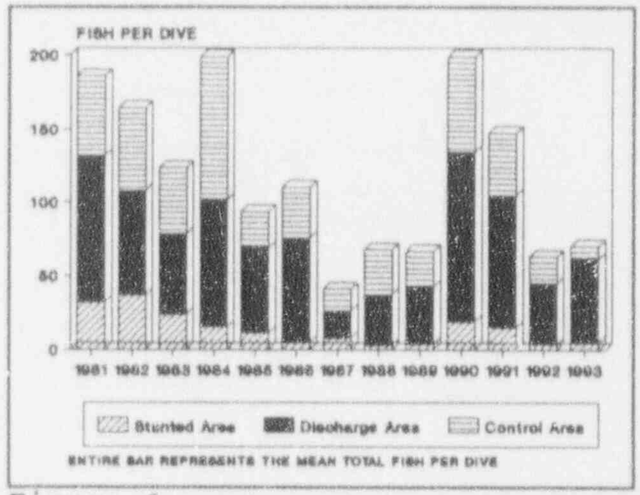

Figure 6. Index of relative abundance (fish per dive) for all species (pooled) observed by divers at Pilgrim Station, 1981 to 1993.

Cunner

Occurring at all stations, cunner was the finfish species observed in greatest numbers by project divers, comprising 41% of all sightings (Table 6). Cunner were found most often in the denuded area (80.5%), followed by the control (12.5%) and stunted (7%) areas. The cunner per dive index was 28.9, the same as that noted in 1992 (Figure 7). The 1992-93 indices are the lowest of the 13-year survey.

As in 1992, a review of individual length estimates made by project divers revealed that few young-of-the-year cunner (2-3 cm)

were sighted in the study area.

Striped Bass and Bluefish

Striped bass ranked second in diver's observations (Table 6). The fish per dive index was 23.2, higher than the index of 16 for 1992 (Figure 8). Bluefish ranked fourth in numbers sighted with 62 recorded. An index of 5.6 bluefish per dive was a moderate increase from the 2.6 recorded in 1992. Bluefish dominated sportfish catches at the Pilgrim Shorefront in 1993, followed by striped bass (see Section 5. Sportfish Survey, this report) likely due to directed effort by the fishermen. Exhibiting an affinity for Pilgrim Station's thermal effluent current, local occurrence and numbers of both species are likely influenced by year-class strength, total mortality (natural and fishing), water temperature, and the abundance of prey in the area. Commonly angled from the discharge jetties, striped bass were sighted by divers almost exclusively at Station D_2; bluefish primarily at Station D_1.

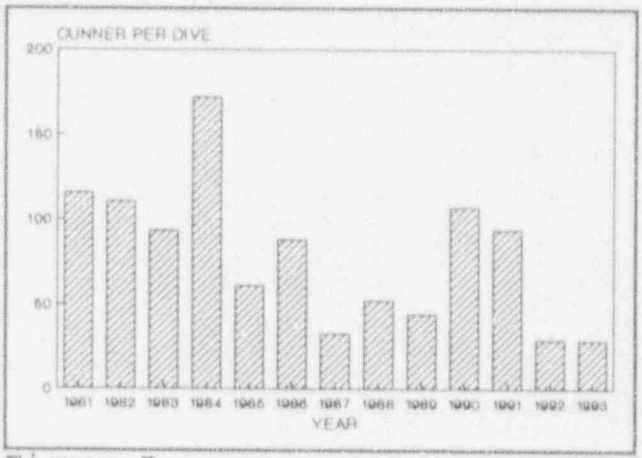

Figure 7. Index of relative abundance (fish per dive) for cunner observed by divers at Pilgrim Station, 1981 to 1993.

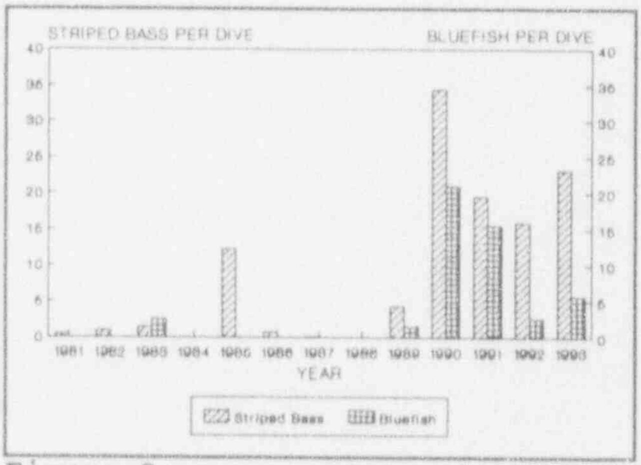

Figure 8. Index of relative abundance (fish per dive) for striped bass and bluefish observed by divers at Pilgrim Station, 1981 to 1993.

Tautog

Ranking third in number sighted (Table 6), tautog were most commonly found along the inside of the lower portion of the southern-most discharge jetty. A fish per dive index of 11.5 for this species (Figure 9) is slightly lower than that noted in 1992 (14.9).

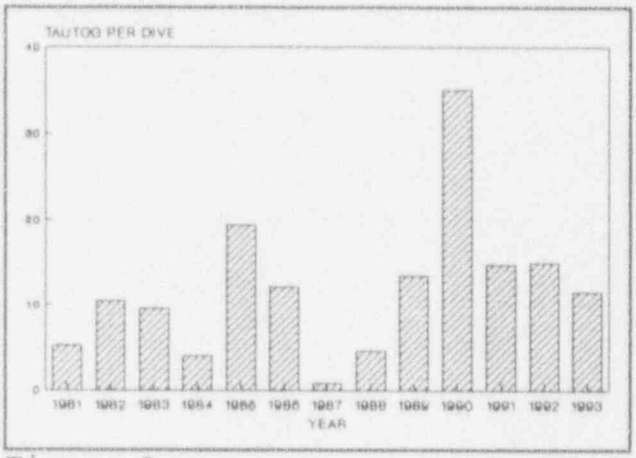

Figure 9. Index of relative abundance (fish per dive) for tautog observed by divers at Pilgrim Station, 1981 to 1993.

5. Sportfishing Survey at Pilgrim Shorefront

The 1993 creel survey began at the Shorefront recreational area at Pilgrim Station on 26 June and concluded on 17 October for a sampling period of 73 days. This sportfishing survey aims at attaining general information on trends in time of fishing, effort, species, and catch per unit effort. Data were collected, as time permitted, by seasonal public relations personnel from Boston Edison Company, who conducted the survey along with other duties.

There were 1,391 reported angler trips made to the Shorefront during the survey. The recorded sportfish catch totaled 461 finfish, belonging to two species: bluefish and striped bass. The average number of fish caught per angler trip was 0.3. There was a decrease in fishing effort and lower catches at the site in 1993 (Figure 10). The daily number of anglers visiting the Shorefront has decreased on average of about five anglers per day from last year (Figures 10 and 11). The mean number of fish caught per

angler trip also has decreased from 0.4 in 1992 to 0.3 in 1993 (Figure 11).

The average number of anglers visiting the site each day peaked in July, with a mean of 21 (Figure 12). The catch rate gradually decreased from the early part of the survey to a low in August. Following this, the catch rate increased substantially to a high in October. This elevated catch rate at the end of the survey also occurred in 1992. Large catches of bluefish in September and October pushed up the overall catch rate. The number of anglers visiting the site also increased in October from a low in September.

In 1993, the recreational catch composition was 87% bluefish and 13% striped bass. Bluefish dominated the catches over the entire season (Figure 13). Only bluefish were reported for

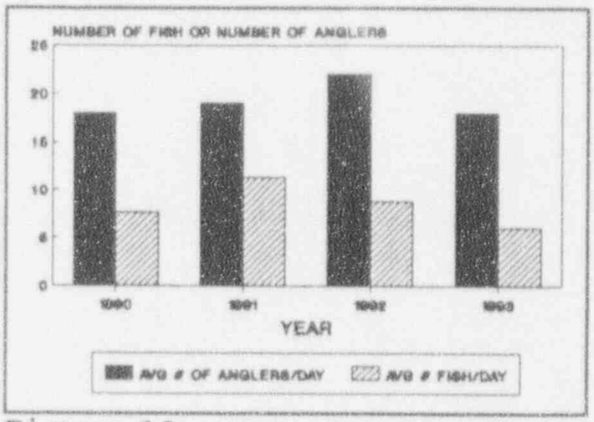

Figure 10. The annual mean number of fish caught per day compared to the average number of anglers per day at Pilgrim Station, 1990 to 1993.

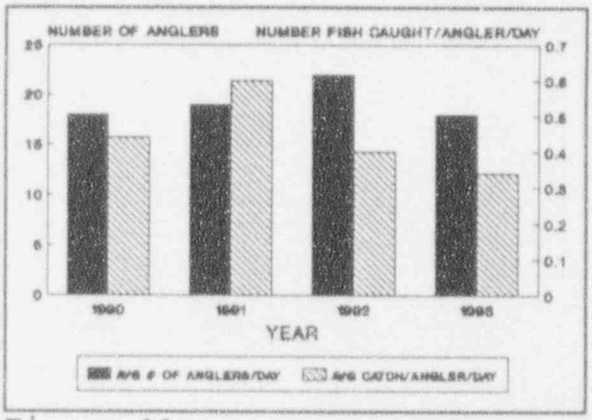

Figure 11. The annual mean number of fish caught per angler per angler trip compared to the average number of anglers per day at Pilgrim Station, 1990 to 1993.

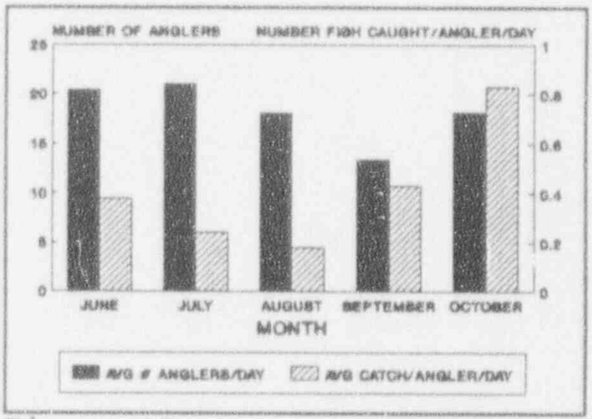

Figure 12. The monthly mean number of fish caught per angler trip compared to the number of anglers at Pilgrim Station, 1993.

September and October. Striped bass comprised a small percent of the monthly catches from June to August, with its highest contribution to monthly catches coming in June. The number of species recorded in the catch decreased this year. Unlike 1992, no winter flounder were reported.

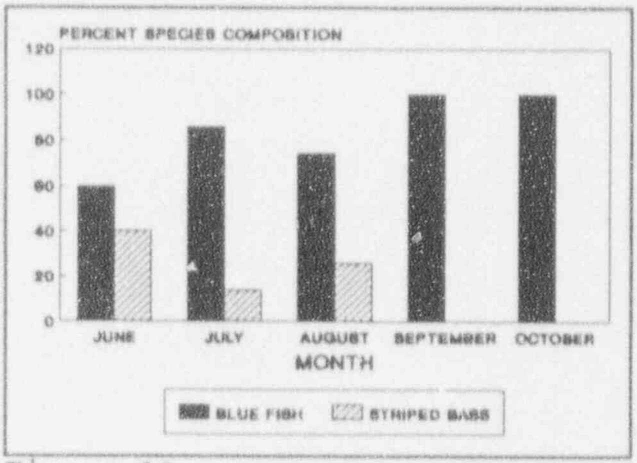

Figure 13. The percent species composition of sportfish catch each month in 1993 at the Pilgrim Shorefront.

There were 46 weekdays and 28 weekend days sampled. Substantially less anglers fished at the Shorefront on weekdays as

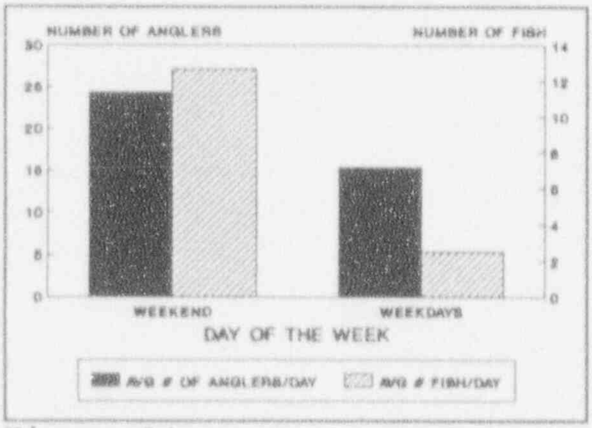

Figure 14. The mean number of fish caught per day and the average number of anglers per day comparing weekends to weekdays at Pilgrim Station, 1993.

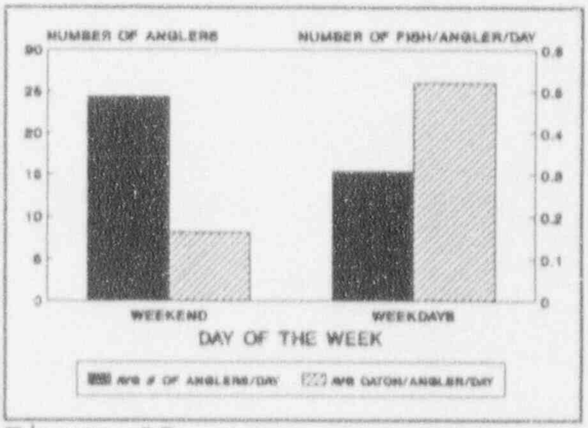

Figure 15. The mean number of fish caught per angler trip and the average number of anglers per day comparing weekends to weekdays at Pilgrim Station, 1993.

compared to weekends. An average of nine fewer anglers per day fished at the Shorefront on weekdays (Figures 14 and 15). With more anglers at the Shorefront on weekends, more fish were caught (Figure 14), but the overall catch rate per angler was lower than

on weekdays (Figure 15). This corroborates last year's survey. A larger number of casual fishermen visited the Shorefront on weekends; their general lack of fishing experience translated into lowering the overall catch rate per angler.

Again this year, it is evident that bass and bluefish are attracted to the thermal discharge current at the power plant. In mid-September, we observed numbers of bluefish and striped bass in the thermal plume at Pilgrim Station.

6. Cunner: Tagging and Aging

The cunner, a temperate water-reef species, is one of the most abundant groundfish in the inshore waters off Pilgrim Station. Cunner form localized populations, where the individuals are structure-oriented and have small home ranges. Our mark-recapture data indicate that the adults are site-tenacious at least during the warmer months in the environs of Pilgrim Station. Our ultimate tagging objective is to estimate absolute abundance of the local adult population using an open population model which allows for recruitment, mortality, or movement to occur during the experiment. We also continued our aging work and development of an age-length key.

From June through September 1993, we captured and measured 2,576 cunner. There were three tagging areas along the Plymouth shoreline: Rocky Point, seaward of the outer intake breakwater and discharge of Pilgrim Station, and White Horse Beach. A total of 1210 (≥12 cm total length) cunner was tagged with external anchor tags during 31 marking events. Sex was not always determined, but

ripe fish were noted as well as dichromatism. All fish were released in the area of capture, except for a sub-sample of 81 individuals removed from the population for aging. There were multiple recaptures, e.g., one cunner tagged in 1993 was recaptured eight times that year.

Over the last four years, we have tagged 2,613 cunner in the study area. Through 1993, 517 (20.0%) marked individuals have been recovered at least once. In 1993, 247 (20%) of those tagged that year were recaptured one or more times. Each return was from the respective tagging area. There were 78 cunner tagged in 1993 that were retaken more than once. Also in 1993, we recaptured 44 tagged fish (one or more times) marked in 1992 and at-large for about one year; they were recovered in the release area.

With the use of physical tags, retention may be compromised. Some tag loss occurred in the field in 1993. Cunner in the Pilgrim area are found in proximity to structure, often taking refuge under rocky outcrops and within crevices. Therefore, there is the potential for snagging and loss of tags. Over the last two years, we observed two shed tags on the bottom of the tagging area, several scarred fish apparently resulting from tag wounds, and a few double-tagged fish that had lost one of their tags.

In many finfish tagging programs, the percentage of recoveries typically ranges from 3 to 10% (Matthews and Reavis 1990). Our technique of trapping cunner in fish pots rendered an eight percent tag return in 1992 and a 20% return in 1993. The increase in 1993 was attributable to a four-fold increase in effort. By recapturing

our own tagged fish, a bias common to many mark and recapture programs - namely, a failure to report tag returns - is avoided.

Open population estimators necessitate certain assumptions be met. Marked individuals do not lose their tags. Marked and unmarked animals need to experience the same natural mortality i.e., they have the same probability of surviving from sample i to i + 1. All samples are instantaneous. Both marked and unmarked organisms are equally vulnerable to capture during the ith sample given they are alive during the ith sample. Losses to the population through emigration are permanent.

Of the above, high tag retention and differential mortality are in question. The first tag used in 1990 and 1991 was tested under control conditions and had a short-term tag loss of only seven percent. However, the modified tag used in 1992 and 1993 had a tag loss of 13% and 65%, respectively, in controlled mini-experiments. This is not acceptable, and we have gone to a scaled down version of the T-bar anchor tag for 1994 which is being evaluated presently for its effectiveness.

An additional 81 cunner from the Pilgrim study area were aged in 1993 using otoliths. These fish ranged in total length from 10 to 20 cm. Six age groups were present in the samples, ages 2-7. Cunner that appeared to be young-of-the-year and yearlings were observed or captured in the area but were not in the aging samples. An updated age-length key was prepared from the 163 cunner aged over the last three years (Table 7). There was overlap in lengths

of cunner amongst most age classes because of growth variation in fish of the same age.

Table 7. Age-length key for cunner in the Pilgrim area, 1991-1993 (pooled data).

Length (cm)	Age (years)							Total in this length category sampled for age
	2	3	4	5	6	7	8	
9	3							3
10	11	2						13
11	2	6						8
12	5	10						15
13	1	9	4					14
14		3	3					6
15			12	6				18
16			12	3		1		16
17			6	18	6	1		31
18			1	7	4	4		16
19				3	1	2	4	10
20					2	1	1	4
21					2	2		4
22								0
23						1		1
24						1	3	4
	Total fish aged							163

V. HIGHLIGHTS

Lobster - Research Study

1. Fifty-six sampling trips were completed from June to September 1993, yielding 6,465 lobster (55% male; 45% female).
2. Ovigerous (egg - carrying) females comprised 2.7% of the research catch of females. Eighty-four percent of the ovigerous females were sublegal.
3. The cull rate decreased from 29% in 1992, to 23% this year.
4. Carapace lengths of lobster in research catches ranged from 35-130 mm, and averaged 74.5 mm.

Groundfish - Bottom Trawling

1. Twenty-four fish species were collected by bottom trawling in the nearshore area of Pilgrim Station.
2. The highest catches in number of fish were at Station 1, Warren Cove.
3. Little skate ranked first at 43% of the total catch.
4. Winter flounder ranked second in catch, comprising 20% of the trawl total.
5. Windowpane ranked third at 15% of the trawl catch.
6. The remaining 22% of the groundfish catch consisted of 31 species.

Groundfish - Diving Transects

1. Diving transects were monitored at the Discharge, Intake, and Priscilla Beach trawl stations from May through October, 1993.
2. The diving survey was used to supplement the trawl data on the

relative abundance, size and distribution of winter flounder, windowpane and little skate.

3. Winter flounder accounted for the majority of fish recorded (84%), with highest abundance in the intake embayment.

Winter Flounder Preliminary Assessment

1. Pilgrim Station entrained an estimated 8.2 million winter flounder larvae. Equivalent adult analysis equates this to approximately 4,820 age-three fish from the local population.
2. Preliminary sampling began in 1993 to determine where adult winter flounder may be congregating to spawn in the Pilgrim Station vicinity in order to estimate adult population size via a tagging program and density extrapolation technique.
3. The study was conducted from January to May and again from November to December.
4. A total of 189 flounder ≥ 25 cm total length from 77 tows outside the Plymouth-Kingston-Duxbury bay estuary were marked by clipping the upper (eyed-side) pectoral fin.
5. Seventeen flounder ≥ 25 cm total length were marked inside the estuary by clipping the lower (blind-side) pectoral fin.

Underwater Finfish Observations

1. Over 750 fish, comprising 6 species, were observed during 11 dives in 1993.
2. Observed fish were distributed as follows: 80.5% in the

denuded zone, 12.5% in the control zone, and 7% in the stunted zone.

3. Cunner were numerically dominant, comprising 41% of all sightings.
4. Fish per dive index for striped bass was 23.2, higher than the index of 16 for 1992.
5. A bluefish per dive index of 5.6 moderately increased from 2.6 in 1992.
6. The number of tautog sighted in 1993 was slightly lower than 1992.

<u>Sportfishing Survey</u>

1. Sportfishing was surveyed at the Pilgrim Shorefront from late June until mid-October 1993.
2. A reported 1,391 angler-trips were made by shore-based fishermen to the Shorefront, and about 461 fish, representing 2 species, were caught during the survey.
3. Bluefish comprised 87% and striped bass 13% of the surveyed recreational catch.
4. Effort and catch rate (0.3 fish caught per angler trip) decreased somewhat from last year.

<u>Cunner Tagging and Aging</u>

1. From June through September 1993, 2,576 cunner were captured and measured.
2. A total of 1,210 (≥ 12 cm total length) was tagged with

external anchor tags during 31 sampling events. There were three tagging areas along the Plymouth shoreline: Rocky Point, seaward of the outer intake breakwater and discharge of Pilgrim Station, and White Horse Beach.

3. Eighty-one fish were removed from the population for aging. These fish ranged in total length from 10-20 cm and were aged to be 2-7 years old.
4. In 1993, 247 (20%) of the tagged cunner were recaptured one or more times. There were 78 cunner retaken more than once.
5. There were 44 recaptures from 1992.

VI. ACKNOWLEDGEMENTS

The authors thank the following staff members - Steve Cadrin, Neil Churchill, and Jessica Harris for assisting in field sampling operations. Terry O'Neil assisted in graphics for this report, while Erin Casey helped with data entry and field work. We acknowledge commercial lobsterman, Chris Kyranos, for his valued assistance in our research lobster sampling program over the years. Raymond Dand and Robert Ellenberger of Boston Edison Company (BECo) collected sportfish data at Pilgrim Shorefront. Jay Burnett from the National Marine Fisheries Service (NMFS) in Woods Hole, MA aged cunner from the Pilgrim area. A special thanks to Kim Trotto of our staff for word-processing several sections of this report. We appreciate the guidance of Robert D. Anderson of BECo, W. Leigh Bridges of our Division, and members of the Pilgrim Administrative-Technical Committee. Their input on various studies and editorial comments on project reports and papers have been most helpful.

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ANNUAL REPORT
ON
MONITORING TO ASSESS IMPACT
OF THE
PILGRIM NUCLEAR POWER STATION
ON THE MARINE FISHERIES RESOURCES
OF WESTERN CAPE COD BAY
(<u>IMPACT ON INDICATOR SPECIES</u>)

Project Report No. 56 (January-December, 1993)
(Volume 2 of 2)

By

Robert P. Lawton, Brian C. Kelly,
Vincent J. Malkoski, John Chisholm,
Paul Nitschke and William O'Brien

April 1, 1994
Massachusetts Department of Fisheries,
Wildlife, and Environmental Law Enforcement
Division of Marine Fisheries
100 Cambridge Street
Boston, Massachusetts 02202

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I. EXECUTIVE SUMMARY

The following are the highlights of findings on indicator species selected to assess power plant impact:

Cunner

- Cunner abundance in the Pilgrim Station area remained depressed, with 1993 diver estimates unchanged from the time-series low (29 fish per dive) recorded in 1992.
- Impingement of cunner at Pilgrim Station was relatively light in 1993; however, entrainment of their eggs and larvae equated to a loss of 60,819 adults.
- Movement of cunner in the outfall area is limited by the existence of an exclusion zone that results in shifts of local distribution by size class in the outfall area.

Lobster

- Entrainment of lobster larvae is not a concern at Pilgrim Station. Only one larva was collected at the plant in 1993.
- An estimated 1,184 adolescent phase lobster (21-76 mm carapace length) were impinged at Pilgrim Station in 1993.
- The research trap study was redesigned in 1993. The 5-pot trawls were set so as to form a gradient array within and across the thermal plume area. Comparisons were made between individual trawls, and groupings of trawls into rows and columns.
- We found no clear relationship between proximity to the discharge canal and legal or sublegal catch rates for research lobster data collected in 1993.

Winter Flounder

- An estimated 1,100+ winter flounder - mostly young-of-the-year and yearlings - were impinged in 1993 at Pilgrim Station.
- Of greater concern is the effect of entrainment. In 1993, 8.2 million flounder larvae were entrained at Pilgrim Station, which equates to the loss of 4,820 age-three adults from the local population. High conditional mortality may add an unacceptable burden to stocks that are already overfished.
- There is a small thermal exclusion zone to flounder off the discharge canal during late summer and early fall at the time of highest ambient water temperatures.
- Commercial landings and research trawl surveys point to substantially reduced flounder abundance north of Cape Cod.

II. INTRODUCTION

The Massachusetts Division of Marine Fisheries conducts a field monitoring program to assess impact of Pilgrim Nuclear Power Station (PNPS) on marine fisheries resources in the offsite waters of western Cape Cod Bay. This investigation was funded by Boston Edison Company (Purchase Order No. LBR107003 in 1993). Focusing on lobster, cunner, and winter flounder in the Pilgrim area, we sampled at surveillance and reference sites employing a variety of gear types to collect data over time. Measurements, counts, percentages, and indices of relative abundance are used in the analyses. These data are summarized in graphs, plots, and tables, and descriptive and inferential statistical procedures are used to test for plant effects.

Volume 2 is an assessment of PNPS impact on three selected indicator species in the Pilgrim area (Table 1). The plates that follow depict various field sampling operations in our investigative program.

Table 1. Indicator species assessed for impact of Pilgrim Nuclear Power Station.*

Species	Background History	Basis for Selection as an Indicator Species	Possible Sources of Impact	Sampling Methods
American lobster	RIS	d,r,c,s	I,E,T/C	intake screens/trap/trawl/diving/gill net
Cunner	RIS	d,r,s	I,E,T/C	intake screens/diving/gill net/sportfish catch
Winter flounder	RIS	d,r,c,s	I,E,T/C	intake screens/trawl/diving/sportfish catch/gill net

RIS - representative species selected in the original 316 (a and b) Demonstration Document and Supplement to assess Pilgrim Station impact (Stone and Webster 1975 and 1977).

d - a dominant species in the Pilgrim area.

r - a local resident

c - commercial importance

s - recreational importance

I - impingement

E - entrainment

T/C - discharge current effects: thermal/current

* Note: Indicator species selection rationale: these three species were selected for assessment in 1992 because they have shown the most potential for impact off Pilgrim Station.

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

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

Plate 3. Bottom trawl being set to sample groundfish in the inshore waters of western Cape Cod Bay. Catches are used to measure potential impacts of Pilgrim Station on the benthic fish community.

Plate 4. Typical trawl catch is processed which includes identifying enumerating, and measuring the different species for environmental assessment. Catches of winter flounder have been consistently largest at the Pilgrim Station intake trawl station.

Plate 5. Tagged cunner seen swimming off the seaward side of the outer intake breakwater at Pilgrim Station. Diving observations have recorded the greatest number of fish sighted off Pilgrim Station to be cunner, which are structure oriented.

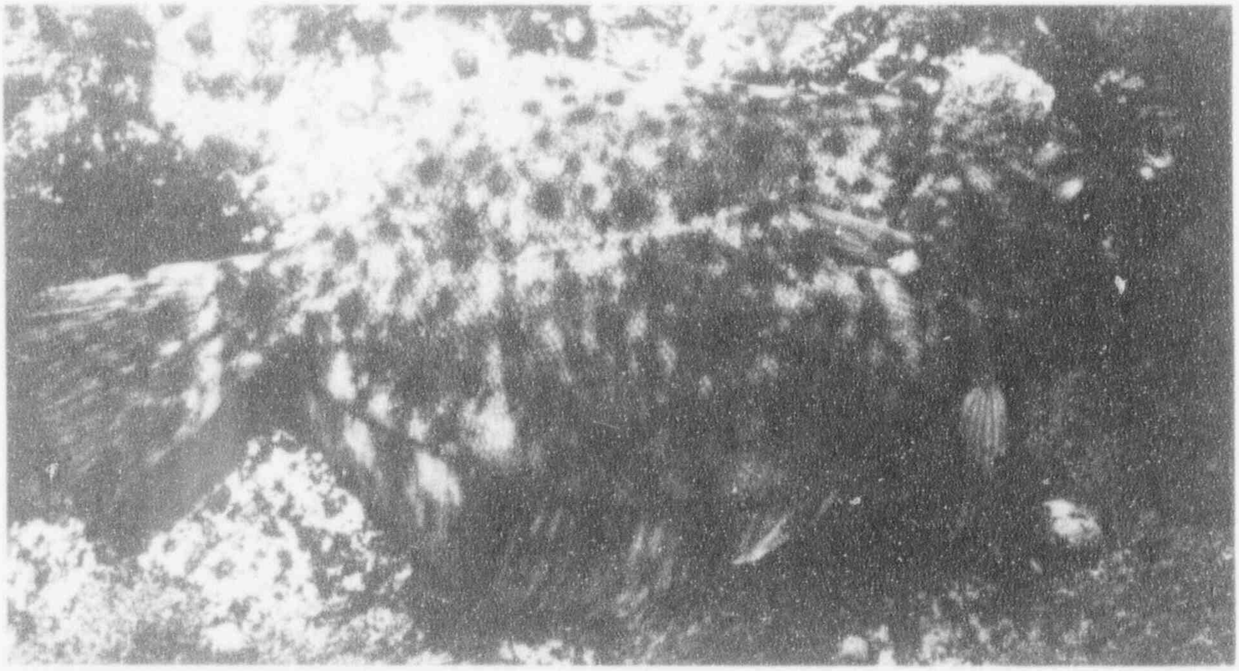

Plate 6. A winter flounder on the bottom near diving Station D_1 (~ 50 m, seaward of the discharge canal) in the "denuded" zone off Pilgrim Station. An important commercial and recreational fish, flounder inhabit the Pilgrim area throughout the year and have been used as an "indicator" species to assess stress imposed by the release of the heated effluent.

Plate 7. Pictured is the thermal effluent discharging into Cape Cod Bay, and anglers fishing off the discharge jetties and from boats in the plume which is visible in the background as the calm water. Striped bass and bluefish, which are attracted to and concentrate in the thermal current, are the dominant species sought by sport fishermen at this location.

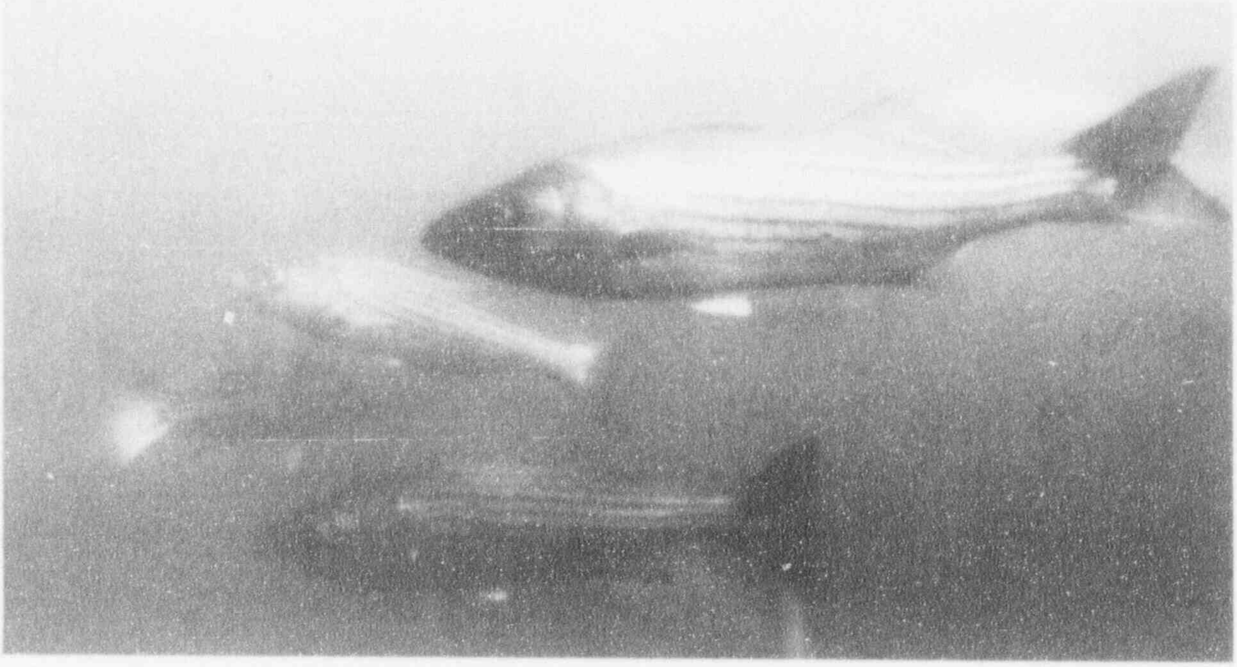

Plate 8. Striped bass aggregate in the thermal discharge current at Pilgrim Station, often swimming just off the bottom into and out of the discharge canal. Bass are attracted to moving water as a feeding ground.

III. RESULTS AND DISCUSSION

A. PHYSICAL FACTORS

1. Power Output-Thermal Capacity

Pilgrim Station's capacity factor (MDC net percent) is an index of operational status that approximates thermal loading into the receiving waters. This factor should be considered when assessing thermal impact on marine populations in the receiving waters. By regulation, the plant is allowed a maximum temperature rise (Δ T) in the effluent of 18° C (32° F) above ambient. During the 21-year history of operation, the overall MDC at Pilgrim Station has averaged 50.2%, with annual means ranging from 0.0% (outage years) to 84.4% in 1985 (Figure 1). The annual power level decreased from 80.6% in 1992 to 74.0% in 1993. Even with this decline, production was still higher than for eight of the last 10 years (Figure 1). Average monthly thermal capacity in 1993 ranged from 0.4% in May to 99.0% in January.

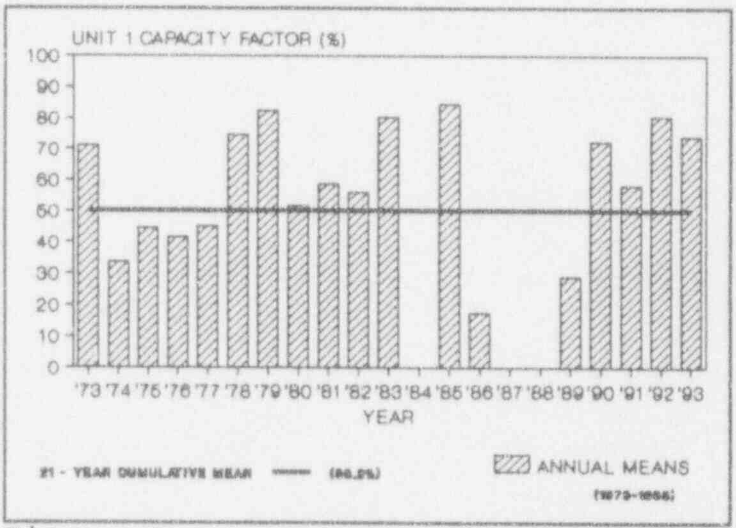

Figure 1. Annual means and 21-year cumulative Mean Capacity Factor (MDC Net %) for Pilgrim Nuclear Power Station, 1973-1993.

2. Discharge Current

The once-through, open-cycle cooling water system at Pilgrim Station induces a localized current immediately in front of the

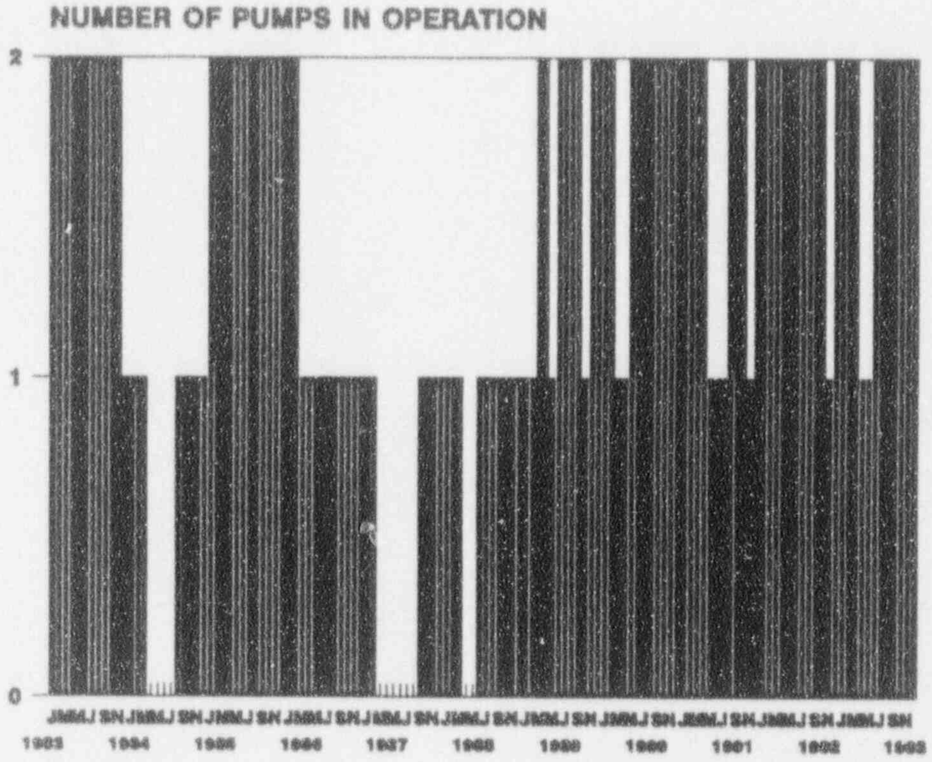

Figure 2. Operational history of the two circulating seawater pumps at Pilgrim Station by month for the years, 1983-1993.

plant. The two circulating seawater pumps draw water from the Intake embayment, which is passed through the condenser tubes, and discharged back into Cape Cod Bay laden with waste heat. At low tide, effluent velocities often exceed 2.1 meters per second (7 feet per second) at the mouth of the discharge canal. This results in a scouring effect on the benthos and concomitant erosion of substrate in the vicinity of the discharge.

Through the operational history of the plant, there have been outage periods when one or both circulating pumps were shut down (Figure 2). Such periods are generally short-lived and occur

sporadically. However, prolonged outages occurred in 1984 and again from 1986-1988 (Figure 2). Both circulating seawater pumps were operated during 1993, except for portions of April and May, when only one pump was in operation.

3. Water Temperature

Point measurements of surface and bottom water temperature were recorded during routine sampling in the vicinity of Pilgrim Station. After pooling the data from each study by area (Long Point, Warren Cove, Discharge, Intake, and Priscilla Beach) and season (winter, spring, summer, and fall), we computed an arithmetic average for each grouping. A plot of 1993 average surface and bottom water temperatures can be found in Figure 3. As we are presenting pooled data, the highest and lowest recorded temperatures are not reported.

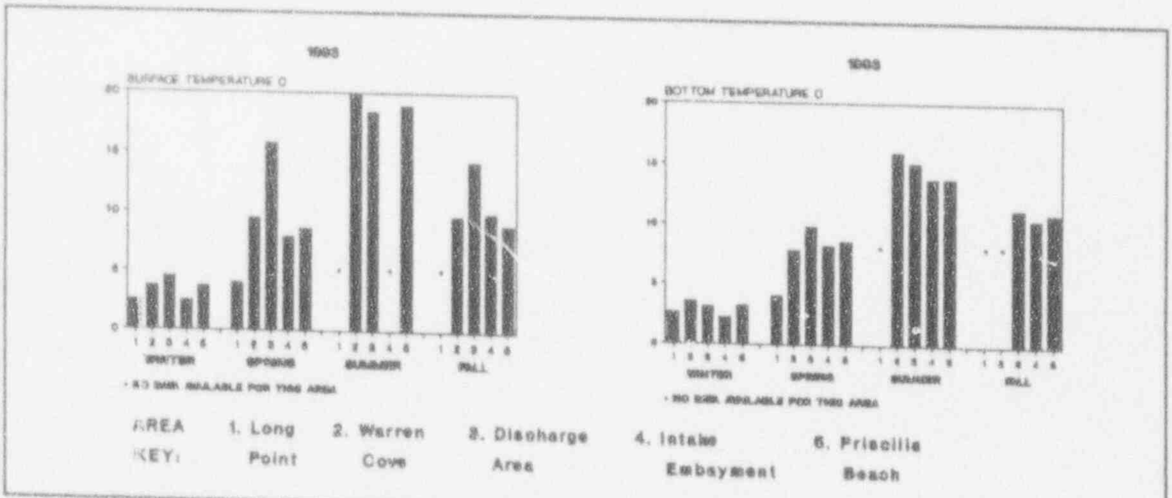

Figure 3. Surface and bottom water temperatures (° C) in the Pilgrim Station area by location, averaged by season for 1993.

B. IMPACT OF PILGRIM STATION ON INDICATOR SPECIES

1. Cunner

Background

Cunner (*Tautogolabrus adspersus*) are shelter-dependent groundfish that reside in rocky areas common to the Plymouth shoreline. Year-round residents throughout much of their range (Green and Farwell 1971; Olla et al. 1975), cunner move seasonally to deeper water to escape cold temperatures. In the Gulf of Maine (Bigelow and Schroeder 1953) and off Newfoundland (Green and Farwell 1971), cunner activity decreased at water temperatures below 8° C. Olla et al. (1975) found that in the fall at temperatures of 5-6° C, cunner become first inactive and then torpid, remaining so until the water warms above 6° C in the spring.

Cunner exhibit highly localized abundance with small home ranges (Green 1975), generally restricted to the structure to which they were originally recruited (Olla et al. 1975). As such, a resident population of cunner is vulnerable to localized perturbations (e.g., point-source pollution or sportfishing mortality). They are especially vulnerable to stress after dark when they enter a sleep-phase, which is characteristic of labrid fish. This reduces their responsiveness to environmental stimuli. At Pilgrim Station, the intake breakwaters and discharge canal jetties have augmented the naturally occurring structure, creating habitat for this temperate water-reef fish. The large boulders and attached macroalgae provide shelter imperative to the cunner's sleep phase and cover to escape predators and avoid power plant

discharge current velocities that might impair their maneuverability.

Abundance data from gill-net, diving, and creel sampling indicate that cunner is a dominant fish species in the Pilgrim Station area. Evidence of their site tenacity comes from our tagging work off the plant. Therefore, cunner has the requisites to be a good indicator species to assess power plant impact.

Life Stages Impacted and Sampling Protocol

Cunner can be affected by the operation of Pilgrim Station via mechanical effects and from the high velocity thermal effluent. Temporally, impact would be expected primarily during summer and fall when cunner are most active and abundant off the plant. Having captured ripe cunner seaward of the outer intake breakwater in May and June, we conclude that spawning occurs near the power plant. The eggs and larvae are pelagic and subject to entrainment in the plant's circulating seawater system. Larger fish, juveniles and adults, are vulnerable to impingement on the travelling-water screens. The discharge current, laden with waste heat and periodically with chlorine, can influence all life stages of cunner in the receiving waters.

Conditional Mortality - Power Plant Impact

Impingement

Among the dominants impinged at Pilgrim Station (Lawton and Anderson et al. 1984), most cunner are collected from June through

September. In 1993, annual cunner impingement was estimated to be 104 fish.

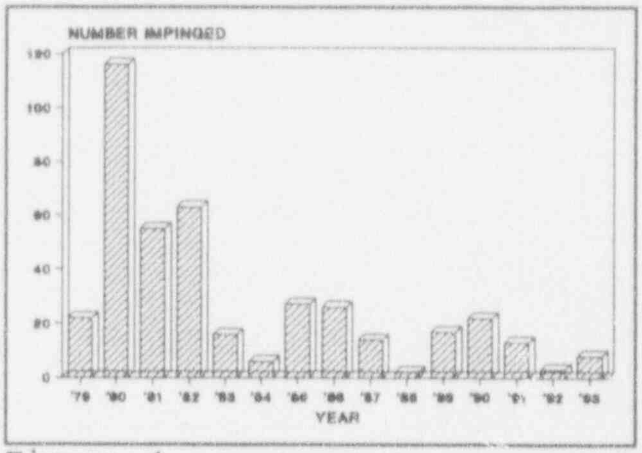

Figure 4. Annual totals for cunner collected during impingement sampling at Pilgrim Station, 1979 to 1993.

In 1979, Pilgrim Station impingement sampling was reduced to three samples (each sample represented an 8-hour collection period) per week (Bridges and Anderson 1984). Impingement totals from 1979 to 1993 fluctuated (Figure 4), with a range of 3 (1992) to 116 (1980) cunner. Annual impingement rates (fish per year) which are adjusted for the number of hours of actual sampling are found in Figure 5. Initial survival of impinged cunner at the power plant during these years has varied from - 24% in 1989 (Anderson 1990) to 100% in 1992 (Anderson 1993). Influencing factors include the strength of the intake current and the operational mode of the screen wash (static vs. continuous). A relatively high impingement in 1980 of an estimated 1,683 cunner has the potential to impact the local population in a given year, particularly when combined with sportfishing and entrainment mortality and a depressed stock size.

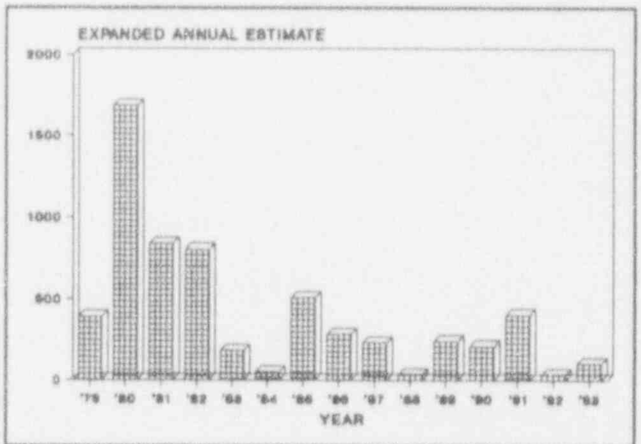

Figure 5. Annual estimated impingement rates (fish per year) for cunner collected from the intake screens at Pilgrim Station, 1979 to 1993.

Entrainment

In 1993, cunner eggs were entrained at Pilgrim Station from May through September, with highest abundance in June. During the history of Pilgrim Station operation, the Labridae-*Pleuronectes* group has dominated entrainment of fish eggs at the station, comprising over 90% of eggs entrained. Cunner larvae were entrained at Pilgrim Station from June through September 1993 (Mike Scherer, personal communication)[1].

The large quantities of cunner spawn (eggs and larvae) entrained annually by Pilgrim Station are assumed to be lost from the population (Marine Research, Inc. 1991). With respect to conditional mortality, Pilgrim Station entrained 2.61 X 10^9 eggs and 1.35 X 10^7 larvae of cunner in 1993, which equates to 60,819 adult fish as estimated by adult equivalency analysis (Mike Scherer, personal communication). Modelling of the mark-recapture population estimate using the Jolly-Seber model for 1993 is still in progress. In 1992, about 5,000 adult cunner larger than 10 cm were estimated to reside off the Pilgrim outer intake breakwater. While the magnitude of the loss to entrainment seems substantial, the significance of this loss to the local cunner population is not yet known. We must define the areal limits of the local population, which includes recruitment sources. With a three-day incubation period at 15.6° C for cunner eggs and a three-week larval stage (Bigelow and Schroeder 1953), cunner may recruit into

[1]Michael Scherer, President, Marine Research, Inc., Falmouth, MA.

the Pilgrim Station area from offsite spawning grounds.

Discharge Effects - Heat and Current

Thirteen years of underwater finfish observations off Pilgrim Station, totaling 167 SCUBA dives, confirm that cunner is a numerically dominant species in the vicinity of the outfall, although abundance has declined in recent years. Since a high of 171.8 cunner per dive in 1984, the diving abundance index has fluctuated widely, with time-series lows of 29.0 and 28.9 cunner per dive in 1992 and 1993, respectively.

A review of temperature tolerance data on cunner (Kinne 1969) suggests the presence of an exclusion area within and just outside the discharge canal in summer and fall when the plant is fully operational. However, no overt mortality is expected (Lawton et al. 1993). Since 1981, observations during research dives in August and September in the discharge area (limited to flood tide), revealed generally far fewer cunner at Station D_2 (inside the mouth of the discharge) than out at Station D_1 (60 m out from the mouth). As we have often measured bottom temperatures in excess of 30° C during these dives, it would appear that cunner are avoiding the area at the mouth of the discharge in late summer.

Avoidance of the fast-flowing discharge current may also be an exclusion factor. It is known that small cunner, e.g., 2-3 cm fish (young-of-the-year), do not move far from their home shelter. Furthermore, the speed of the effluent current at Pilgrim Station, which can exceed 2.1 m/sec (7 ft/sec) at the egress of the discharge canal, becomes a limiting factor to these small fish in

the discharge. When the plant is operational, these individuals are most often are seen in the 'control' area. Auster (1987) found, at different sites throughout New England, that larger cunner foraged further from reef substrate and on current exposed surfaces for longer time periods. As current velocity decreased, smaller size- classes of cunner moved up into the water column out of the reef infrastructure and onto current-exposed surfaces to feed. As the speed of the current increased the process was reversed.

Sportfishing Effects

Readily caught by anglers bottom fishing off the outer intake breakwater at the plant, cunner led the shore-based sportfish catch during past creel surveys at the Pilgrim Station Shorefront. Although none reportedly were caught in 1993 or 1992, we feel this may be due to incomplete reporting by anglers.

Given their small home ranges which they occupy for an extended time (Green 1975), cunner are susceptible to increased sportfishing mortality. Most cunner caught at Pilgrim Shorefront by anglers had been allowed to die, and past fishing mortality on the local population has been high. In 1983 and 1985, for example, about 2,600 and 3,500 cunner, respectively, were caught by anglers at the Shorefront. To address fishing mortality, we have encouraged fishermen, via posters placed at the Shorefront, to release their catch alive if not kept for consumption.

2. <u>Lobster</u>

Background

The American lobster (*Homarus americanus*) is one of the most common members of the nearshore benthic community, and is highly prized, being subject to intense commercial and recreational fishing. In the Pilgrim Station area, lobster inhabit boulder "fields", rocky ledges, and even depressions in the sand. Lobster are most active at night when they leave refuge areas to forage. As water temperatures rise in the spring, lobster migrate inshore where they remain until cooling waters in late-fall trigger an egress offshore. It is during their summer sojourn inshore that lobster are subject to power plant impact.

Life Stages Impacted and Sampling Protocol

Potential impact to lobster from power generation at Pilgrim Station is greatest during the juvenile and adult life stages, as few entrained lobster larvae have been sampled.

We rely on data collected by our experimental trap sampling program to assess thermal/current effects of plant impact. It should be noted, however, that with this methodology, measurement of plant effects is indirect. Catch rates from lobster traps likely are influenced by such factors as substrate, fishing and natural mortality, in addition to thermal and current influence from the plant discharge. Bay-wide environmental conditions such as short and long-term water temperature patterns can affect the timing of migrations, small-scale movements, and even the onset of

the molt. With high fishing pressure, plant effects may be masked and difficult to measure.

Conditional Mortality - Power Plant Impact

Impingement

A total of 91 sublegal lobster (mean size - 39 mm CL) was sampled on Pilgrim's intake screens in 1993. This equates to an estimated annual impingement of 1,184 lobster. Assuming 100% mortality of these adolescent impinged lobster, it is still likely that impact to the population is negligible. The area immediately in front of the intake wall is not preferred habitat for lobster.

Entrainment

Since 1974, only 12 lobster larvae have been recorded in entrainment sampling at Pilgrim Station (Marine Research, Inc. 1991). Only one larva was collected in 1993. It is apparent that entrainment at Pilgrim Station poses no threat to lobster.

Discharge Effects - Heat and Current

Research Trap Catch Data

Our research trap study has run for eight years, albeit 1993 was the first year where all pots were fished in the immediate vicinity of the Pilgrim discharge. Our assumption in establishing the research lobster station gradient (Figures 6 and 7) was that the Pilgrim thermal discharge current could impact lobster abundance and/or size distribution. Station 0, the site closest to the discharge current, should be subject to the most impact of any of the fixed sampling stations. We tested three lobster catch

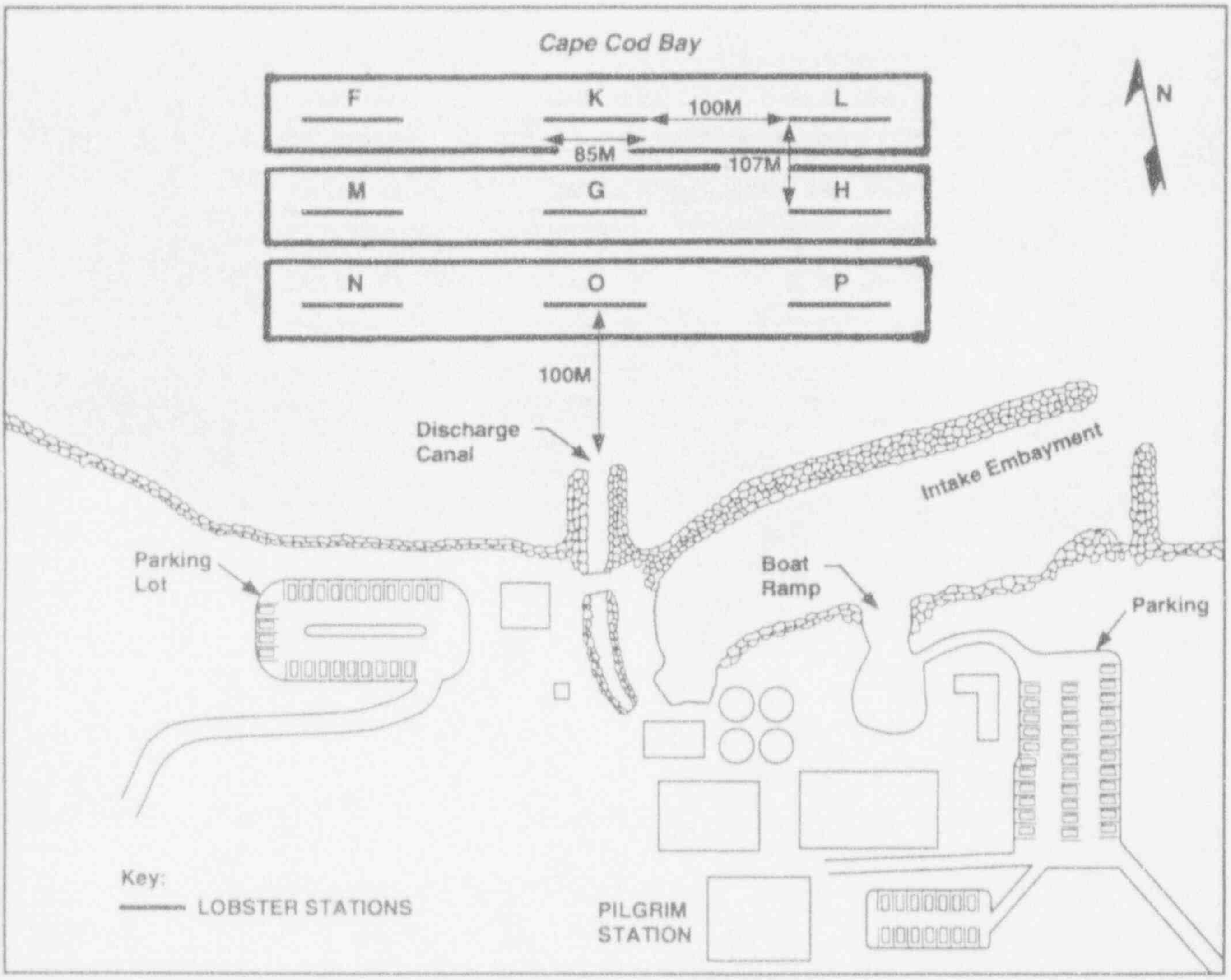

Figure 6. Diagram of experimental lobster stations, 1993 (not drawn to scale), with pooled stations arranged in rows parallel to shore.

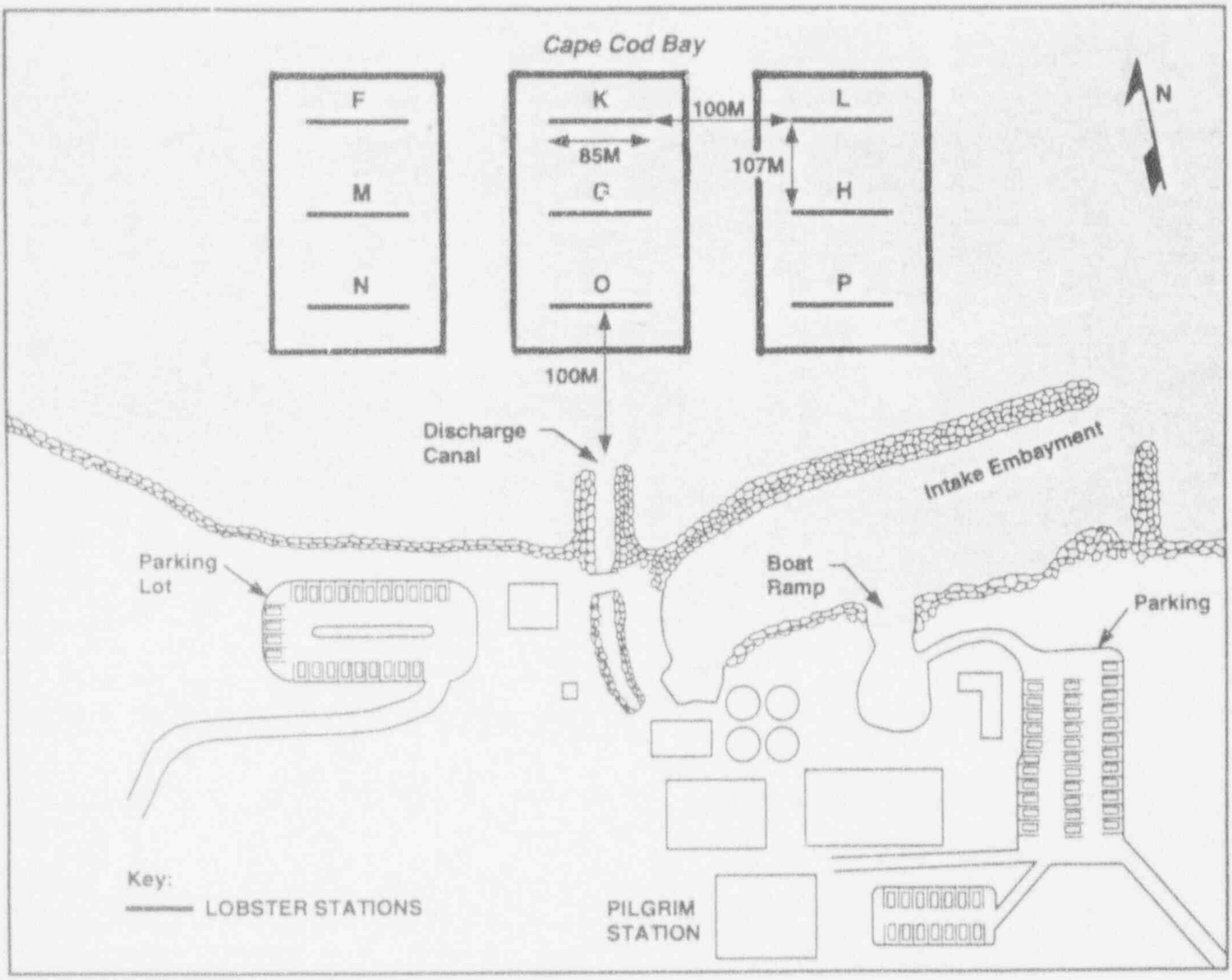

Figure 7. Diagram of experimental lobster stations, 1993 (not drawn to scale), with pooled stations arranged in columns perpendicular to shore.

parameters: (1) catch per trap haul per set over day (CTHSOD) of legal-sized lobster, which is an index of relative abundance of legals; (2) catch per trap haul (CTH) of sublegal lobster, which is an index of sublegal catchability (CTH is a biased index of abundance as sublegals have the ability to escape the traps through escape vents); and (3) lobster length-frequency composition at stations closest to the discharge canal.

In our initial analyses we pooled stations into cells (sites) of three stations each with two orientations. There are three rows parallel to shore with stations within a row at the same depth (Figure 6). The rows are designated as Inner (Stations N, O, and P), Middle (Stations M, G, and H), and Outer (Stations F, K, and L). In addition, there are three columns perpendicular to shore across depth contours (Figure 7); they are designated North (Stations F, M, and N), Discharge (Stations K, G, and O), and South (Stations L, H, and P).

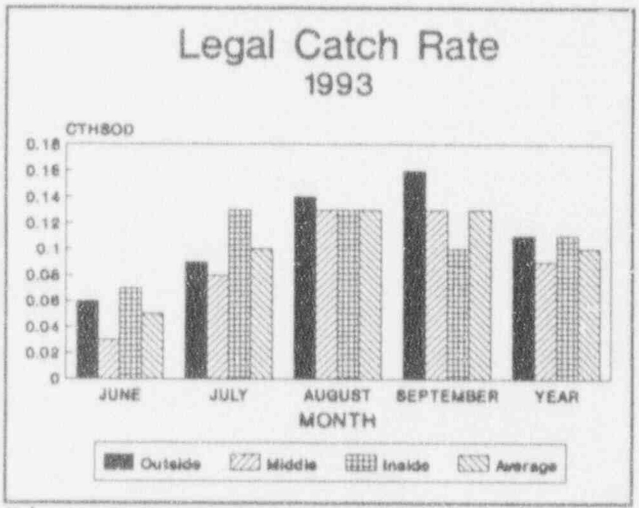

Figure 8. Mean legal CTHSOD for rows of research lobster traps in the vicinity of Pilgrim Station 1993.

Mean legal CTHSOD and sublegal CTH for rows are presented in Figures 8 and 9 and for columns in Figures 10 and 11, respectively. CTH for all lobster pooled (legals and sublegals) was highest for the Outer row (2.96) and the North column (2.82). As in past years, catch rates were generally lowest for legals

in June and for sublegals in July at all sites. This most likely reflects some slight temporal size-dependent variability of lobster availability related to the late spring/early summer molt. Stations F and L had the highest seasonal mean sublegal CTH of 2.91, while Station P had the lowest at 2.05. Stations F, N, and K mirrored each other with the highest seasonal mean legal catch rate of 0.13. The lowest value was 0.06 from Station H.

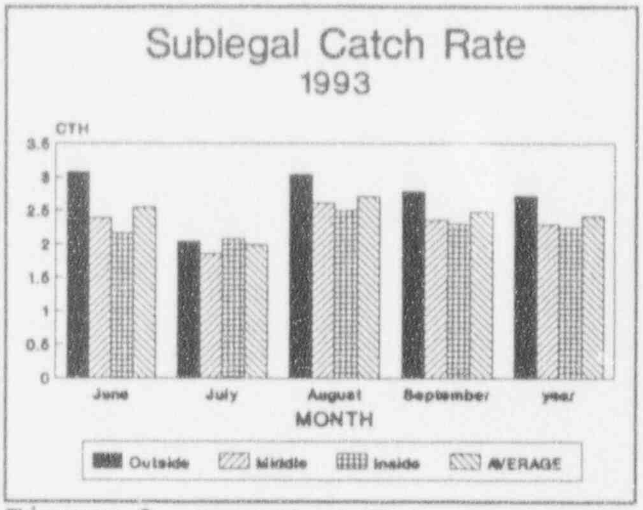

Figure 9. Mean sublegal CTH for rows of research lobster traps in the vicinity of Pilgrim Station 1993.

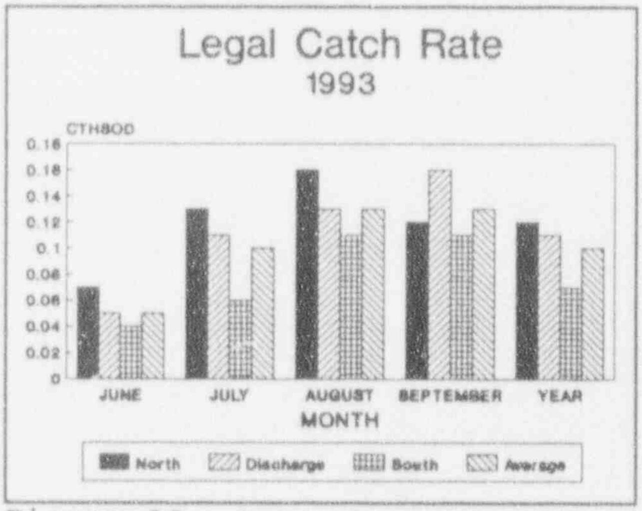

Figure 10. Mean legal CTHSOD for columns of research lobster traps in the vicinity of Pilgrim Station 1993.

As logarithmic transformation of the catch data did not correct heteroscedasticity of variances amongst stations, nonparametric tests were performed on untransformed data. We first compared stations within each row/column to see if data could be pooled on a monthly basis. Using the Kruskal-Wallis test (K-W ANOVA) (Norusis 1990), no significant differences ($P > 0.05$) were found in CTHSOD for legals, but significant differences occurred for sublegal catch rates (Table 2). Even with weighting

CTH of sublegals by trapping effort, the data could not be pooled monthly at a site; consequently, pooled comparisons were not made of CTH between sites in a month.

Legal CTHSOD data for 1993 were pooled by station within rows, and then rows were compared statistically on a monthly basis using K-W ANOVA (Table 3).

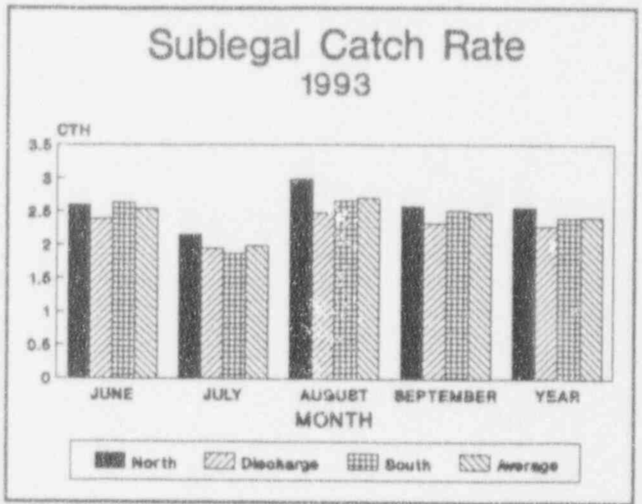

Figure 11. Mean sublegal CTH for columns of research lobster traps in the vicinity of Pilgrim Station 1993.

Table 2. Results of Kruskal-Wallis ANOVA analyses of legal CTHSOD and sublegal CTH data by cell orientations within month for research lobster data collected near Pilgrim Station, June to September, 1993.

Pooled Station Analyses by Row Within Month						
Site		Stations	June	July	August	September
Inner	Legals	N O P	N.S.	N.S.	N.S.	N.S.
	Sublegals		* N>P>O	N.S.	N.S.	N.S.
Middle	Legals	M G H	N.S.	N.S.	N.S.	N.S.
	Sublegals		N.S.	N.S.	N.S.	N.S.
Outer	Legals	F K L	N.S.	N.S.	N.S.	N.S.
	Sublegals		N.S.	N.S.	* F>L>K	* F>L>K

Pooled Station Analyses by Column Within Month						
Site		Stations	June	July	August	September
North	Legals	F M N	N.S.	N.S.	N.S.	N.S.
	Sublegals		* N>F>M	N.S.	* F>N>M	* F>N>M
Discharge	Legals	K G O	N.S.	N.S.	N.S.	N.S.
	Sublegals		* K>G>O	N.S.	N.S.	N.S.
South	Legals	L H P	N.S.	N.S.	N.S.	N.S.
	Sublegals		* L>H>P	N.S.	* L>H>P	* L>H>P

N.S. = non significant
* Significant difference ($p \leq 0.05$) existed amongst the stations at the site; stations are ranked relative to catch rate.

Significant differences ($P \leq 0.05$) were found for September, with the ranking of the grouping being Outer>Middle>Inner; i.e., fewer

legals were caught for the inner row of stations. CTHSOD monthly comparison on pooled station data within columns showed a significant difference ($P \leq 0.05$) in July, with a north to south gradient (North>Discharge>South). Therefore, we could not pool CTHSOD data within sites over the four months of the study. There were no consistent spatial patterns over time for legal CTHSOD data grouped by rows or columns. Plant influence was not clear cut.

Table 3. Results of Kruskal-Wallis ANOVA analyses of pooled legal CTHSOD data for cell orientations within month for research lobster data collected near Pilgrim Station, June to September, 1993.

Site	June	July	August	September
Columns	N.S.	*	N.S.	N.S.
Rows	N.S.	N.S.	N.S.	*

N.S. = non significant
* Significant difference ($p \leq 0.05$) existed amongst cells in the month.

As to sublegal catch rates, Stations F and L had the highest seasonal mean (2.91) and often posted the highest monthly average of all the stations. Consequently, the Outer and North groupings of which these stations were members led in monthly sublegal catches. Habitat differences between stations within rows and columns obviously influenced rates. The Northern column of stations has the most rock substrate (boulders), while the Outer row has the deepest water. Station O was closest to the discharge canal. The velocity of the discharge current at high tide has been measured up to 84 cm/sec (2.8 ft/sec) at 100 m from the discharge canal (Lawton et al. 1992). We speculated there would be lower sublegal catches at Station O because the current could reduce the

mobility of small lobster (Howard and Nunny 1983; Auster 1987). The sublegal catch rate was considerably lower in June at Station O than Stations K and G in the discharge area, but this relationship did not hold for the other months of the study. We analyzed lobster length frequencies on a monthly basis for Station O and selected stations of interest (N, P, G, and K) utilizing the Kolmogorov-Smirnov two sample test. Stations O and G had significantly ($P \leq 0.05$) more smaller lobster < 74 mm than Station N for three of the months. This is the converse of what we expected at Station O. The other noteworthy finding was that Station N had significantly more larger lobster (> 74 mm) than Station P for two of the months. These differences may reflect habitat variability. Station N has more boulders/cover for larger lobster, while Station O has a mix of boulders and cobble and Station P has primarily sand bottom.

3. <u>Winter Flounder</u>

Background and Life History

Winter flounder (*Pleuronectes americanus*) are common in the Northwest Atlantic from the North Shore of the Gulf of St. Lawrence t Chesapeake Bay. They are hardy, being found in waters between 0°-25° C and 4-30 ‰ salinity. Spawning occurs at night when water temperatures are at or near the nadir during late winter and early spring. Spawning/retention areas are located in estuaries, over shoals outside estuaries, and on offshore banks. Extensive reproduction does not occur at water temperatures above 6° ..

Flounder eggs are demersal and adhesive and will clump together after fertilization if not distributed by prevailing currents across the bottom. The larvae are relatively nonbuoyant, and can move vertically in the water column. Fingerlings alternate between intermittent swimming and resting on the bottom. Nursery grounds are located in the general vicinity of spawning areas and include saltwater coves, coastal salt ponds, embayments, and estuarine river systems. Young-of-the-year (YOY) remain in or near their natal waters (Buckley 1982). Saila (1961) found that adults show fidelity and return to the same spawning grounds in consecutive years.

Winter flounder exhibit geographic reproductive isolation, which defines population units. Lux et al. (1970), Howe and Coates (1975), and Pierce and Howe (1977) conducted tagging and meristic studies, and it has been concluded, for management purposes, there are three discrete groups of winter flounder: a stock north of Cape Cod, another south and east of Cape Cod, and a third on Georges Bank. Tag returns from release sites north of Cape Cod indicated that flounder movement there was localized and confined to inshore waters (Howe and Coates 1975). Movements apparently reflect the extent of seasonal dispersal and are temperature driven. The preferred temperature range is 12°- 15° C.

Winter flounder in Cape Cod Bay generally occur as estuarine-specific populations (Stone and Webster 1977). The Plymouth-Kingston-Duxbury Bay (PKDB) estuary is a known winter flounder spawning ground that produces local fish in the environs of Pilgrim

Station. There are seasonal inshore and offshore movements of flounder within this area. Adults disperse from winter/spring spawning aggregations when water temperatures exceed 15° C and move into deeper, inshore waters of Cape Cod Bay in late spring and summer. The local flounder population is exploited by a regulated trawl fishery that is open from November to April. A minimum legal size of 305 mm TL (12 in) is currently in place.

According to the National Marine Fisheries Service, the Gulf of Maine winter flounder landings, both commercial and recreational, have trended downward in recent years (NEFC 1993). Combined landings in 1992 were at a record low for the 14-year time series, with recreational catches at a nadir and commercial catches at their lowest level since 1967. Trawl surveys conducted by the Massachusetts Division of Marine Fisheries both off Pilgrim Station (Lawton et al. 1992) and for the entire Cape Cod Bay/ Massachusetts Bay region (Witherell et al. 1990) documented declining abundance indices after 1983 (Howell et al. 1992). However, the annual relative abundance index (mean number per tow) for the western sector of Cape Cod Bay climbed upwards in 1992 and 1993 (this study). From stock assessment work along the Massachusetts coastline, it was found that the spring survey index (stratified mean weight per tow) for winter flounder north of Cape Cod has fluctuated at low levels without a trend since 1988, while the catch rate (using stratified mean number per tow) increased markedly in 1993 (Correia et al. 1993), which suggests an increase in recruitment. Overfishing has been a major problem, and flounder

stocks consequently have been overexploited (NEFC 1993).

Spawning success, recruitment, and stock cohesion are enhanced in areas where physiography and oceanographic processes lead to larval retention and concomitant improved survival. The size of the spawning and larval retention grounds is a limiting factor to absolute population abundance. Large winter flounder populations are correlated with large geographic spawning and early life history distributional areas, e.g., large bays and offshore banks; whereas, smaller populations are associated with coastal ponds and smaller estuaries (Howell et al. 1992). Clearly the impact of a mortality on a population is inversely related to the size of that population.

Habitat quality is important because the location of most flounder spawning grounds predisposes this species to population losses via effects of alteration and degradation of inshore aquatic areas. The flounder life stages are influenced by energetics processes and can be impacted by dredging and filling of marine habitats, toxic pollutants and disease, and power plant-induced mortality. These can involve direct mortality or a loss of reproductive and growth potential.

Conditional Mortality - Power Plant Impact

Impingement and entrainment mortality of winter flounder should be figured into total mortality. Losses through impingement can be problematic when power plant intakes are in or near nursery areas (Normandeau 1979). All life stages of flounder inhabit Pilgrim's Intake embayment at least seasonally. The Intake at

Pilgrim Station simulates a cove and serves as a mini-nursery ground for several species of fish, including flounder. YOY winter flounder inhabit shallow coves, which is likely related to their attraction to light. Saucerman and Deegan (1991) found that young flounder exhibit limited movements while on nursery grounds.

Impingement

In 1993, an estimated 1,171 winter flounder were impinged at Pilgrim Station. They ranged in total length from 43 mm - 322 mm (mean = 907 mm), with the majority being YOY and yearlings. Impingement was highest in the fall and winter months, peaking in December.

Entrainment

Winter flounder larvae are more susceptible to power plant entrainment than are the eggs which are demersal and adhesive. The benthi-pelagic larvae are generally more abundant near the bottom of the water column and are vulnerable to power plant entrainment. At Pilgrim Station, entrainment of winter flounder larvae has ranged from 3.5 million to 17.9 million annually over the last 7 years (1987-1993). Entrainment in 1993 was estimated to be 8.2 million larvae, which is similar to the 1992 value (8.4 million).

Entrainment mortality at Pilgrim Station in 1993, assuming no survivorship and using the adult equivalent approach, which assumes a population in equilibrium and no density-dependent compensation, equates to the loss of 4,820 age-3 winter flounder. For this calculation, larval stage survival values were taken from work done off the Millstone Nuclear Power Station (NUSCO 1993) and modified

by Gibson (1994). Gibson (1994) examined data for a number of winter flounder stocks and found that after accounting for adult mortality, recruitment rates were found to be lowest in three populations (Mt. Hope Bay, Niantic River, and off Pilgrim Station) that are exposed to entrainment withdrawal at nearby power plants.

The source of entrained flounder larvae at Pilgrim Station is important to establish stock identity, i.e., to delineate the geographic boundaries of the local population. The power plant entrains larval flounder from PKDB but apparently crops larvae produced outside the estuary as well (Marine Research Inc. 1988). Evidence of larval flounder originating outside the estuary, e.g., in Plymouth Bight, complicates our estimation of adult stock size and assessment of power plant impact.

Discharge Effects - Heat and Current

Another concern is the possible effects of waste heat and current on the occurrence, distribution, and behavior of flounder in the outfall area of Pilgrim Station. Direct mortalities of winter flounder have not been observed in the thermal plume. Olla et al. (1969) observed that winter flounder would burrow into the substrate and became inactive when water temperatures exceeded 22.2° C, which is below the incipient thermal tolerance limit estimated by McCracken (1963) at 26.5° C and by Gift and Westman (1971) at 28° C. To avoid high water temperatures, flounder can vacate an area or bury into the bottom which would be lower in temperature than the overlying water (Olla et al. 1969). Mature flounders will leave the shore zone in areas where bottom water

temperatures exceed about 15° C (McCracken 1963). On several occasions in late summer, bottom water temperatures approached 30° C at the mouth of the Pilgrim discharge canal. Stone and Webster (1977) predicted that adult winter flounder would be excluded by high temperatures from the immediate vicinity of the Pilgrim discharge during the late summer and early fall. This impact area is believed to be under 4,047 m^2 (1 ac).

Sportfishing Effects

No winter flounder reportedly were caught by anglers at Pilgrim Shorefront in 1993. This species had previously numbered amongst the top five sportfish angled in the recreational fishery off the power plant in the 1970's and early 1980's.

IV. CONCLUSIONS

Cunner

1. The annual impingement estimate for 1993 was 104 cunner. Annual impingement rates have remained relatively low since 1980, when an estimated 1,683 cunner were impinged.
2. Large numbers of cunner eggs and larvae were entrained at Pilgrim Station in 1993, with the number entrained estimated to equal about 61,000 adult fish.
3. The 1993 cunner abundance index (29 fish per dive) from the underwater finfish observations continued at a time-series low first recorded in 1992.
4. Stressful warm temperatures may cause cunner to avoid the discharge canal and near-thermal plume during late summer.
5. The discharge current at the station is of sufficient velocity to shift the small-scale distribution of cunner by size class, with only larger cunner present in the discharge current on a flood tide.
6. No cunner were reported caught by anglers at the Pilgrim Station Shorefront in 1993; however, this may be due to incomplete reporting.

American Lobster

1. As only 12 lobster larvae have been entrained at Pilgrim Station since 1974 and only relatively low numbers of juveniles have been impinged, these impacts at Pilgrim Station are evidently small.

2. There were no consistent spatio-temporal patterns for legal CTHSOD data grouped by rows or columns. Pilgrim Station influence on legal and sublegal catch rates was indistinct.
3. The catch of small (< 74 mm CL) lobster at Station O, the site closest to the discharge, did not appear to be influenced by plant discharge.

Winter Flounder

1. The nearby location of winter flounder spawning (retention) grounds, the limited movement patterns of flounder north of Cape Cod, and the discreteness of the reproductively-isolated local population make this species especially sensitive to impacts from entrainment and impingement at Pilgrim Station.
2. The winter flounder stock north of Cape Cod has been overexploited by commercial and recreational fishing.
3. In 1993, an estimated 1,171 winter flounder - the majority young-of-the-year and yearlings - were impinged at Pilgrim Station.
4. In 1993, an estimated 8.2 million winter flounder larvae were entrained at Pilgrim Station, which equates to the loss of 4,820 age-3 flounder.
5. Late summer water temperatures in the immediate vicinity of the discharge canal can exceed the upper thermal tolerance limit for winter flounder and would exclude them from this area of stress which is under 4,047 m^2 (1 ac).

VI. ACKNOWLEDGEMENTS

The authors thank the following staff members - Steve Cadrin, Neil Churchill, and Jessica Harris for assisting in field sampling operations. We acknowledge Chris Kyranos, a commercial lobsterman, for his valued assistance in our research lobster sampling program. Raymond Dand and Robert Ellenberger of Boston Edison Company (BECo) collected sportfish data at Pilgrim Shorefront. Jay Burnett from the National Marine Fisheries Service (NMFS) in Woods Hole, MA aged cunner from the Pilgrim area. A special thanks to Kim Trotto of our staff for word-processing several sections of this report. We appreciate the guidance of Robert D. Anderson of BECo, W. Leigh Bridges of our Division, and members of the Pilgrim Administrative-Technical Committee. Their input on various studies and editorial comments on project reports and papers have been most helpful.

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FINAL
SEMI-ANNUAL REPORT
Number 43

BENTHIC ALGAL MONITORING AT THE PILGRIM NUCLEAR POWER STATION (QUALITATIVE TRANSECT SURVEYS)

January-December 1993

to

BOSTON EDISON COMPANY
Licensing Division
Pilgrim Nuclear Power Station
Plymouth, Massachusetts 02360

From

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

1 April 1994

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EXECUTIVE SUMMARY

This report presents results of qualitative surveys taken in 1993 of benthic algae in the area affected by the thermal effluent flowing from the Pilgrim Nuclear Power Station (PNPS) and summarizes the potential impacts caused by the PNPS on algal distributions in the vicinity of the discharge canal. Field studies for 1993 were confined to qualitative transect surveys used to map algal cover in the area of water outflow and were conducted in April, June, September, and December 1993. Field survey techniques were identical to those used in prior years. These investigations represent the most recent phase of long-term efforts to monitor effects of the thermal effluent on the benthic algal communities within and just offshore of the PNPS discharge canal.

PNPS is a base-load, nuclear-powered electrical generating unit designed to produce 670 megawatts of electrical energy under full operational conditions. The station is cooled by water withdrawn from Cape Cod Bay and then returned to the Bay via a discharge canal designed to dissipate heat through rapid mixing and dilution of the outflowing water. Two circulating pumps produce a maximum water flow of approximately 20 $m^3 s^{-1}$. The PNPS cooling system may affect the benthic community in three ways: 1) warming ambient waters, 2) chemical discharge (mainly Cl_2), and, 3) increased current velocity that scours the seabed. Increasing temperature and chemical discharges may stress the algal community so that species composition and community structure change; the extent of such change depends upon season of the year and the influence of local oceanographic conditions. Increased current velocity directly affects the benthos by actually removing benthic organisms and preventing settlement and recolonization; intense bottom scouring may cause the rock surfaces to become bare and devoid of macroscopic marine life.

The qualitative transect studies performed to evaluate the *Chondrus crispus* (Irish moss) community in the thermal plume area indicated that in April and June 1993 the condition of the denuded and total affected areas was typical of that seen in previous years when the power plant was in full or nearly full operation. The denuded area in April (1239 m^2) was well within the size range seen in earlier spring surveys taken when the plant was in operation (765 m^2 in April 1986 to 1321 m^2 in March 1991). By June, the denuded zone had decreased 15% to 1055 m^2, again a size well within the range seen in previous summer surveys. The dense mat of newly settled mussels (*Mytilus edulis*) seen during the June survey covered a considerably smaller area than in the June 1990 and June 1992 surveys. Consequently, the denuded area decreased in size between April and June when sunlight and warmth permitted the algae to flourish, following the pattern seen in 1983, 1985, and 1991. In addition, there was no difficulty in discerning the boundaries of the sparse and stunted *Chondrus* zones in June. In contrast, the fall and

winter surveys showed a denuded area larger than had been measured in the same season in any previous year. In September the area of the denuded zone (1648 m^2) was only slightly larger than that measured in 1990 and 1992 and the area of the total affected zone was within the range (1003 m^2 in 1985 and 1908 m^2 in 1992) seen in earlier surveys. However, the area of the denuded zone in December (1522.5 m^2) was much larger (from 16-65% larger) than seen in previous years and the total affected area in December was the largest seen since measurements began in 1983, rivaled only by areas measured in the summers of 1990 and 1992. Such a large *Chondrus* affected area may be explained in part by the very early date (Dec. 2) of the winter survey and perhaps by damage imposed by a heavy infestation of *Chondrus* plants by an encrusting bryozoan, tentatively identified as *Membranipora membranacea*, an exotic species reported from the east coast of the United States only since 1987 (Lambert, et. al., 1992). Potential effects of *M. membranacea* on the *Chondrus* beds will have to be kept in mind as Lambert et. al. (1992) have already noticed a deleterious impact of *M. membranacea* on kelp beds in the Gulf of Maine.

Recent aerial photographs of the effluent canal show some differences between the actual position of the jetties and those shown in the base map. The submerged portion of the southern jetty clearly trends toward the central transect line relative to the northern jetty. In addition, the underwater profile of the nearshore portion of the jetties (especially the southern jetty) has changed somewhat over the years. Storms have moved some boulders away from the jetty to positions closer to the central transect line. For the sake of maintaining consistency in calculations of the area of the *Chondrus* denuded zone, the same base dimensions of the jetty that have been used in figures for this report for many years are continued for the current surveys.

1.0 INTRODUCTION

This report represents a continuation of long-term (20 yr) benthic studies at Pilgrim Nuclear Power Station (PNPS) designed to monitor the effects of the thermal effluent. The 1993 monitoring program was identical to that performed in 1992 and was limited to qualitative SCUBA surveys of algal cover in the nearfield thermal plume of the effluent within and beyond the discharge canal (Figure 1). Surveys were conducted quarterly in April, June, September, and December. No quantitative evaluation of the benthic algae or fauna was made. This Semi-Annual Report includes qualitative observations recorded in April, June, September, and December 1993 as well as a summary of the potential impact on algal distributions caused by PNPS. Work was performed under Boston Edison Co. (BECo) Purchase Order 107009, in accordance with requirements of the PNPS NPDES Permit No. MA 0003557.

2.0 FIELD STUDIES

2.1 METHODS

The qualitative algal survey is performed by SCUBA divers in the same location and with the same techniques that have been used since the current monitoring program began, approximately 12 years ago. The effluent area is surveyed by two or three SCUBA-equipped biologists operating from a small boat. For the qualitative transect survey, SCUBA observations are made along the axis of the discharge canal. A line is stretched across the mouth of the discharge canal (Figure 2). A weighted central transect line (CTL), 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. Using a compass, divers extend a 30-m measuring line, marked at 1-m intervals, perpendicular to the CTL at each 10-m mark. A diver swims along this third line, recording changes in algal cover from the CTL through the denuded and stunted *Chondrus* areas, until the algal cover looks normal. A large boulder that is nearly exposed at mean low water, and that is used as a landmark by both the Science Applications International Corporation (SAIC) and the Massachusetts Division of Marine Fisheries dive teams serves as a visual fix for the proper placement of the transect line. To ensure consistency among the surveys the CTL or survey is adjusted so that the boulder is always located at 65 m along and just to the north of the CTL.

To attempt to explain various reports by the divers that placed the jetties (particularly the southern jetty) closer to the CTL than figured on the base map, photographs were taken on an overflight performed on Oct. 19, 1993, approximately one hour before high tide. The aerial view of the effluent canal shown in Figure 3 clearly shows that the submerged portion of the southern jetty is pitched toward the CTL relative to the northern jetty. For reference, the 0-m mark on the CTL is just somewhat seaward of the

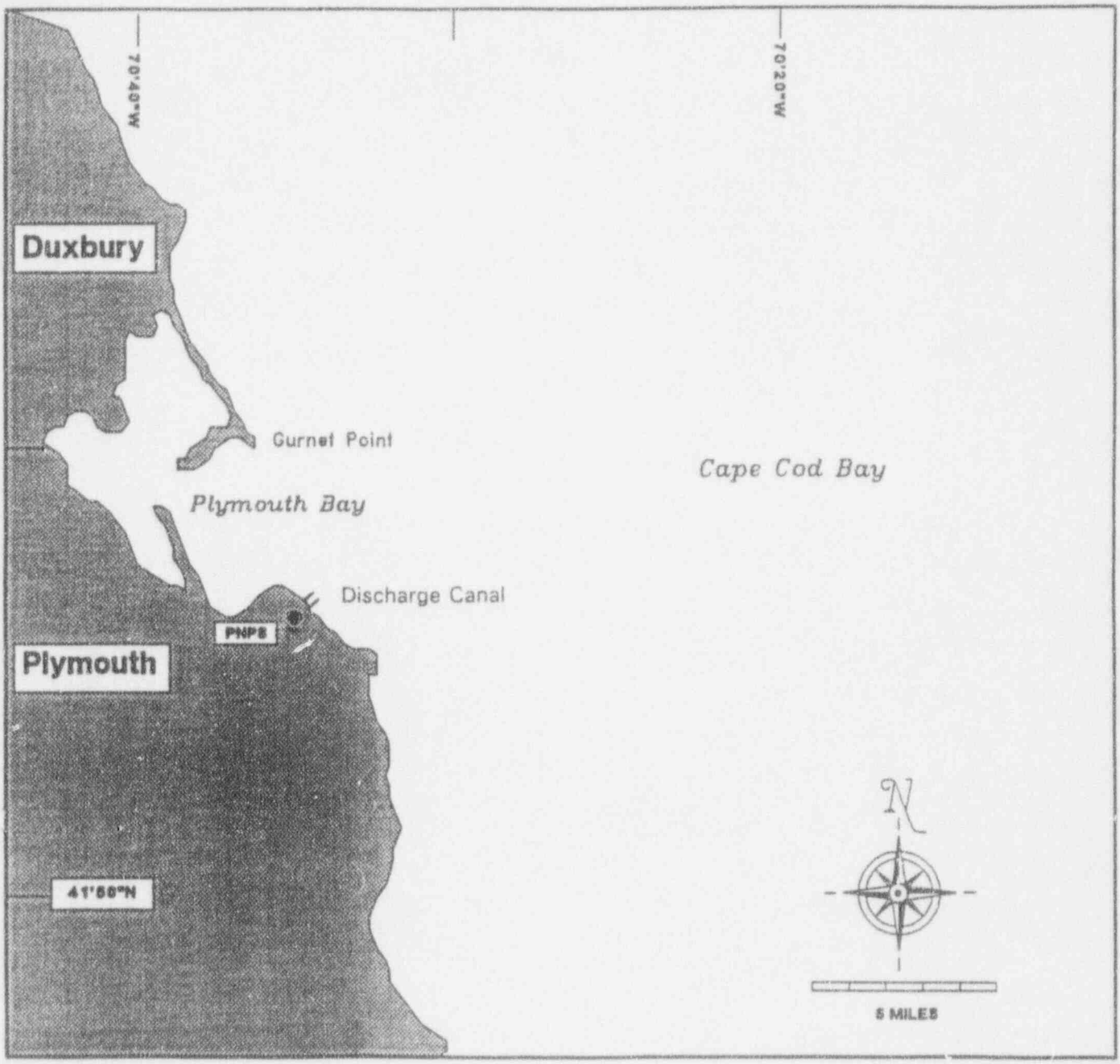

Figure 1. Location of Pilgrim Nuclear Power Station Discharge Canal.

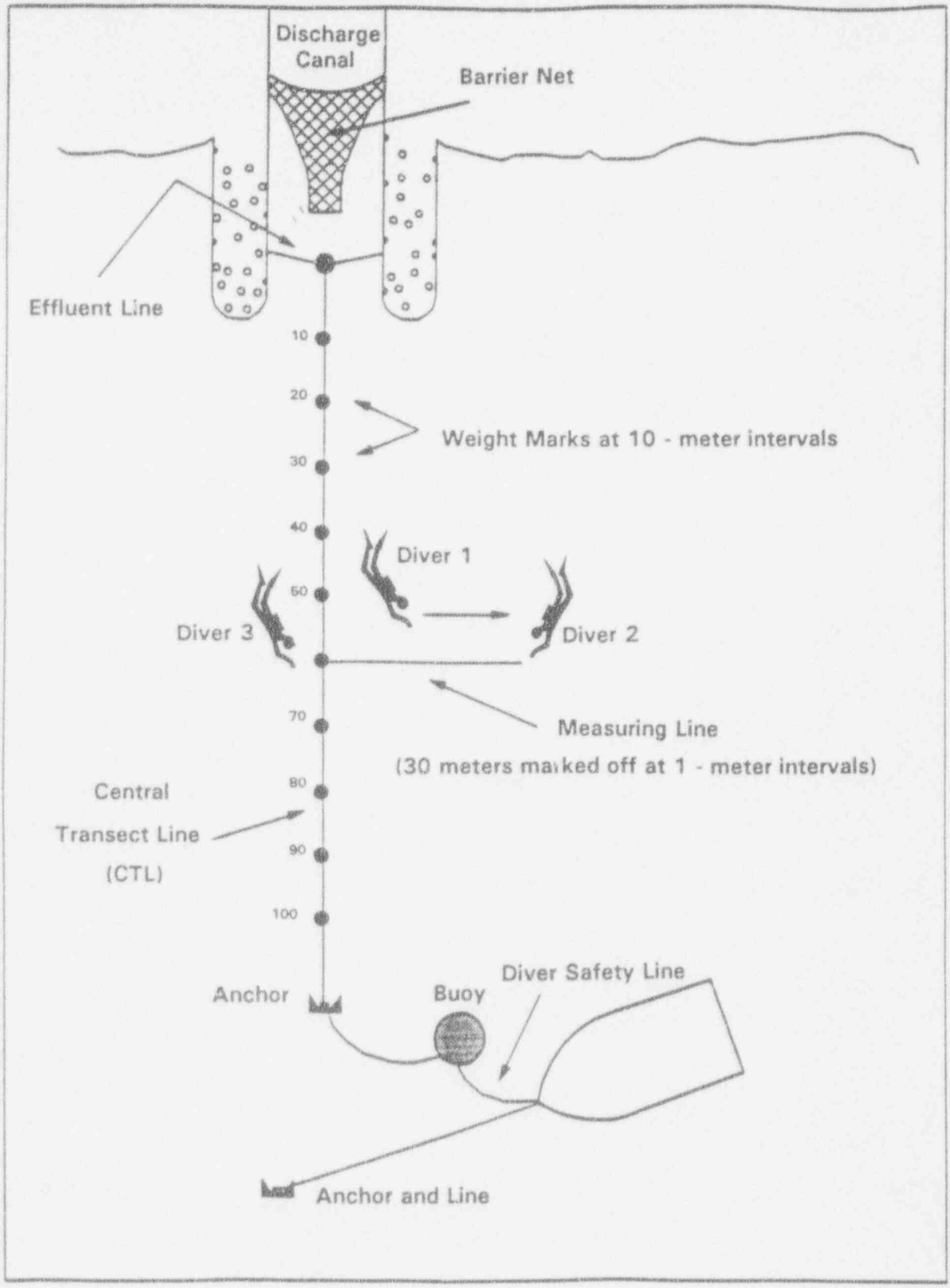

Figure 2. Design of Qualitative Transect Survey.

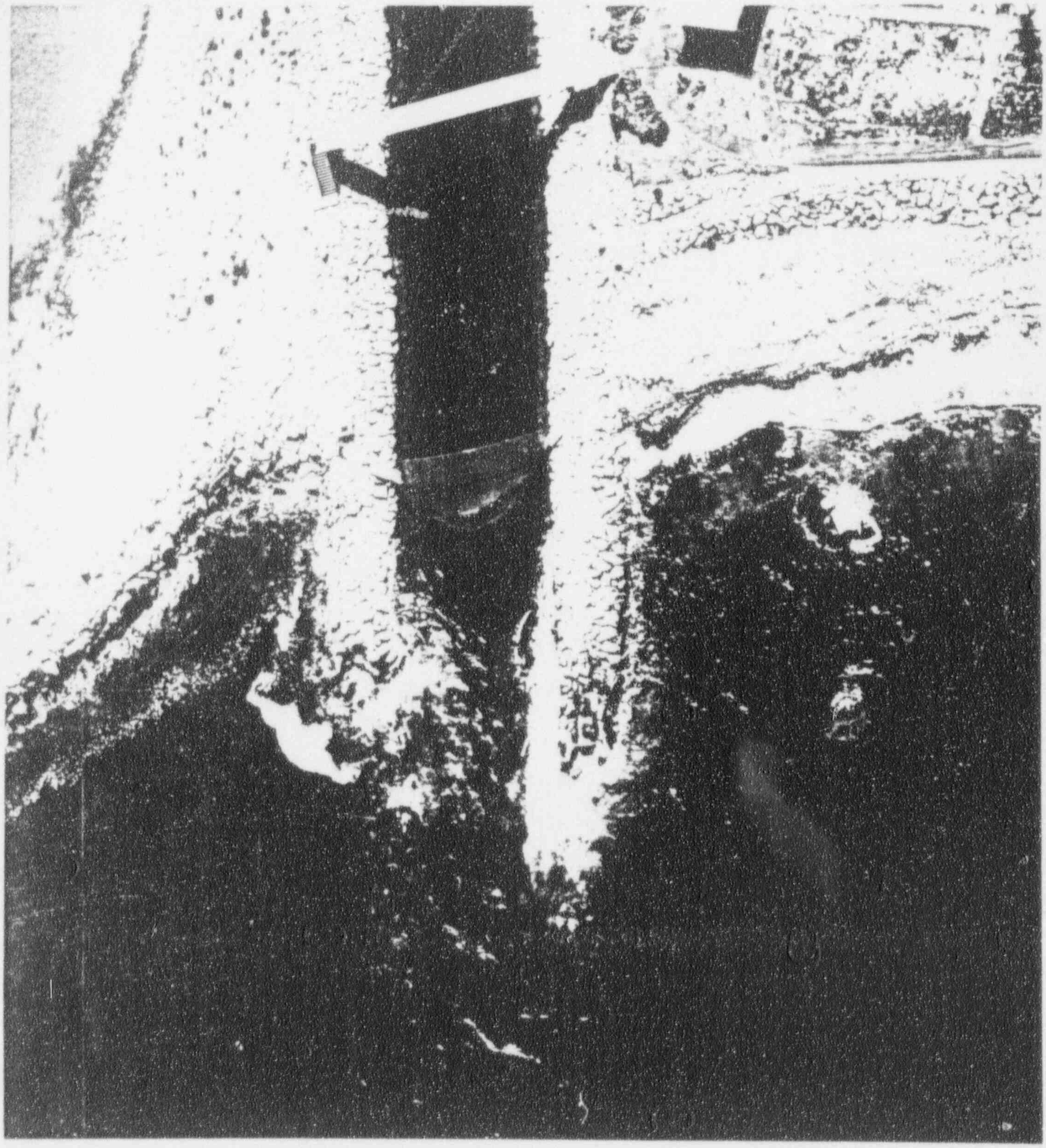

Figure 3. Aerial Photograph of PNPS Effluent Canal Taken in October 1993.

cod-end of the barrier net. Other differences between the actual jetties and the baseline figure are, 1) the portion of the northern jetty that is above water extends further into Cape Cod Bay than the southern jetty, 2) the jumble of boulders displaced from the southern jetty into the mouth of the effluent canal, and 3) the much longer submerged portion of the jetties (they extend seaward at least 15 m beyond that shown in the base maps). In spite of these differences, for consistency, the base map that has been used for a number of years was retained for calculation of the areal extent of the various *Chondrus* zones.

The terminology established by Taxon (1982) and followed in subsequent years uses the growth morphology of *Chondrus crispus* to distinguish between "denuded" and "stunted" zones. The **denuded zone** is the area in which *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 rocks but is noticeably inferior in height, density, and frond development compared to plants growing in unaffected areas. In 1991 the divers began to discriminate between a stunted zone and a "sparse" zone. The **sparse zone** is an area with normal-looking *Chondrus* plants that are very thinly distributed. The **normal zone** begins at the point where *Chondrus* height and density are fully developed. The dive team must keep in mind while taking measurements that the shallow depths northwest of the discharge canal hamper normal *Chondrus* growth. In addition to evaluating extent and condition of algal cover, the divers record any unusual events in the area, such as the occurrence of unusually strong storms, and note the location of any distinctive algal or faunal associations.

2.2 RESULTS

Qualitative transect surveys of acute nearfield impact zones began in January 1980 and have been conducted quarterly since 1982. Four surveys were performed (April 8, June 28, September 20, and December 2, 1993) during the current reporting period, bringing the total number of surveys conducted since 1980 to 52. Results of surveys conducted from January 1980 to June 1983 were reviewed in Semi-Annual Report 22 to BECo (BECo, 1983). A summary of surveys conducted between 1983 and 1992, including a review of the four performed in 1992, was presented in Semi-Annual Report No. 41 (BECo, 1993). The present report summarizes the April and June 1993 surveys and presents new data obtained in September and December 1993.

Figures 4,5,6, 7, and 8 show the results of the 1993 transect surveys performed by SCUBA divers. The denuded zone is essentially devoid of *Chondrus crispus*, the sparse zones are those in which normal looking *Chondrus* is sparsely distributed, and the stunted zones are areas where *Chondrus* plants

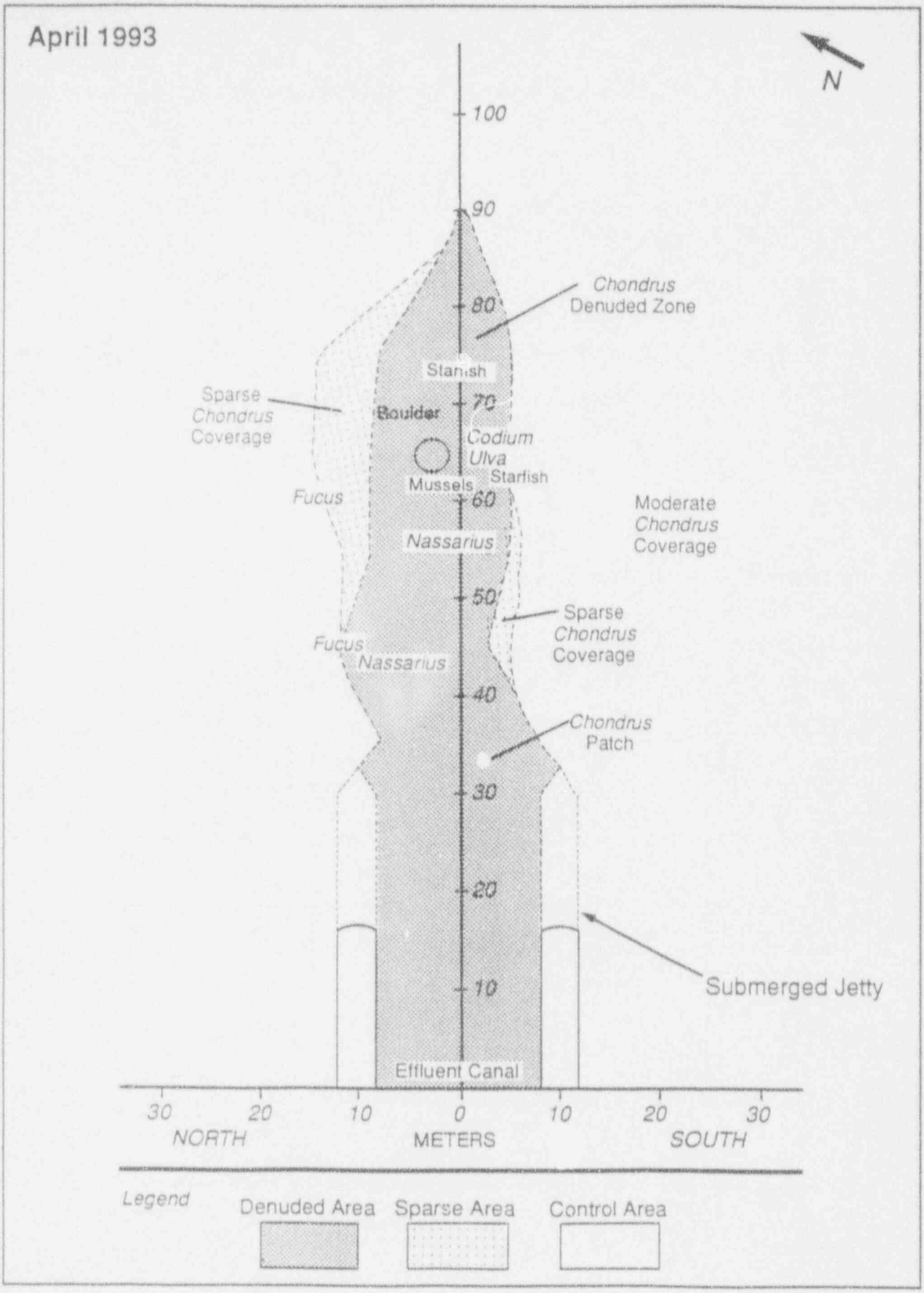

Figure 4. Denuded and Sparse *Chondrus* Zones Observed in April 1993.

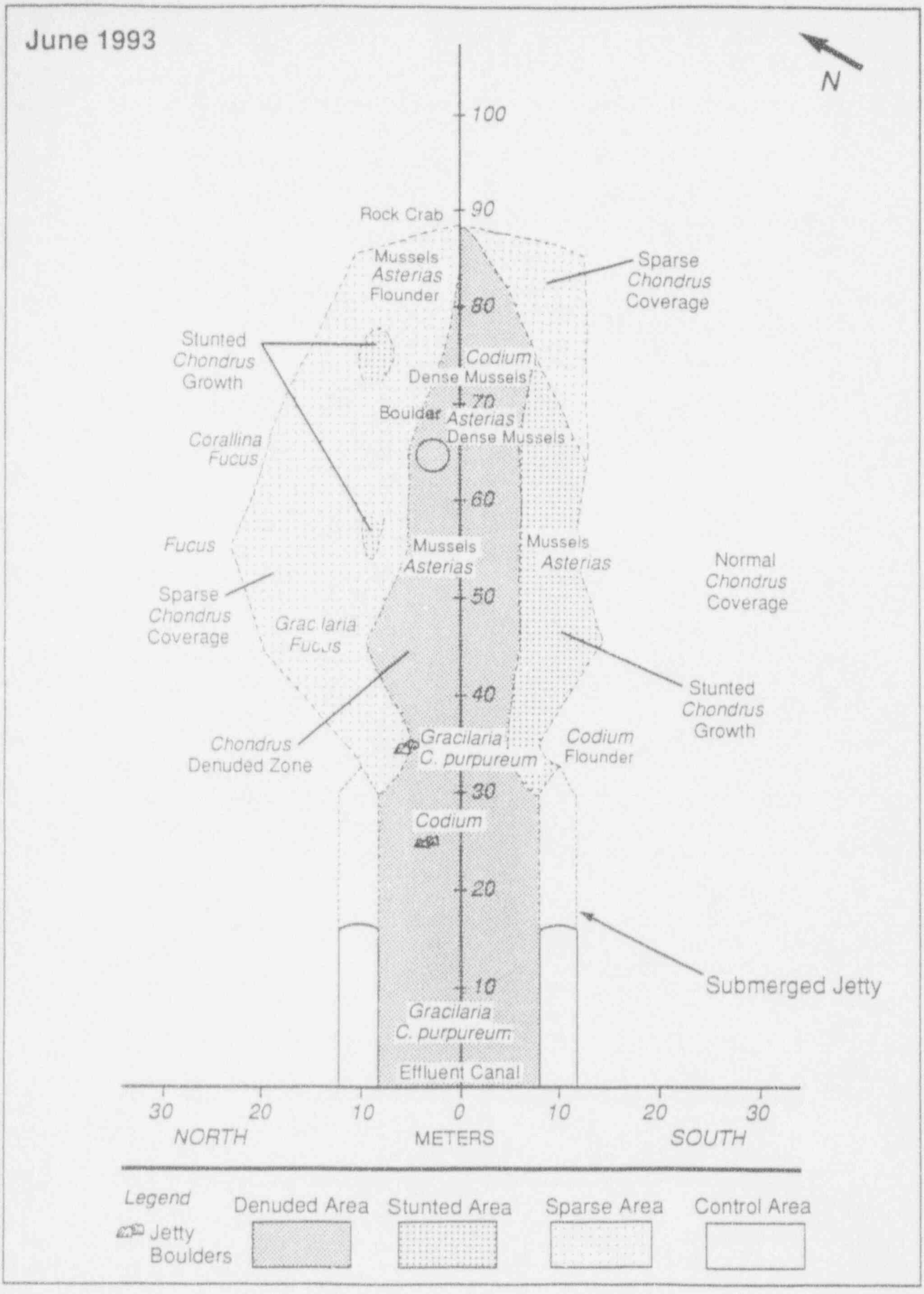

Figure 5. **Denuded, Sparse, and Stunted *Chondrus* Zones Observed in June 1993.**

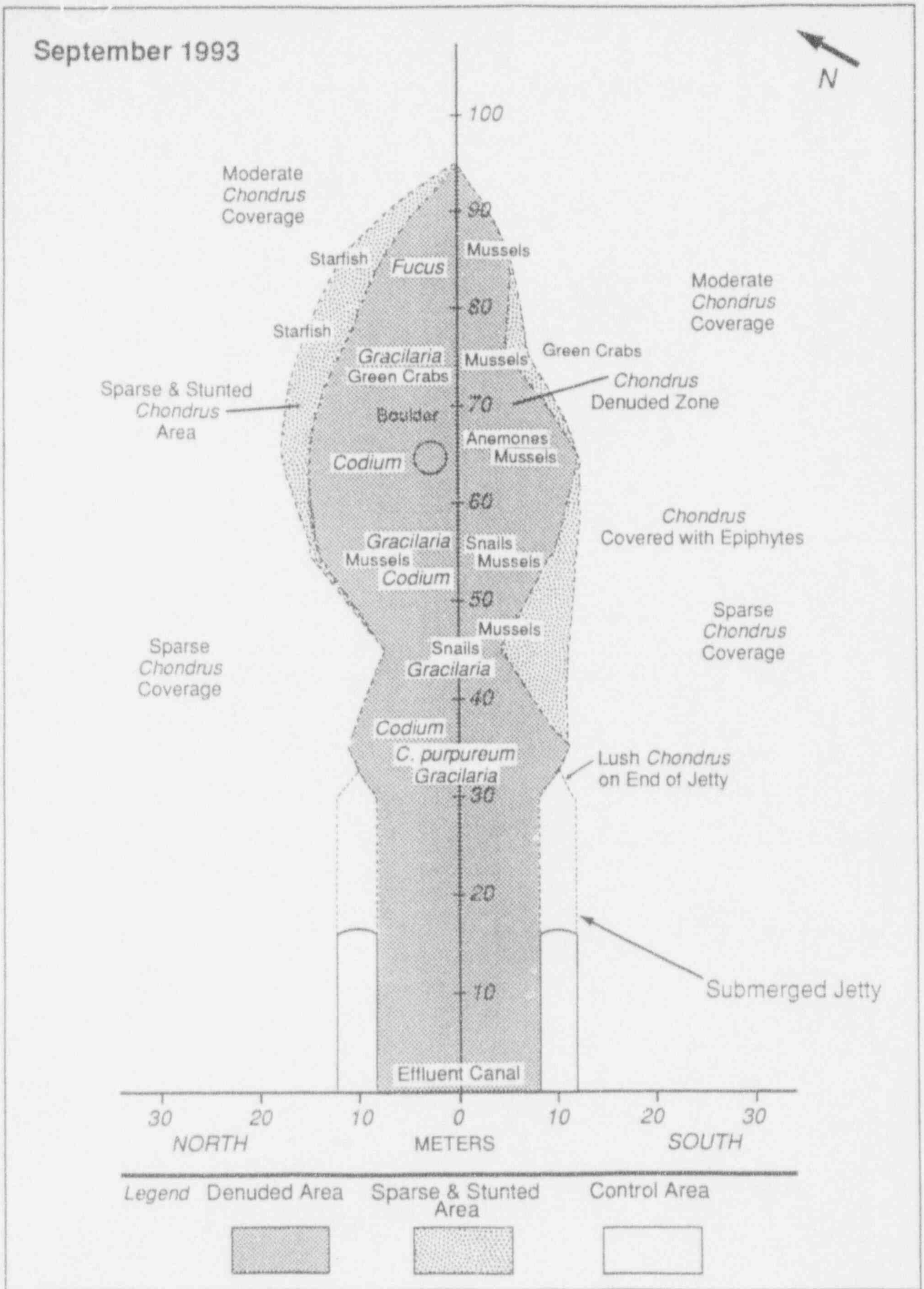

Figure 6. Denuded and Sparse/Stunted *Chondrus* Zones Observed in September 1993.

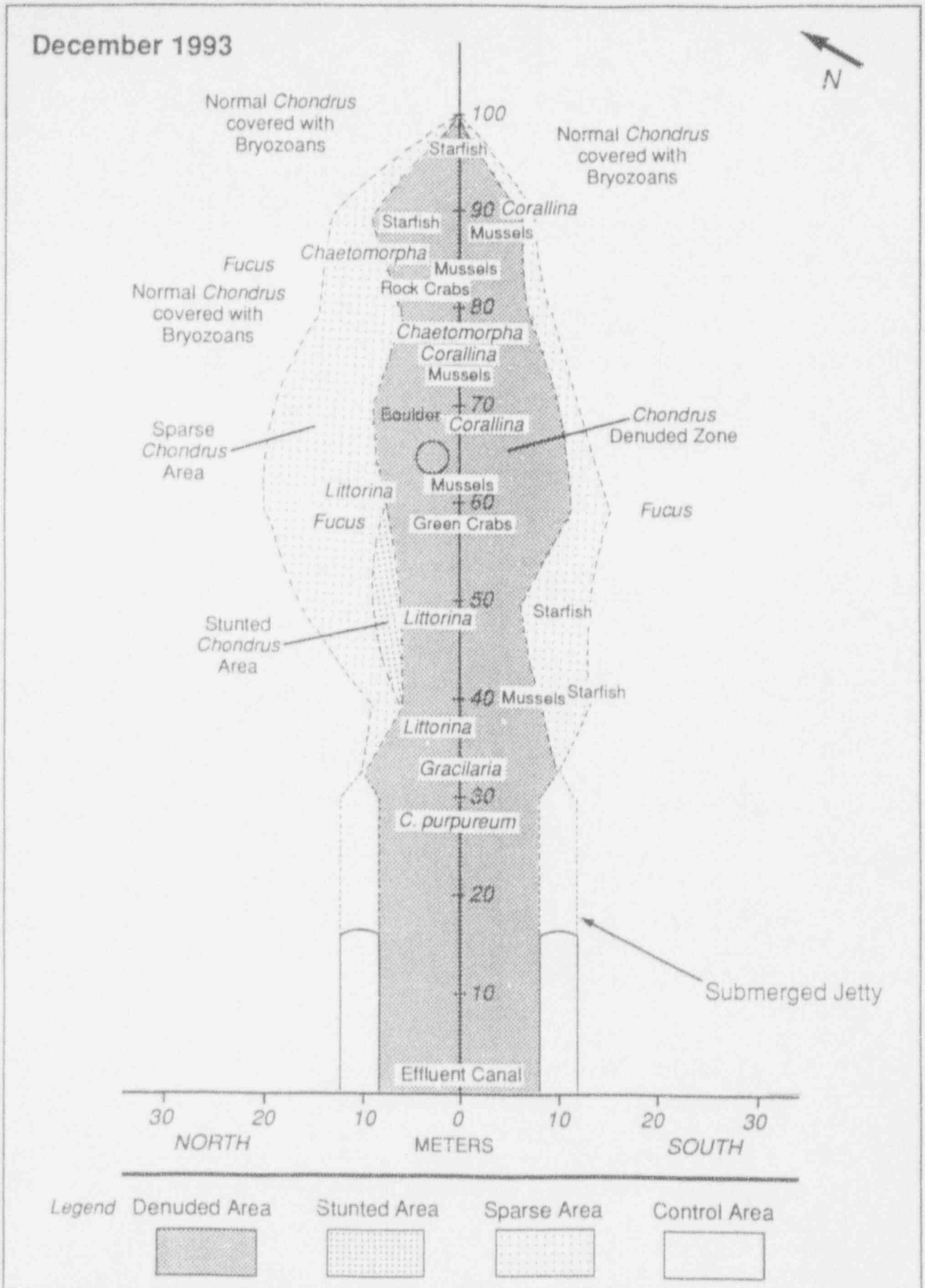

Figure 7. **Denuded, Sparse, and Stunted *Chondrus* Zones Observed in December 1993.**

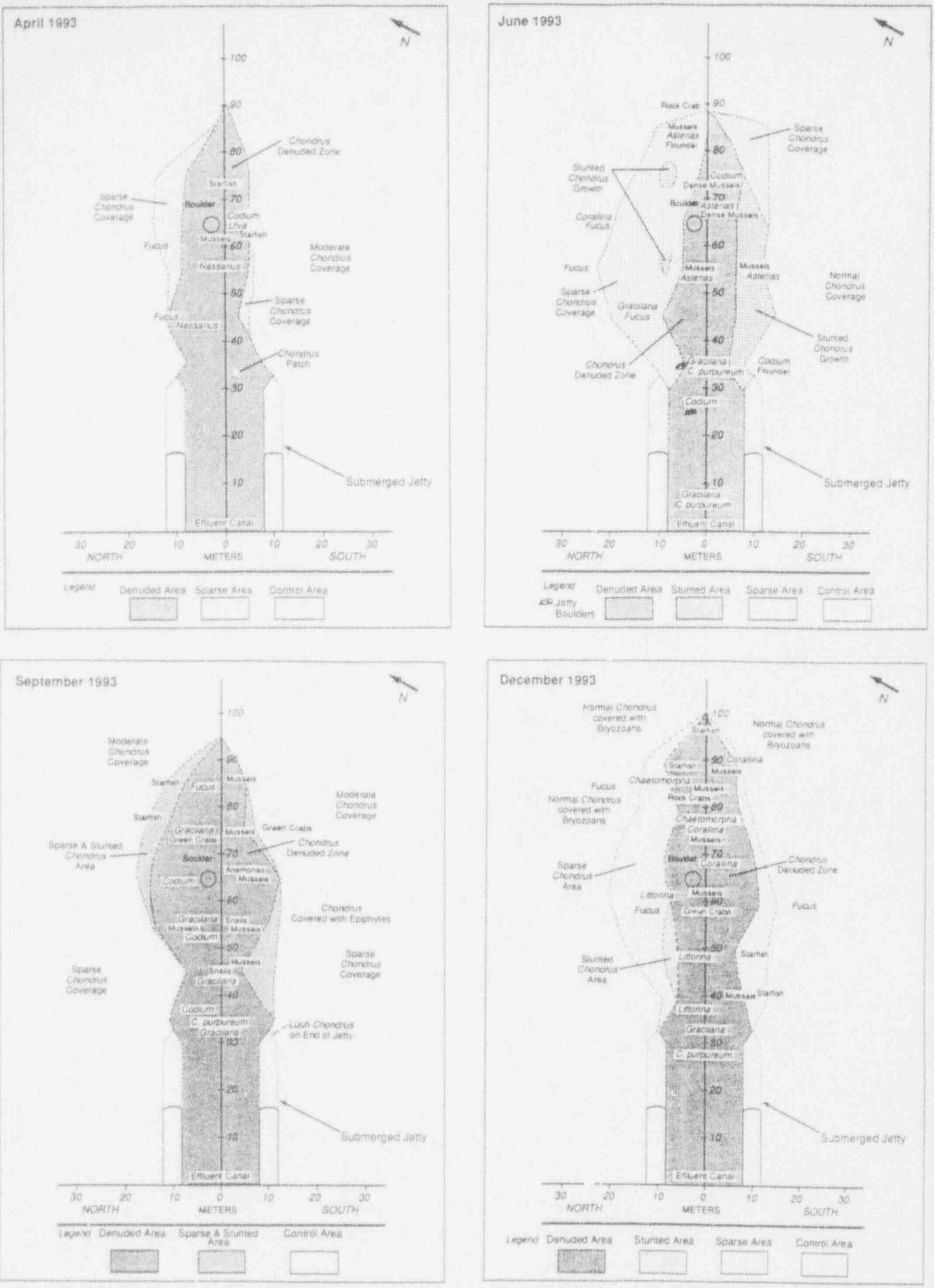

Figure 8. **Results of the 1993 Qualitative Transect Surveys of the PNPS Acute Impact Zone off the Discharge Canal taken in April, June, September, and December 1993.**

are shorter and less developed than normal. The landmark boulder is plotted in all figures as are positions of the most common algal and faunal species observed by the divers.

2.2.1 APRIL 1993 TRANSECT SURVEY

The denuded and sparse *Chondrus crispus* areas mapped on April 8, 1993, immediately offshore of the PNPS are shown in Figure 4. The *Chondrus* denuded zone extended approximately 90 m offshore along the central transect line and was asymmetrically distributed around it with 58% of the denuded area north of the central transect line. However, nearly two-thirds (64.5%) of that portion of the denuded area projecting beyond the jetties extended north of the CTL. The denuded zone extended furthest from the CTL at the 45-m mark (12 m to the northwest). The area (approximately 1239 m^2) of the *Chondrus* denuded zone was slightly smaller (5.7%) than in the February 1993 survey. Adult snails, possibly *Nassarius*, were observed throughout much of the denuded zone (from the 45-m mark to the 65-m mark along the transect line). The divers classified no area as a stunted zone but did define a sparse zone with an area of about 351 m^2; this was more than twice the area of the sparse zone measured during the April 1992 survey and nearly twice that seen in the February 1993 survey. No *Laminaria*, fish, or crabs were observed within the study area.

2.2.2 JUNE 1993 TRANSECT SURVEY

The results of the June 28, 1993 survey are mapped in Figure 5. Note that a few errant jetty boulders northwest of the transect line are displayed in Figure 5. The boundary between the *Chondrus* denuded zone and regions with normal healthy *Chondrus* was easily seen. Algal density and diversity finally had recovered to conditions seen before the December 1992 storm. The denuded area extended 85 m along the north side of the central transect line and to 88 m on the south side, 2 to 5 m less than in April. The asymmetrical distribution of the denuded zone around the transect line was opposite from that seen in prior years with more area denuded of *Chondrus* south of the line than north of the line; however, slightly more of the total affected area extended north of the line than south. Juvenile blue mussels (*Mytilis edulis*) had settled so thickly in some parts of the dive zone that large areas of benthic substrata were carpeted; *Chondrus* found in this area was sparse and stunted due to competition for space. The total affected area (2058 m^2) was 30% larger than in April 1993 and nearly the same as in June 1992. A few fronds of *Laminaria* were seen. Bass, winter flounder, starfish, blue mussels, rock crabs (*Cancer*), and lobsters (*Homerus americanus*) were also observed within the dive area.

2.2.3 SEPTEMBER 1993 TRANSECT SURVEY

Figure 6 shows the results of the transect survey conducted on September 20, 1993. The denuded zone extended to the 95-m mark on the transect line. The asymmetry of the denuded zone around the transect line had returned to its usual aspect, with more of the area north (56%) of the line than south (44%) of the line. The greatest lateral extent of the denuded zone was 15.4 m from the transect line at the 65-m mark. The area (1648 m^2) of the denuded zone was much larger (55%) than that seen in June but similar (only 5% larger) to that seen in the previous September survey.

Extensive beds of juvenile mussels (*Mytilus edulis*), first seen in June 1993, were present near the 45-m mark on the central transect line and 4 m south of the line. Mussels were found from the 45-m mark to the 85-m mark on the transect line, especially on the south side and were closer to the transect line at marks more distant from the discharge canal. Other invertebrates included snails (*Littorina obtusata*), starfish (*Asterias forbesi*), green crabs (*Carcinus maenas*), and anemones. Only three demersal fish were observed during the entire survey; one cunner (*Tautogolabrus*) and two tautog (*Tautoga*) were present in the denuded zone between the end of the jetties and the 45-m mark on the transect line.

Within the discharge canal, the only two algal species seen were *Gracilaria* and *Cystoclonium purpureum*, both of which were widespread and growing luxuriantly. At more seaward locations, *Codium fragile* and *Fucus* sp. occasionally co-occurred with *Gracilaria* and *C. purpureum*. The divers rarely saw any large healthy *Chondrus* plants within their survey area. The dense June settlement of mussels had damaged the *Chondrus* plants and contributed to their reduced growth and infestation by epiphytes, consisting mainly of smaller, filamentous species of algae, including *Chaetomorpha linum*, *Polysiphonia* spp., and *Rhizoclonium riparium*. Epiphytic growth was particularly dense on the sparse plants seen at the boundary of the denuded zone south of the transect line near the 55-m and 95-m marks.

Chondrus plants along the boundary of the denuded zone were categorized as sparse or stunted or both in such an intricate pattern that these areas were combined to simplify the September survey map. Between the end of the jetties and the 65-m mark on the transect line it was very difficult for the divers to distinguish the border between the sparse/stunted zone and normal zone of healthy *Chondrus*. Sometimes, as the divers swam away from the transect line, a few *Chondrus* plants would look healthier and then an area of more stunted or sparse plants would appear. There was no clear delineation between the affected area and a control area as has been observed in many previous surveys, including the last fall survey in September 1992. Basically, the size and shape of the *Chondrus* sparse/stunted zone was similar to that seen in September 1992; however, the area (215 m^2) mapped as sparse/stunted for the current September 1993 survey should be considered a minimum area.

The sparse/stunted zone extended 17.8 m north and 12.4 m south of the CTL at the 65-m mark. Beyond the 75-m mark, where the divers could more readily distinguish sparse or stunted from healthy *Chondrus*, the sparse/stunted zone was wider north of the line than south.

2.2.4 DECEMBER 1993 TRANSECT SURVEY

The results of the 1993 winter dive, performed on December 2, 1993, are mapped in Figure 7. The denuded zone extended to the 100-m mark on the transect line. The area (1522.5 m^2) of the denuded zone was 6% less than in the September survey but still larger than in June (44%). The area of the denuded zone was unusually symmetrical around the transect line with 49% of the area north of the line and 51% south of the line. The greatest lateral extent of the denuded zone was 11.8 m south of the transect line at the 60-m mark.

Gracilaria plants that were generally sparse and stunted were growing from the head of the effluent canal to the 70-m mark on the south side of the transect. Normal *Cystoclonium purpureum* plants were present from the head of the canal to the 70-m mark on both sides of the transect line. *Corallina officinalis* was present from the 70-m to 90-m marks on the line. *Chaetomorpha linum* first appeared at the 80-m mark and was seen to the end of the transect line.

Normal *Chondrus* plants that occurred outside the sparse area, particularly those beyond the 80-m mark on the transect line were covered by an encrusting bryozoan, tentatively identified as the exotic species, *Membranipora membranacea*. This was the first time that the divers had noticed such a vast coverage of the *Chondrus* by *M. membranacea*; whether this species was present prior to December in lesser numbers is not known. This British species has been found throughout the Atlantic Ocean and parts of the Pacific Ocean but only recently (since 1987, in the Gulf of Maine) has appeared to be invading kelp bed communities along the northeast coast of the United States and has had some dramatic effects on kelp bed structure (Lambert et al., 1992).

Mussels, *Mytilus edulis*, were still very abundant from the 50-m to 90-m marks on the transect line. From the 60-m to 80-m marks, dense beds of 2.5-3 cm long mussels extended to 6 m north and 10 m south of the line. Both small (less than 1 cm in diameter) and larger individuals of the starfish, *Asterias forbesi*, were common and everywhere associated with the mussels. Snails, belonging to the genus *Littorina*, were common from the 40-m to 60-m mark on the transect line and extended to 6-12 m north of the line. A number of rock crabs (*Cancer irroratus*) and green crabs (*Carcinus maenas*) were seen from the 30-m mark to the 80-m mark on the line often in association with the mussel beds. Only one or two fish were seen.

The area inhabited by sparsely distributed or stunted *Chondrus* plants was 720 m², a 234% increase from September. This large increase in area can be attributed partly to the recolonization of a portion of the denuded zone north of the transect line. In addition, the boundary between the sparse and normal *Chondrus* areas was very indistinct in September; in fact, the divers reported difficulty in finding any normal *Chondrus* coverage between the jetties and the 75-m mark on the transect line, so they may have mapped a very conservative outline for the total affected area. More than two-thirds of the sparse and stunted *Chondrus* area was to the north of the transect line. Consequently, the mapped shape of the total affected area (2243 m²) was asymmetrical with more than half (56%) north of the transect line.

2.3 DISCUSSION

The configuration of the *Chondrus crispus* denuded zone that may extend as far as 100 m beyond the discharge canal is readily apparent to SCUBA divers and easily mapped from the qualitative transect survey. Stunted and sparse zones are less obvious; in April and June 1993 they were easily delineated, but in September they were very difficult to distinguish. In April and June 1993, the areas of the denuded and total affected zones were well within those seen previously (1983, 1985, 1989-1992) when the power plant was in full or nearly full operation. In June 1993, a dense mussel mat, similar to those seen in June 1990 and 1992, although covering less area, was seen. The area of the denuded zone in June was less than it had been in April, the usual trend when early summer growth of *Chondrus* is not adversely affected by high mussel settlement.

The denuded area in June (1055 m²) was the smallest seen in any summer when the power plant was in full or nearly full operation since 1985. Such a small area may be due partly to fewer mussels settling on the *Chondrus*, thus causing less damage than in some previous years, which, in turn, may be a function of the two-month (April/May) spring power plant outage when only one circulating pump was running and the discharge current was consequently less severe. On the other hand, 1) the total affected area was only slightly less than that measured in 1990 and 1992, and 2) the delay in response of the acute impact zone to changes in thermal effluent discharge is known to be six to nine months (BECO, 1986). In 1990, there was also a two-month spring power plant outage (in March and April) and the denuded area measured in the following June survey was the largest denuded area since 1983, not only for June but for all surveys. Timing, both that of a power outage and that of the appearance of mussel larvae, may be critical factors in causing the variability seen in the denuded areas in the June surveys.

The areas of the denuded zone in September and December were both greater than they had been in the same season in earlier surveys when the plant was in full or nearly full operation. In fact, the total

affected area in December was the largest seen since measurements began in 1983, rivaled only by areas measured in the summers of 1990 and 1992; this may be explained in part by the very early date (Dec. 2) of the survey and perhaps by damage imposed by a heavy infestation by the encrusting bryozoan *Membranipora membranacea*.

3.0 IMPACT OF EFFLUENT DISCHARGE AT PNPS ON ALGAL DISTRIBUTION

The presence of hundreds of square meters of seafloor where *Chondrus crispus* is unnaturally absent provides evidence that the nearfield discharge area is intensely affected by bottom scouring produced by the cooling water outflow. To study this acutely impacted area, a qualitative diver transect study was designed to provide maps showing the effects of thermal effluent on nearby algal distributions. SCUBA divers perform quarterly transect surveys to measure the extent of denudation and other reductions in size or density of the algal flora in the nearfield discharge area. The focus of these studies is the commercially important red alga *Chondrus crispus* (Irish Moss), a species common to western Cape Cod Bay. Divers swim along a measured transect line in the discharge area and note the boundaries of the denuded, stunted or sparse, and normal *Chondrus* zones. Variations in the size of these zones, recorded over time, help determine the area most severely affected by PNPS operations.

3.1 BACKGROUND

Historically, operational conditions at the PNPS have provided opportunities to assess long-term trends associated with the impact on the benthic community. Plant operations have included years of nearly full operation as well as times when there were complete shutdowns, sometimes for prolonged periods. The longest outage in the history of the plant began in April 1986 and continued until March 1989. During this period the benthic community associated with the effluent canal and nearby areas immediately offshore experienced reduced current velocity as the use of circulating pumps was restricted to one or none (Figure 9). In addition, the discharge water remained at ambient temperature. As a consequence, the benthic community normally affected by these effluent parameters recovered, so that by 1988 there was essentially no difference between the control stations and the areas near the discharge canal.

Studies conducted after the power plant returned to full operation, with the resumption of electrical generation and the operation of either one or both circulating pumps, originally were designed to assess the impact of plant operation on a benthic environment that had returned to near ambient conditions. Quantitative faunal and algal monitoring studies and qualitative transect surveys were

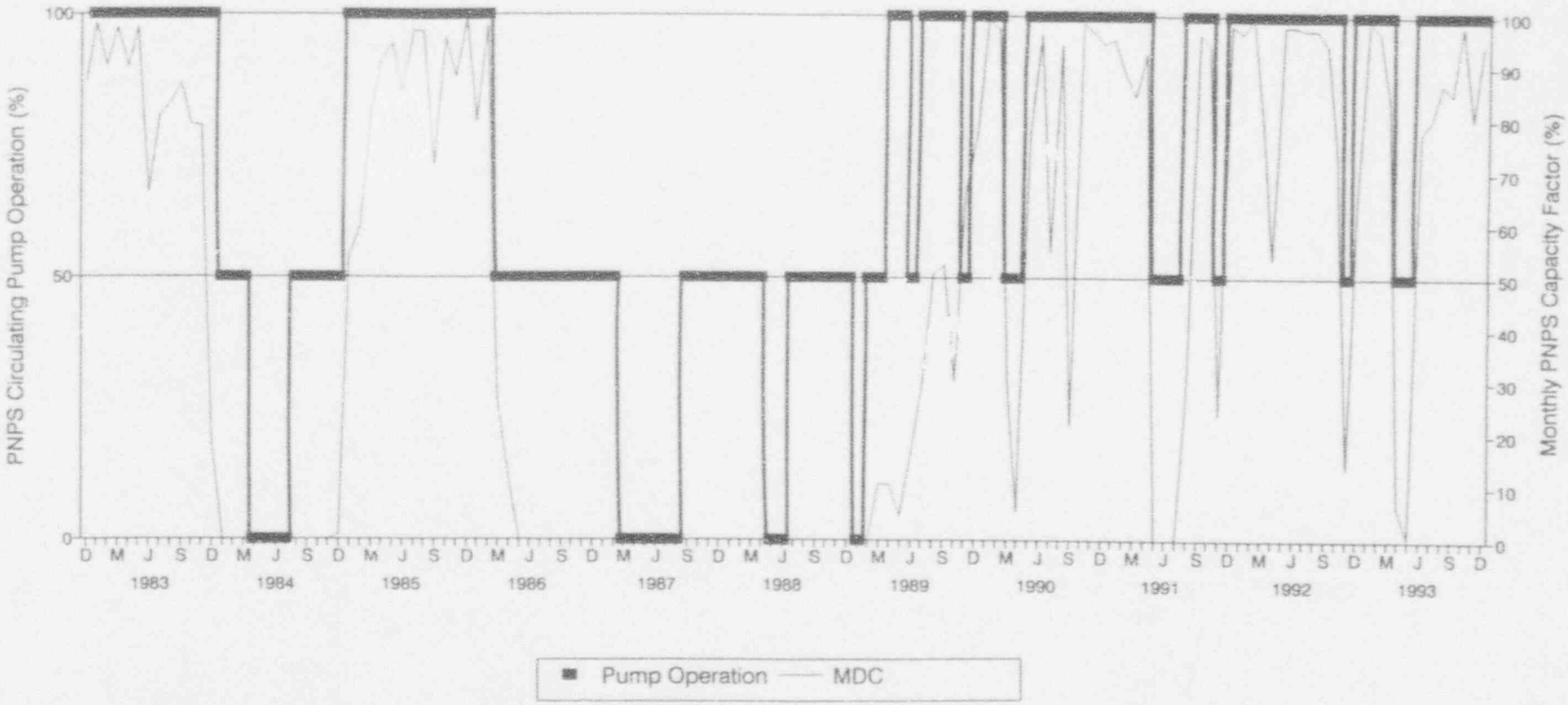

Figure 9. **Monthly PNPS Capacity Factor (dashed lines) and Circulating Pump Activity (black bars at 100% = 2 pumps; at 50% = 1 pump; at 0% = 0 pumps) Plotted for the Period 1983 Through 1993.**

conducted through 1991. In 1992, community studies of the benthic algae and fauna were discontinued. For 1992 and 1993, the monitoring program continued seasonal qualitative surveys of the discharge area.

PNPS operated for a high percentage of time in 1993. Figure 9 shows the monthly maximum dependable capacity (MDC) factor and circulating water pump operation of PNPS since 1983. The percent MDC is a measure of reactor output that approximates thermal loading to the marine environment. A maximum MDC value of 100% represents the highest allowable change in ambient temperature for water discharge to Cape Cod Bay (18°CΔT). In 1993, the monthly maximum dependable capacity factor was greater than 94% for 4 months and above 75% for six of the remaining months. These high monthly capacity factors resulted in an annual capacity factor of 74.0% for 1993, an amount exceeded previously only in 1979, 1983, 1985 and 1992. In addition, both pumps were in operation for 10 months of the year; in April and May only one pump was in operation.

3.2 QUALITATIVE TRANSECT SURVEYS: 1983-1993

Results of the qualitative transect surveys from 1983 through 1992 are summarized in Figure 10. The total acute impacted area (denuded, sparse, and stunted), the area of the denuded zone only, and the monthly PNPS capacity factor (MDC) are plotted. The difference between the denuded and total acute impact zones represents combined sparse and stunted zones. A lag in recovery time by the acute impact zone following the 1984 PNPS power outage was reported in Semi-Annual Report No. 27 (BECO, 1986). Evidence of this slow recovery included a decrease in the area of the total acute impact zone that began in mid-1984 (5 months after the cessation of power plant operations) and continued through mid-1985. Between December 1984 and December 1985, the total affected area was the smallest recorded between 1983 and 1986, indicating a delay in recovery of this area in response to the absence of thermal discharge in 1984. This delay phenomenon also held true when the situation was reversed, so that the size of the acute impact zone began to increase only 6 to 9 months (September to December 1985) after the resumption of thermal effluent discharge. These results confirmed a delay of 6-9 months between the causal factor (cessation or resumption of thermal effluent discharge) and associated response (decrease or increase in size of the acute impact zone). In 1987, increased recolonization of the denuded and stunted zones by *Chondrus crispus* made zone boundaries difficult to distinguish (no areal differences could be discerned from September 1987 through June 1989). As in summer 1984, the considerable decrease of the denuded area of the acute impact zone between December 1986 to June 1987 was primarily the result of the shutdown of the circulating water pumps from late March to early September (BECO, 1988). Apparently, water current scouring is a greater stress to algal colonization than increased

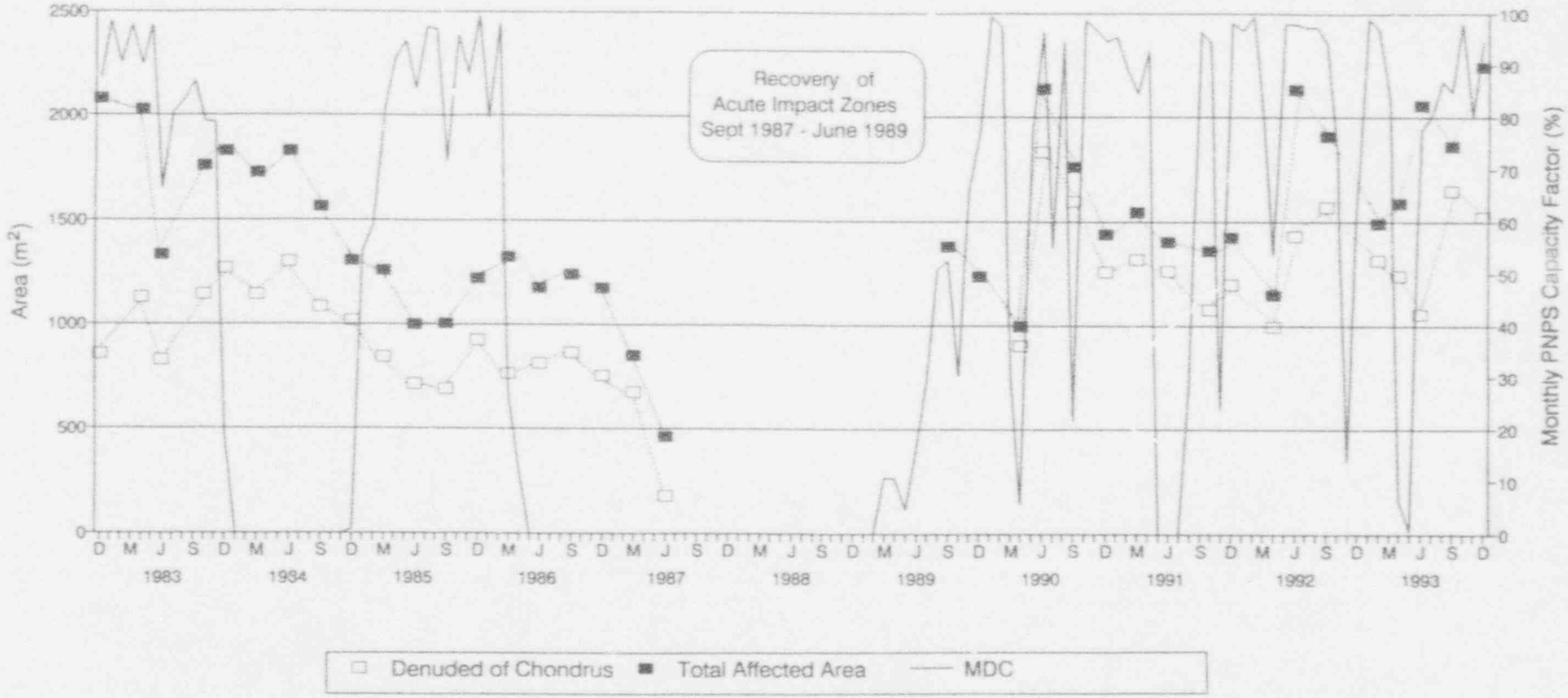

Figure 10. **Area of the Denuded and Totally Affected Zones in the Vicinity of the PNPS Effluent Canal Plotted with the Monthly PNPS Capacity Factor (MDC) for the Period 1983 Through 1993. No area measurements were made from September 1987 through June 1989 because definitive demarcations of denuded and stunted zones were absent.**

water temperature. Scouring denudes the substratum, whereas elevated temperature results in stunted growth (Bridges and Anderson, 1984).

In 1988, circulating water pump activity was low, resulting in few thermal loading and scouring effects. The 1988 transect surveys showed such an increase in recolonization of the formerly denuded and stunted zones by *Chondrus*, in response to the continuing outage, that divers were unable to detect zonal boundaries and no area measurements could be made. In March and June 1989, divers were still unable to detect boundaries of the denuded or stunted zones, and again no area measurements were made (BECO, 1990). In September and December 1989, presumably in response to increased PNPS operations and the resultant scouring of the acute impact zone, boundaries began to be redefined and area measurements were made of the total impact zone.

During 1990, boundaries between the stunted and denuded zones became even more clearly defined and areal measurements of both zones were made. The areas of the denuded and total impact zones in June 1990 were the largest seen since 1983 (BECO, 1991). The dramatic increase in total affected area that occurred between April and June 1990 had not been seen before in the 1983-1990 period. The typical pattern seen prior to 1990 was that during the spring, with warmer temperatures and increased sunlight, algal growth flourishes, and the impact area declines even in years when the power plant is operating at high capacity. The pattern seen in 1990 appeared to be anomalous.

In 1991, the boundaries of the acute impact zone remained well-defined, except that in June there was no true stunted zone but only an area described by the divers as "sparse", that is, where the algal plants grew normally but were thinly distributed. From March to June, the total affected area and the *Chondrus* denuded zone decreased in area, a return to the typical pattern seen before 1990 (BECO, 1992). This decrease in area continued through the October survey, perhaps aided by the May through July power plant outage. There was a slight increase in affected area in December.

During 1992, the divers were unable to discern a *Chondrus* stunted region. Except for June, they noted zones containing normal but sparsely distributed *Chondrus* plants. An enormous set of mussels that had reached 0.5 cm in length by June, totally obliterated the boundary between the denuded and sparse areas. Parallel to results seen in 1990, the areas of the denuded and total acute impact zones in June 1992 were larger than any seen (except for 1990) since 1983, and the dramatic increase in total affected area that occurred between April and June 1990 happened again in 1992. Thus, the pattern seen in 1990 should no longer be considered as anomalous but may be related to oceanographic conditions that lead to a large settlement of mussel larvae and consequent damage to the *Chondrus* plants (BECO, 1993).

In 1993, divers again distinguished regions of stunted *Chondrus* from areas that were sparse, although in September, the areas were so intermingled that they were combined to facilitate mapping. A mussel set in June was not as dense as those that occurred in 1990 or 1992 hampering the spring *Chondrus* growth in those years; in 1993, abundant spring growth of *Chondrus* resulted in a denuded zone that was smaller in June than it had been in April, the opposite of the situation seen in 1990 and 1992. In both September and December, the area of the denuded zone was larger than in the same seasons in previous years. The area of the denuded zone in September was only slightly larger, 3-5%, than it had been in September of 1990 and 1992, but the denuded zone area in December was much larger than seen in previous years, 16% larger than in February 1993, and from 21-27% larger than measured in the December surveys of 1989, 1990, and 1991. In addition, the total affected area in December was the largest seen since 1983 and rivaled the areas measured in the summers of 1990 and 1992; this may be explained in part by the very early date (Dec. 2) of the survey and perhaps by damage imposed by a heavy infestation by the encrusting bryozoan *Membranipora membranacea*.

4.0 CONCLUSIONS

- The size of the denuded and total affected areas of the acutely impacted region in April and June 1993 was similar to that observed in the same seasons during prior surveys at times of full power plant operation.

- The sizes of the denuded zones in September and December were larger than had been seen before in the same seasons in surveys performed during times of full or nearly full power plant operation. The denuded zone area in December was much greater than seen in prior December surveys. The total affected area in December was higher than seen anytime previously. The greater affected areas measured in December may be due in part to a very early winter dive date (Dec. 2) and in part to a heavy infestation by the encrusting bryozoan, *Membranipora membranacea*.

- The decrease in size of the denuded zone from April to June followed the pattern of a decrease in denuded area when sunlight and warmth permit the algae to flourish and the mussel set is not so dense as to be extremely damaging to the plants. The total affected area did increase from April to June, following the pattern set in 1990 and 1992 when there were enormous mussel settlements and damage to the *Chondrus* plants.

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ICHTHYOPLANKTON ENTRAINMENT MONITORING

AT PILGRIM NUCLEAR POWER STATION

JANUARY-DECEMBER 1993

Volume 1 of 2

(Results)

Submitted to

Boston Edison Company

Boston, Massachusetts

by

Marine Research, Inc.

Falmouth, Massachusetts

April 1, 1994

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*Available upon request.

SECTION I

EXECUTIVE SUMMARY

PNPS ichthyoplankton entrainment sampling in 1993 was completed twice per month during January, February, October-December; weekly during March and June-September. A refueling outage reduced sampling to five times in April and May combined.

Numerical dominants among the 38 species taken included American plaice and sand lance during winter-early spring; tautog, cunner, Atlantic mackerel, and radiated shanny during late spring-early summer; and Atlantic menhaden and cunner during late summer-autumn.

Comparisons among ichthyoplankton densities recorded in 1993 suggest that Atlantic menhaden were particularly abundant in the fall. Atlantic mackerel eggs remained abundant, continuing an upward trend apparent over the 1973-1993 time frame. Atlantic cod, fourbeard rockling, cunner, and winter flounder were relatively uncommon.

Atlantic menhaden eggs were unusually abundant on September 21 as defined by the contingency sampling plan. Repeat sampling two days later showed continued high densities (although not unusually high) suggesting that strong autumn spawning occurred nearshore and perhaps throughout Cape Cod Bay.

A single lobster larva was taken in 1993 bringing the 19-year total to twelve.

SECTION II

INTRODUCTION

This report summarizes results of ichthyoplankton entrainment sampling conducted at the Pilgrim Nuclear Power Station (PNPS) discharge canal on a systematic basis from January through December 1993. Work was carried out by Marine Research, Inc. (MRI) for Boston Edison Company (BECo) under Purchase Order No. 107011 in compliance with environmental monitoring and reporting requirements of the PNPS NPDES Permit (U.S. Environmental Protection Agency and Massachusetts Division of Water Pollution Control). In an effort to condense the volume of material presented in this report, details of interest to some readers may have been omitted. Any questions or requests for additional information may be directed to Marine Research, Inc., Falmouth, Massachusetts, through BECo.

SECTION III

METHODS AND MATERIALS

Entrainment sampling at PNPS was completed twice per month during January, February, October-December; weekly during March and June-September. Although scheduled weekly, sampling was possible only twice in April, three times in May due to a refueling outage. On those five occasions sampling occurred with one CWS pump out of service. 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).

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 1992.

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 since the impact attributable to any large entrainment density would be greater if ichthyoplankton densities were particularly high only close to shore near PNPS. 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.

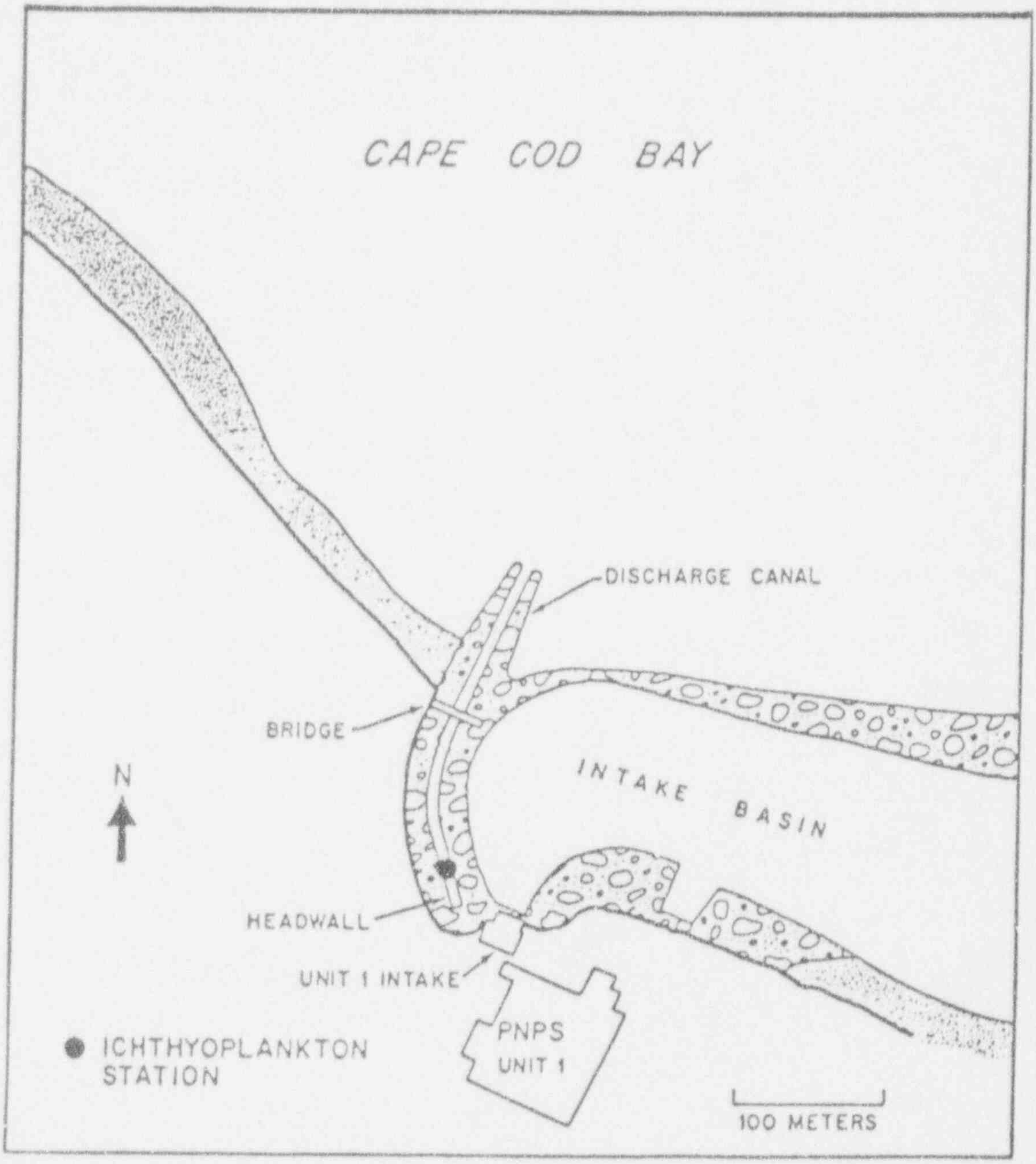


Figure 1. Entrainment sampling station in PNPS discharge canal.

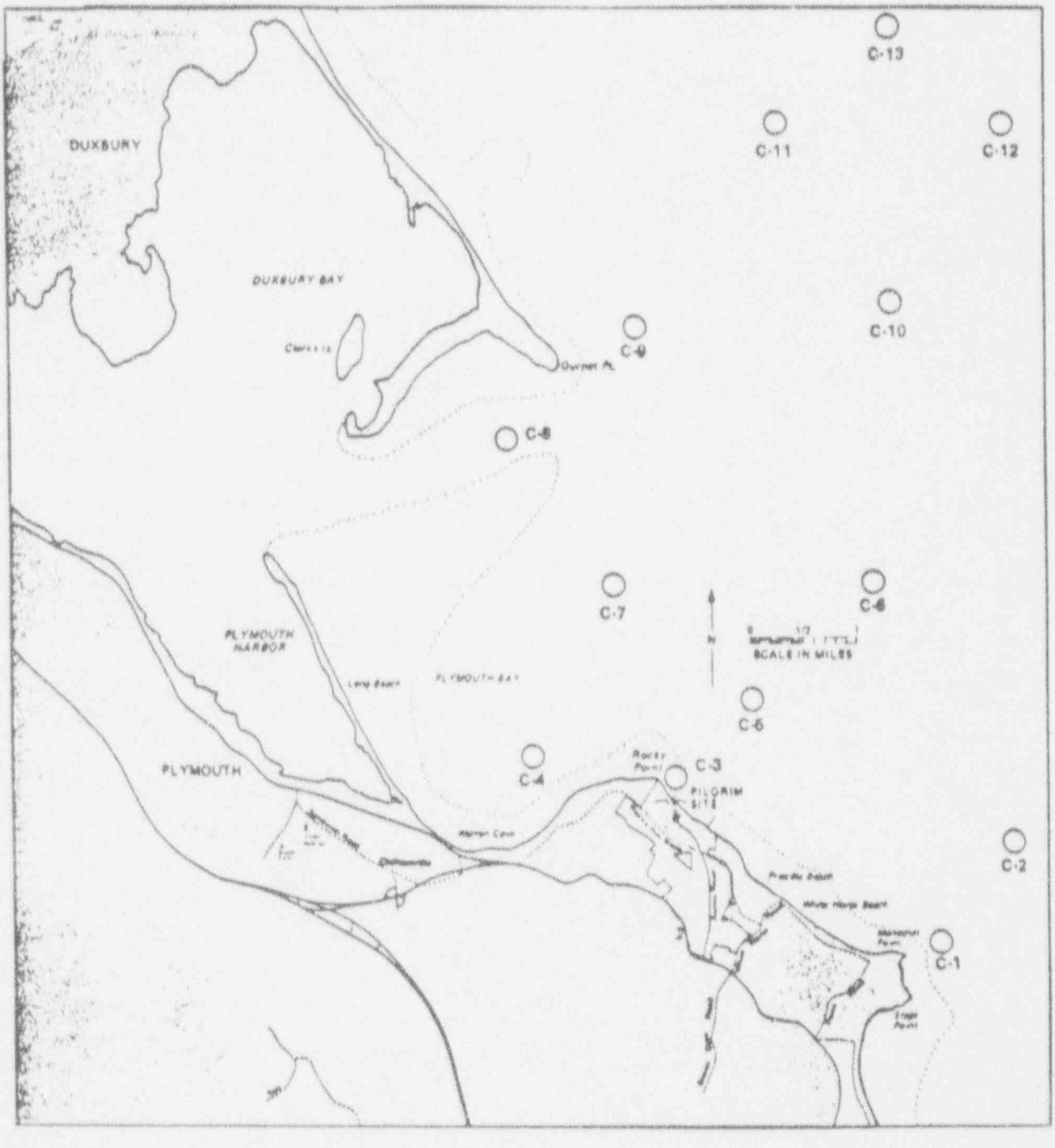


Figure 2. Location of entrainment offshore contingency program sampling stations, C-1 through C13.

SECTION IV

RESULTS AND DISCUSSION

A. Ichthyoplankton Entrained - 1993

Population densities per 100 m^3 of water for each species listed by date, station, and replicate for 1993 are presented in Appendix A (available upon request). Table 1 lists all species represented in the 1993 collections, indicates the months eggs and/or larvae of each species were found and, for the more common species, the months of peak abundance.

Ichthyoplankton collections are summarized below within the three primary spawning seasons observed in Cape Cod Bay: winter-early spring, late spring-early summer, and late summer-autumn. Figure 3 shows the dominant species of eggs and larvae and their percent contribution within each season for 1993.

Winter-early spring spawners (December-April)

This spawning season is split between the beginning and end of the calendar year. The number of species represented in the discharge collections was seven in January and February, twelve in March and April, two in December. Fish eggs are typically uncommon during the winter-early spring period since species spawning in the PNPS area during that time employ a reproductive strategy utilizing demersal, adhesive eggs not generally subject to entrainment. Only three eggs were, in fact, found in the January and February collections, in each case eggs spawned by yellowtail flounder

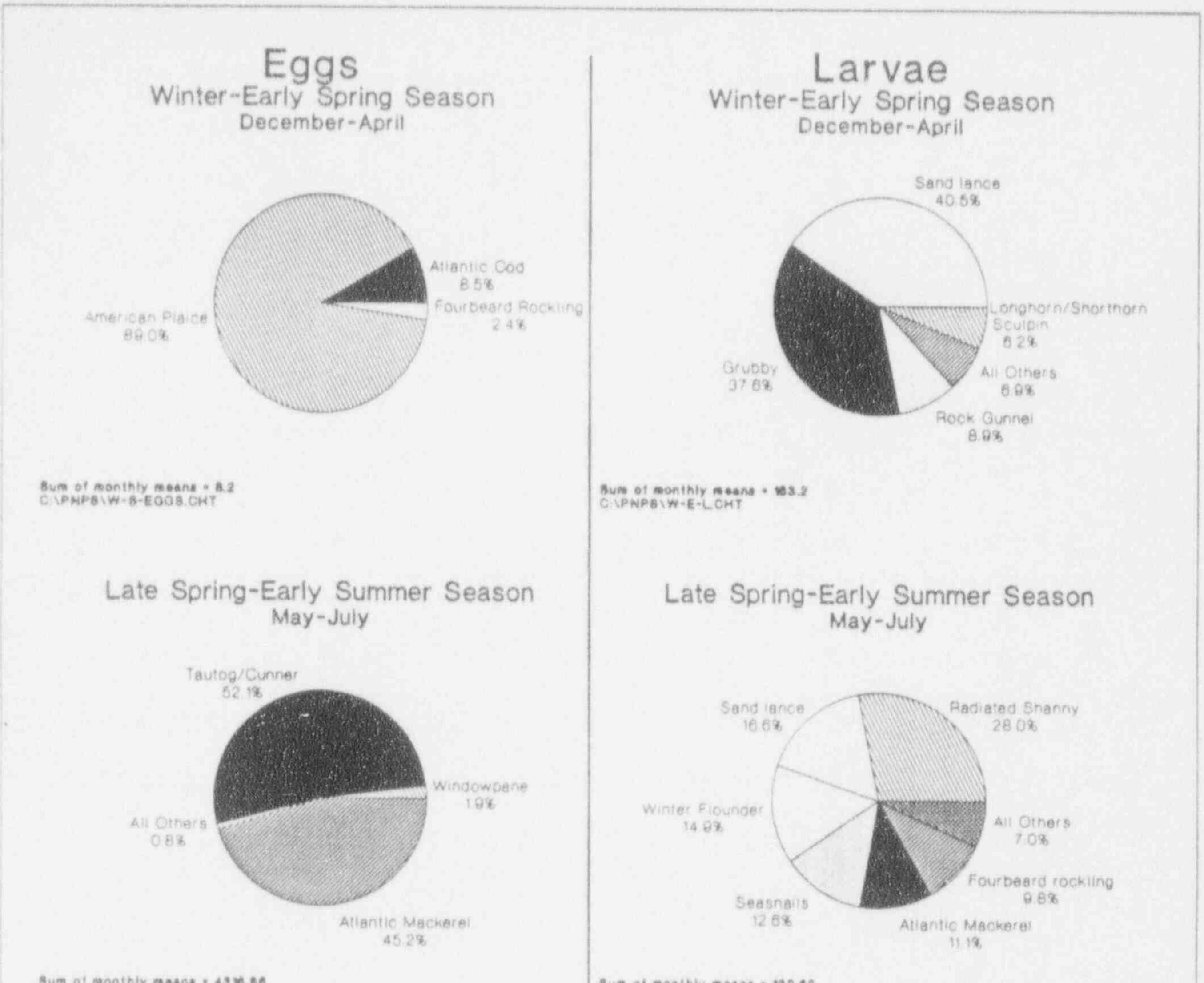


Figure 3. Dominant species of fish eggs and larvae found in PNPS ichthyoplankton samples by season for 1993. Percent of total and summed monthly means for all species are also shown.

(Pleuronectes ferrugineus); monthly mean densities amounted to 0.2 and 0.1 per 100 m³ respectively. In March three species were represented by eggs, winter flounder (P. americanus), Atlantic cod (Gadus morhua,) and American plaice (Hippoglossoides platessoides). Over the month as a whole, respective mean densities were 4, 0.2, and 0.05 per 100 m³. Three species were also represented in April - American plaice with a monthly mean of 7.2, Atlantic cod with a mean of 0.4, and fourbeard rockling (Enchelyopus cimbrius) with a mean of 0.2 per 100 m³.

Since they are demersal and adhesive, winter flounder eggs are not regularly 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 movements of fish and invertebrates.

Typical for the period, the number of larvae increased with time during the winter-early spring period. Six species were recorded in January and February, ten in March, and eleven in April. Sculpin (Myoxocephalus spp.), sand lance (Ammodytes sp.), and rock gunnel (Pholis gunnellus) were the numerical dominants during the period. Larval sculpin contributed 44% to the seasonal total with mean densities of 0.4 in January, 6 in February, 53 in March, and 12 per 100 m³ in April. Sand lance were present on each sampling occasion accounting for an additional 41% of the seasonal total. Monthly mean densities were 5, 16, 16, and 29 during the four respective months. Lastly, rock gunnel accounted for 9% of the seasonal total with respective mean densities of 1, 4, 8, and 2 per 100 m³.

Three species contributed to the larval sculpin catch. Grubby (Myoxocephalus aenaeus) were most numerous overall, representing 86% of all sculpin. Shorthorn (M. scorpius) and longhorn (M. octodecemspinosus) followed in order contributing 13 and 1% of the total, respectively. Shorthorn sculpin were absent in January; otherwise all three species were represented each month.

December 1993 collections were typically light. A single cod egg was taken in the six samples (monthly mean = 0.1 per 100 m^3) along with one cod and one silver hake (Merluccius bilinearis) larva.

Late Spring-Early Summer (May-July)

May, June, and July collections encompass the late spring-summer season, a period of typically increasing water temperature and spawning activity. A total of 19 species were represented in May, 22 were represented in June, and 21 in July. Seasonal dominants included Atlantic mackerel (Scomber scombrus), tautog/cunner (Tautoga onitis/Tautogolabrus adspersus), windowpane (Scophthalmus aquosus) among the eggs; radiated shanny (Ulvaria subbifurcata), sand lance, winter flounder, mackerel, and fourbeard rockling among the larvae. Mackerel eggs accounted for 84% of the May total, dropping to 5% of the June and less than 1% of the July total with respective monthly mean densities of 4145, 170, and 0.3 per 100 m^3 respectively. Tautog/cunner, assuming they dominated within the labrid-Pleuronectes group, contributed 14% of all eggs in May, 92% in June, and 96% in July; monthly mean densities were

666, 2976, and 1331 per 100 m³, respectively. Windowpane, the numerical dominant within the Paralichthys-Scophthalmus grouping, accounted for 2% of the eggs during all three months with respective mean densities of 91, 58, and 28 per 100 m³.

Among the late spring-early summer larvae, radiated shanny contributed 45, 8, and 1% to the three respective monthly totals with mean densities of 32, 5, and 0.1 per 100 m³ of water. Sand lance remained numerous later into spring than they typically do, accounting for 25% of the May catch with a mean density of 17, 8% of the June catch with a mean density of 4, and 5% of the July catch with a mean of 0.3 per 100 m³ of water. Larval winter flounder contributed 17, 14, and 4% of all larvae in May, June, and July respectively, with monthly mean densities of 12, 8, and 0.2 per 100 m³. Mackerel were uncommon in May and July accounting for less than 1% of the monthly total in each case but accounted for 24% of the June catch with a mean density of 14 larvae per 100 m³ of water. Lastly, fourbeard rockling were similar to mackerel, contributing relatively little in May and July while accounting for 20% of the June catch with a monthly mean of 11 per 100 m³.

Late Summer-Autumn Spawners (August-November)

This is generally a season of rapid decline in both ichthyoplankton density and species richness. Number of species represented by eggs declined from 12 in September to 2 in November while the number represented by larvae declined from 16 in September to 3 in November. Numerical dominants included Atlantic menhaden

(Brevoortia tyrannus), tautog/cunner, and windowpane among the eggs; cunner, menhaden, the hakes (Urophycis spp.), fourbeard rockling, and tautog among the larvae. Menhaden eggs occurred in August and September accounting for 2 and 91% of those monthly totals with mean densities of 2 and 2190 per 100 m^3, respectively. Tautog/cunner eggs were taken throughout the seasonal period representing 59, 1, 3, and 61% of the eggs each respective month with densities dropping steadily from 56 to 0.2 per 100 m^3. Windowpane eggs were taken through October accounting for 28, 3, and 9% of total during the three months; densities of 26, 81, and 1 per 100 m^3 were recorded.

Larval menhaden were among the seasonal dominants for the first time in 1993 as a result of an unusual level of spawning in the PNPS area in September (see below). They appeared primarily from late August through September but occurred in low densities through November. They accounted for 2, 30, 72, and 64% of the respective August-October collections with monthly mean densities of 0.4, 15, 4, and 0.6 per 100 m^3. Larval cunner and tautog were found during August-October in steadily declining numbers. They represented 60 and 24% of the August larval catch with mean densities of 13 and 5 per 100 m^3; 18 and 3% of the September catch with mean densities of 9 and 21 per 100 m^3; and 3% each in October with mean densities of 0.1 per 100 m^3. Fourbeard rockling wee collected each month. Respective densities of 0.3 13, 0.6, and 0.2 represented 3% of the total in August, 26% in September, 11% in October, and 22% in November. Hake larvae appeared from August

through October with respective monthly mean densities of 0.4, 6, and 0.6 per 100 m^3 of water which accounted for 2, 13, and 12% of the catch.

B. Multi-year Ichthyoplankton Comparisons

Table 2 presents a master species list for ichthyoplankton collected from the discharge canal at PNPS and indicates the years each species was taken from 1975 through 1993. The general period of occurrence within the year is also indicated for each species including the peak period for the numerical dominants. A total of 38 species was represented in the 1993 collections, equal to the time series average of 38. No new species were added to the overall list in 1993 nor were any particularly rare species encountered.

Monthly mean densities per 100 m^3 of water were calculated for each of the 13 numerically dominant fish eggs or fish egg groups, those accounting for 99.0% of the 1993 egg total, as well as total eggs (all species combined) for each year from 1975 through 1993 (Appendix B, available upon request). To help compare values over the 19-year period, egg data were plotted in Figure 4. For this figure cod and pollock eggs were combined with the gadid-Glyptocephalus group, rockling and hake were combined with the Enchelyopus-Urophycis-Peprilus group, and labrids and yellowtail were combined with the labrid-Pleuronectes group. For each category shown, the highest monthly means obtained from 1975 through 1992 were joined by solid lines as were the lowest monthly

means, and the area between was shaded, indicating the range of these values. Monthly mean values for 1993 were joined by a dashed line. Alongside each plot is a bar graph showing annual abundance indices for each year. These were generated by integrating the area under each annual curve using trapezoidal integration. Appendix B and Figure 5 contain corresponding data for the eleven numerically dominant species of fish larvae, those accounting for 87.6% of the 1993 catch, as well as total larvae (all species combined). Low values obtained for both eggs and larvae during April through August of 1984 and 1987 were flagged in these figures and omitted from the following discussion where appropriate because exceptionally low values were common then, probably due to low through-plant water volumes (see Impact section).

Based on these data, the following observations were made:

1. Atlantic menhaden eggs were exceptionally abundant during August and September indicating that significant late summer spawning occurred in the PNPS area. Both the August (1.7) and September (2190 eggs per 100 m^3) monthly mean densities were the highest yet observed as was the overall index for 1993 (Figure 4). Over the 19-year time series menhaden eggs have varied widely (high/low annual index = 2436) but without trend (Figure 4). Larval menhaden increased with the abundance of eggs in September, their monthly mean density of 15 per 100 m^3 exceeding the previous September high (3 in 1982) by a factor of 5. Over the whole larval season 1993 ranked third behind 1980 and 1981.

2. Atlantic cod eggs were typically collected in low numbers (<5 per 100 m^3 of water) at PNPS during winter months from 1975-1987. From 1988 onward they have rarely been collected during January and February; none were found either month in 1993. The gadidae-Glyptocephalus group has shown a significant decline from 1975 to 1993 ($p<0.01$) based on a nonparametric sign test (Sprent 1989) which is consistent with the downward trend apparent for Atlantic cod and witch flounder stocks apparently due, at least in part, to overexploitation (NOAA 1993).

3. Fourbeard rockling and hake eggs (grouped in the early developmental stages with less common butterfish as Enchelyopus-Urophycis-Peprilus) were generally uncommon in 1993. The 1993 abundance index (2625) ranked below 1987 (3267), the previous low year, amounting to 27% of the long-term mean of 9819. Over the time series available a significant downward trend ($p<0.004$) is apparent in the annual Enchelyopus-Urophycis-Peprilus abundance indices based on a sign test. Fourbeard rockling dominate within this grouping based on late-stage egg and larval collections. Since this is a small bottom fish with little or no commercial significance, stock size data are not available with which to compare egg densities. Hake stocks in the Gulf of Maine and northern Georges Bank do not appear to be in a period of decline (NOAA 1993).

4. Tautog/cunner eggs were relatively numerous in September (mean density = 23 versus previous September high of 10 per 100 m^3).

However, over the year as a whole the 1993 index (154,776) ranked eleventh, about equal to the long-term mean of 155,482.

5. Atlantic mackerel eggs appear to have been abundant in May 1993 (mean = 4145 per 100 m^3), exceeding every year except 1989 (5584 per 100 m^3). However the absence of samples in early May 1993 due to the refueling outage probably biased the monthly mean upward since mackerel eggs are generally rare early in the month. Over the year as a whole 1993 was a productive one for mackerel eggs ranking second behind 1989. In general mackerel eggs have been numerous over the past six years, consistent with the trend in stock biomass (Fogarty et al. 1991, NOAA 1993, Sherman 1994). Over the whole time series a significant upward trend ($p<0.002$) was detected by a sign test.
6. Windowpane eggs (assuming based on larval collections that they dominate the Paralichthys-Scophthalmus grouping) were abundant in May and September, leading the 1993 annual index to second highest. In general windowpane eggs vary relatively little from year to year. The high/low value of 5.5 is lowest among the dominant fish eggs.
7. The absence of larval tautog in July 1993 stands out since, with the exception of 1991, they have always appeared in July collections before, albeit at densities below 1 per 100 m^3 during some years. They appear to have recovered in August 1993, producing an annual index (250) approaching the long-term mean (293).

8. Larval cunner were relatively uncommon in June and July but were fairly numerous in August, September, and October. Overall 1993 was a poor year like 1992, the annual index (733) ranking thirteenth, 21% of the long-term mean (3468).

9. Larval seasnail were absent in April for the first time (excluding 1984) perhaps due to there being only two sampling events. The annual index for 1993 (535) amounted to 67% of the long-term mean of 798.

10. Radiated shanny were similarly absent in April. However, they were relatively abundant in May (32) and June (5 per 100 m^3), producing an annual index (1118) ranking third, nearly double the long-term mean of 666.

11. Sand lance appeared to have an extended period of occurrence in 1993 being taken in record numbers in June (4.2 per 100 m^3) and for the first time, July. The annual index (2673) was unremarkable, amounting to 88% of the long-term mean index (3051).

12. Larval winter flounder are of particular interest since adult stock size estimates are at historical low levels (NOAA 1993); clearly a stock cannot rebuild without egg and larval production. Larval abundance at PNPS appeared to have shifted later in the season, densities being low in April and May, relatively high in June. Overall the 1993 abundance index (604) was below average (844), ranking twelfth out of 16 years.

On one occasion in 1993 densities meeting the unusually abundant criterion were recorded - menhaden eggs, September 21 (mean density = 11835 per 100 m^3 of water). Sampling was repeated

two days later to determine if spawning in the vicinity of the plant was protracted. A mean density of 732 per 100 m^3 was recorded on the 23rd followed by zero on the 29th. It is not uncommon for Atlantic menhaden to display a bimodal spawning season in Cape Cod Bay (BECo 1977). Menhaden are known to undergo extensive north-south and inshore-offshore seasonal migrations along the Atlantic coast (Rogers and Van den Avyle 1989) and spawn wherever they happen to be when their ovaries ripen (Nicholson 1972). It appears likely that fish spawn in spring as they migrate north and in autumn as they migrate south. The fall contribution was particularly large in the PNPS area in 1993 and apparently lasted much of September. Interestingly, the weekly fish-spotting overflights in western Cae Cod Bay (Section IV.A) did not note any uncommon occurrences of menhaden in the fall of 1993.

C. Lobster Larvae Entrained

One lobster larva (Homarus americanus) was found in the 1993 collections (July 21, Stage IV-V), the first since 1990. Following is a tabulation of the previous lobster larvae collections at PNPS:

1991-1992: none found.
1990: 2 larvae - 1 stage I, June 26; 1 stage IV August 23.
1983-1989: none found.
1982: 1 larva - stage I on June 14.
1981: 1 larva - stage IV on June 29.
1980: none found.
1979: 1 larva - stage I on July 14.
1978: none found.
1977: 3 larvae - 1 stage I, June 10; 2 stage I, June 17.

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

1975: 1 larva - stage I, date unknown.

1974: none found.

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

SECTION V

HIGHLIGHTS

1) Annual numerical dominants among ichthyoplankton entrained in 1993 included American plaice, tautog/cunner, mackerel, and Atlantic menhaden eggs; sand lance, grubby, winter flounder, radiated shanny, cunner, and Atlantic menhaden larvae.

2) Atlantic menhaden eggs were exceptionally abundant during late August and September, resulting in the highest overall annual abundance index yet observed.

3) Atlantic cod/witch flounder eggs have displayed a significant decline in number over the 1975-1993 time series consistent with trends in their overexploited stocks.

4) Fourbeard rockling and hake eggs were uncommon in 1993 continuing a downward trend apparent over the time series.

5) 1993 was a productive year for Atlantic mackerel, the annual index ranking second behind 1989. A significant upward trend in mackerel egg abundance is clearly apparent over the 1975-1993 time series, consistent with stock size estimates.

6) For both cunner and tautog the annual egg index was about equal to the long-term mean. The same was true for larval

tautog while larval cunner were uncommon overall. The 1993 cunner index ranked thirteenth, 21% of the long-term mean.

7) Larval winter flounder peaked somewhat later in the season than they typically do. The annual index was below average, ranking twelfth out of 16 years.

8) Atlantic menhaden eggs exceeded the unusually abundant criterion established for PNPS in late September. On September 21 a mean density of 11835 eggs per 100 m^3 was obtained, exceeding the previous high of 1962 by a factor of six. Larval densities for September (15 per 100 m^3) also topped all past years for that month.

9) One lobster larva was found in the 1993 collections, the first since 1990, bringing the PNPS total to 12 since 1974.

Figure 4. Mean monthly densities per 100 m³ of water in the PNPS discharge canal for the eight numerically dominant egg species and total eggs, 1993 (dashed line). Solid lines encompassing shaded area show high and low values over the 1975-1992 period.

Brevoortia tyrannus

Enchelyopus-Urophycis Peprilus

Gadidae-Glyptocephalus

Prionotus spp.

Labridae-Pleuronectes

Scomber scombrus

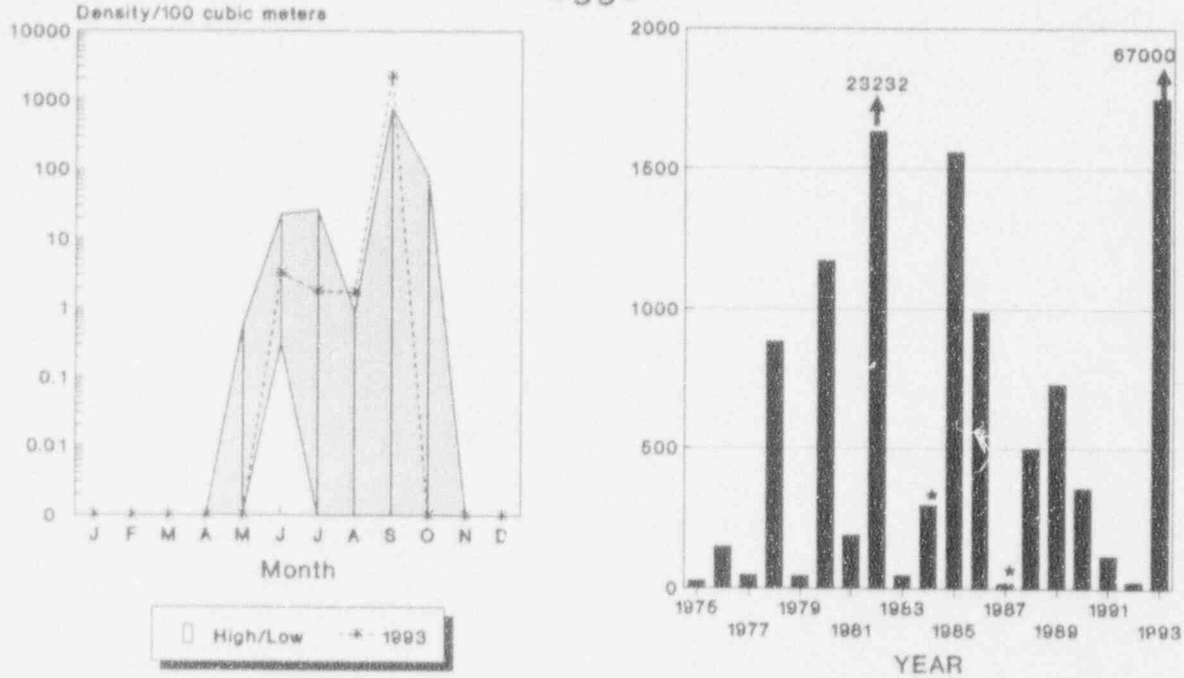
Paralichthys-Scophthalmus

Hippoglossoides platessoides

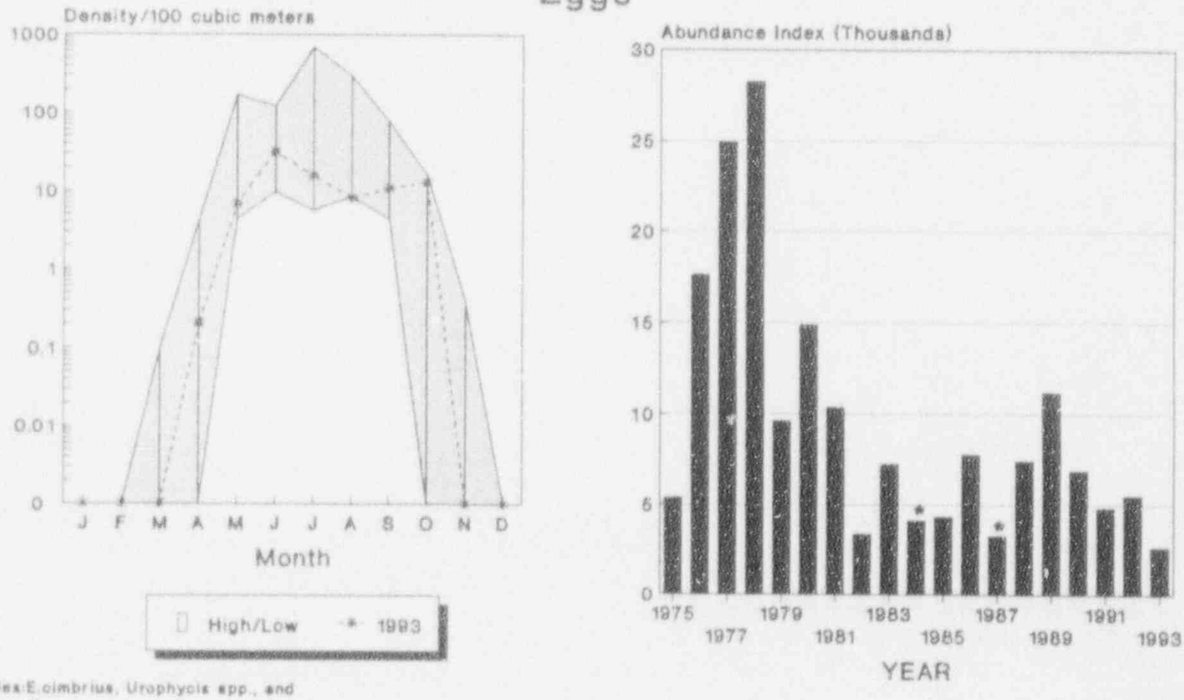
Total eggs

To the right are plotted integrated areas under the annual entrainment abundance curves for 1975-1993. An asterisk above 1984 and 1987 marks the two years when values may have been low due to low through-plant water volumes from April-August; see text for clarification.

Brevoortia tyrannus
Eggs

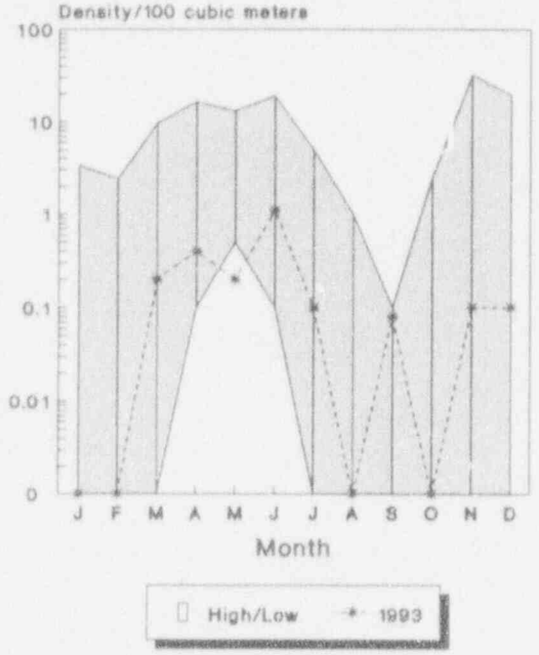


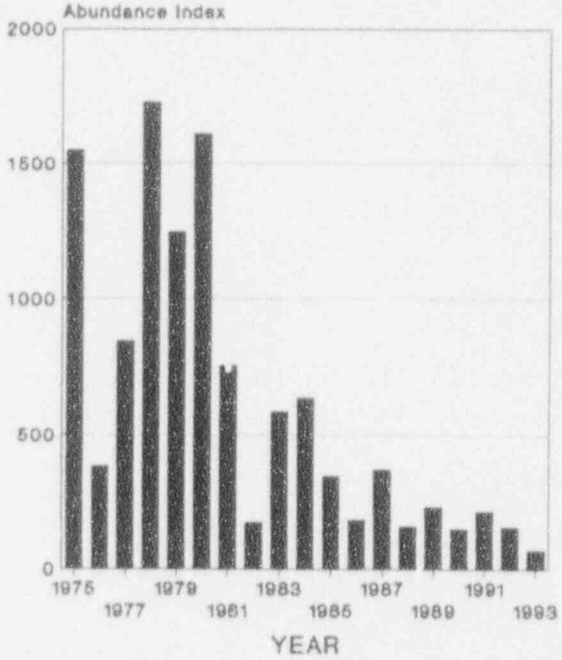
Enchelyopus - Urophycis - Peprilus
Eggs



Includes:E.cimbrius, Urophycis spp., and P.triacanthus

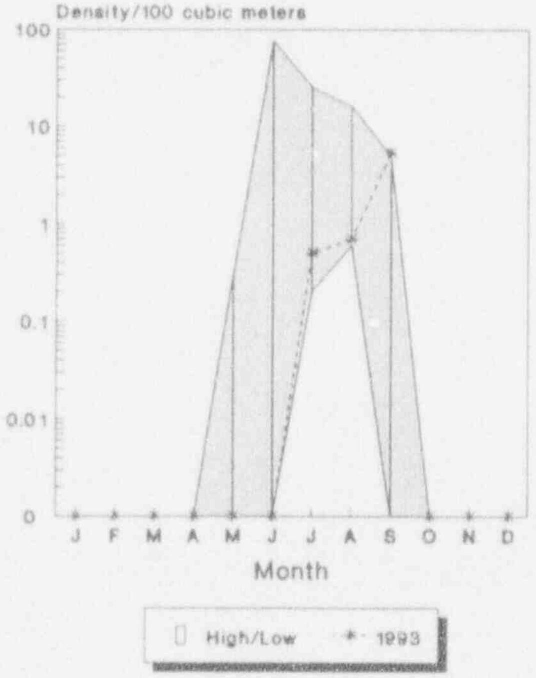
Gadidae - *Glyptocephalus*
Eggs

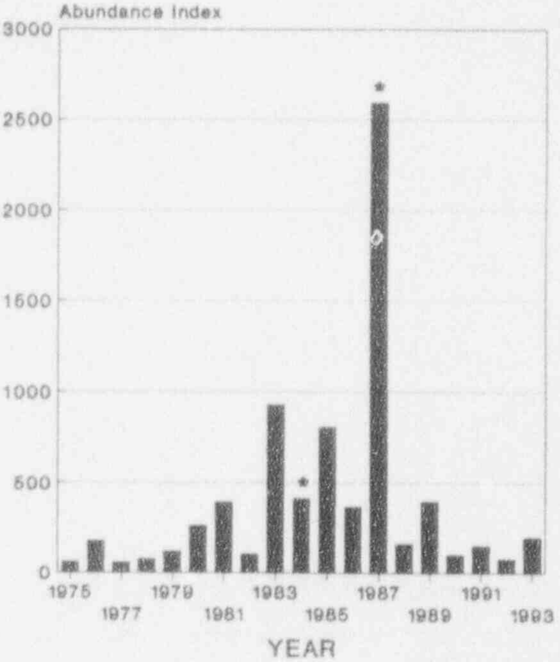




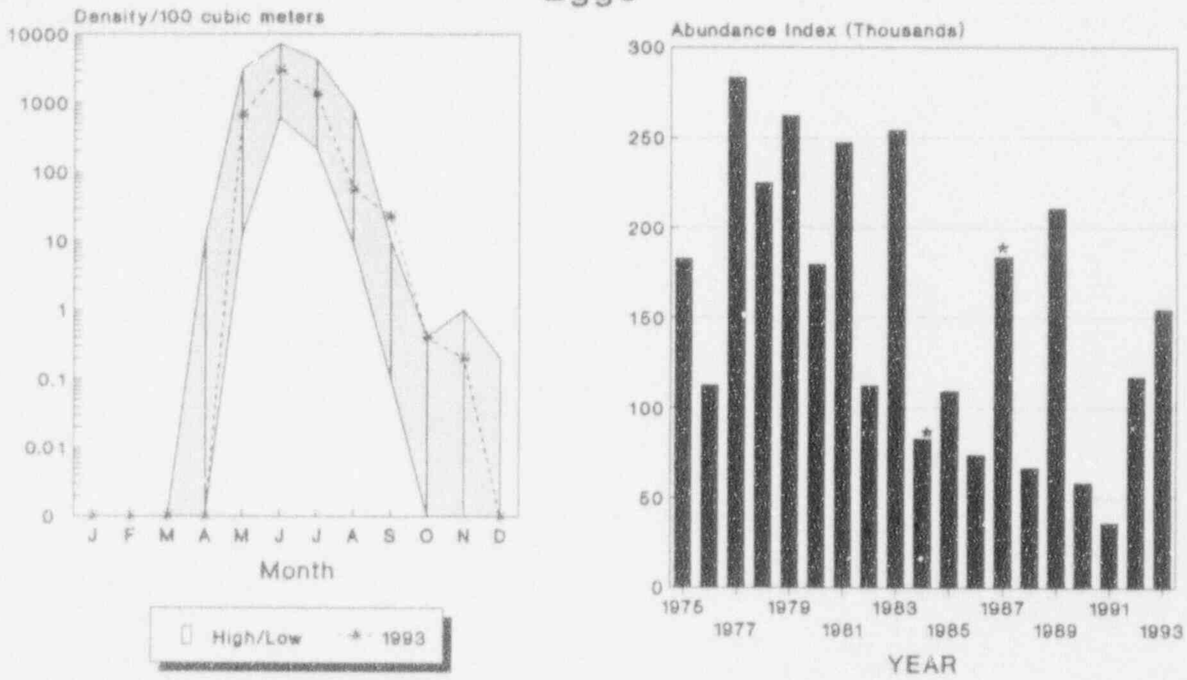
Includes:G.morhua, P.virens, and G. cynoglossus

Prionotus spp.
Eggs



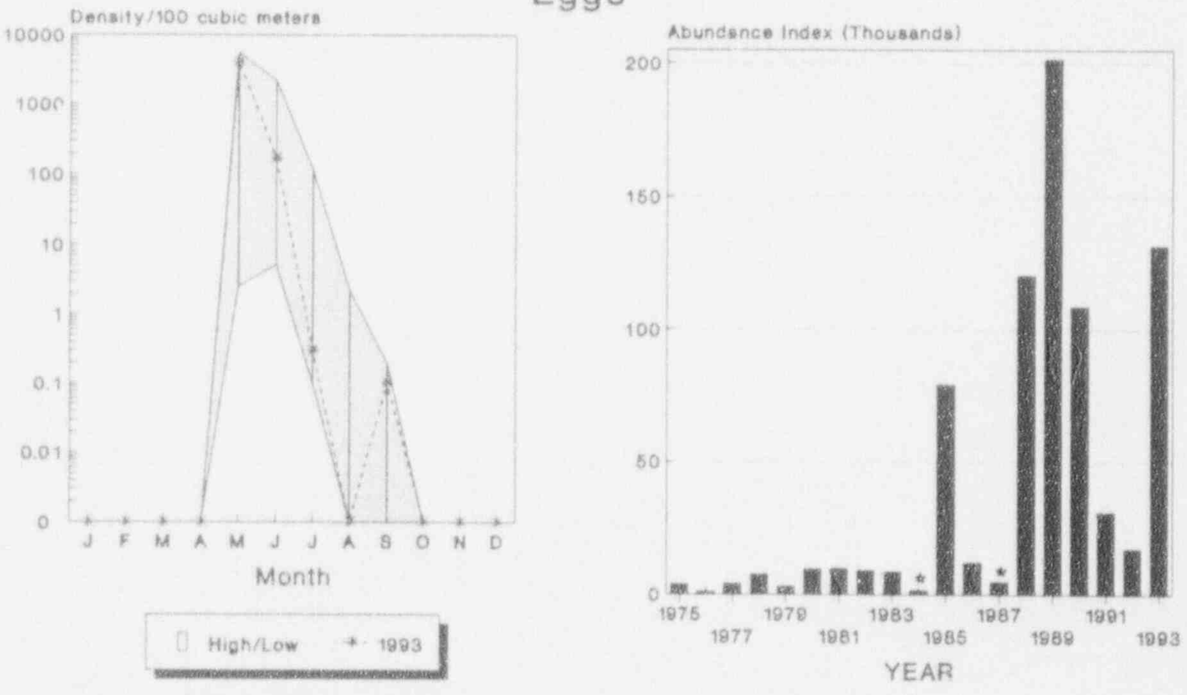


Labridae - *Pleuronectes*
Eggs

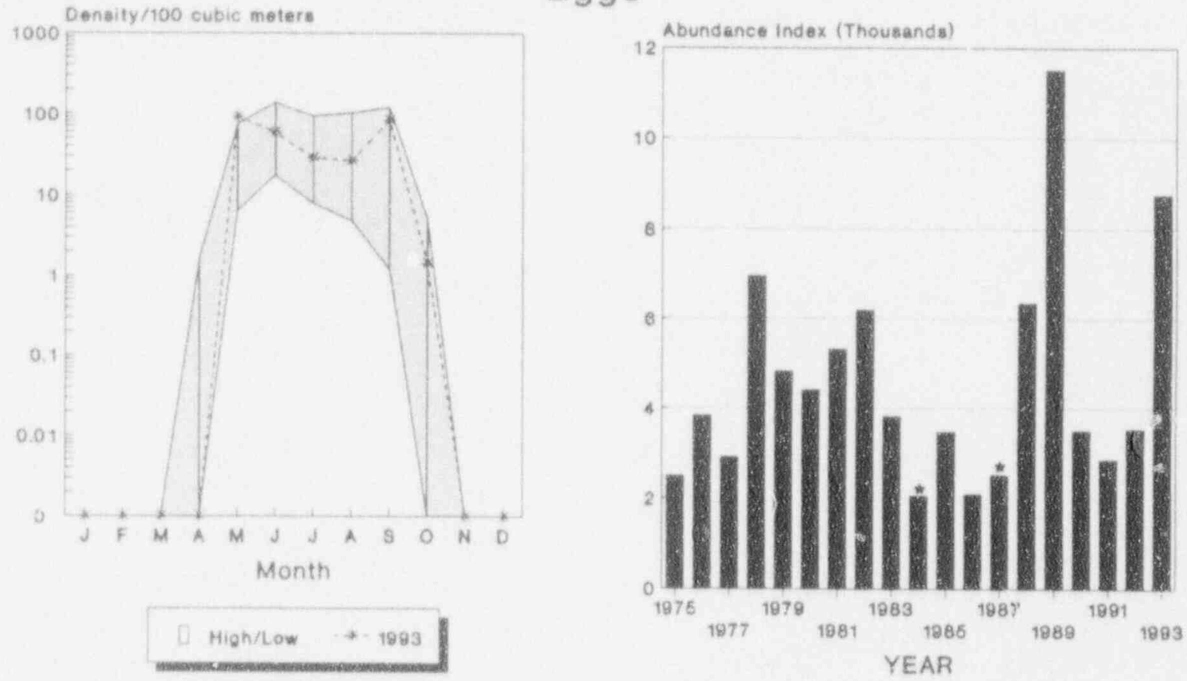


Includes Labridae and P. ferrugineus

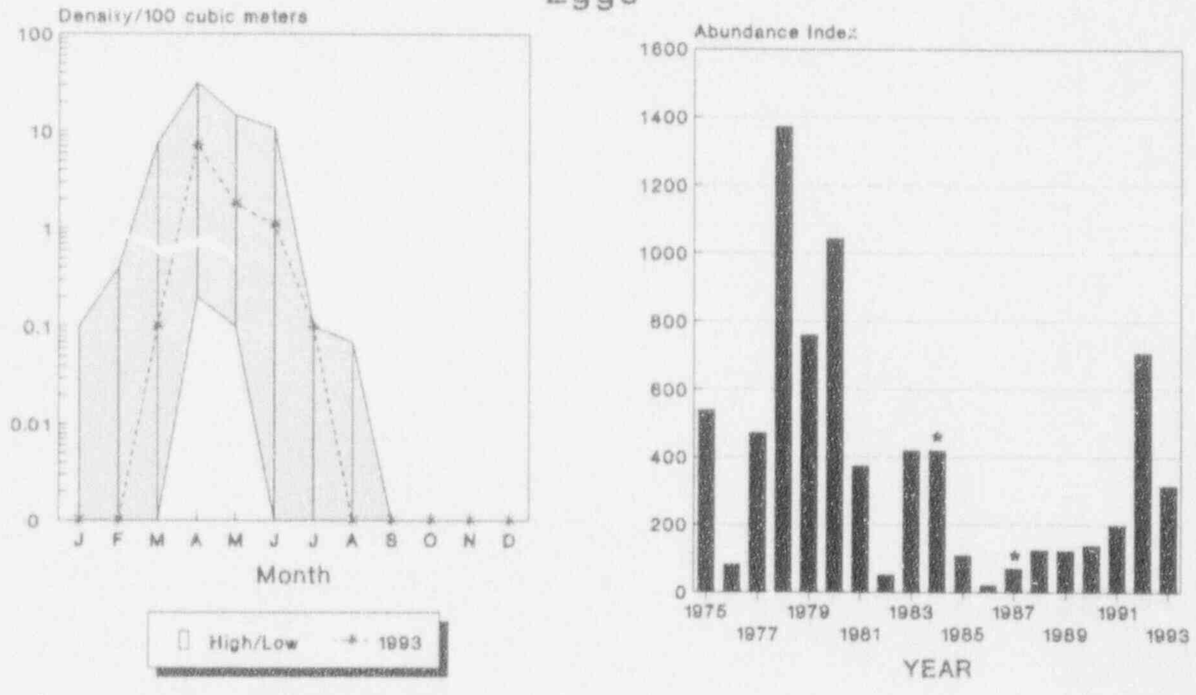
Scomber scombrus
Eggs



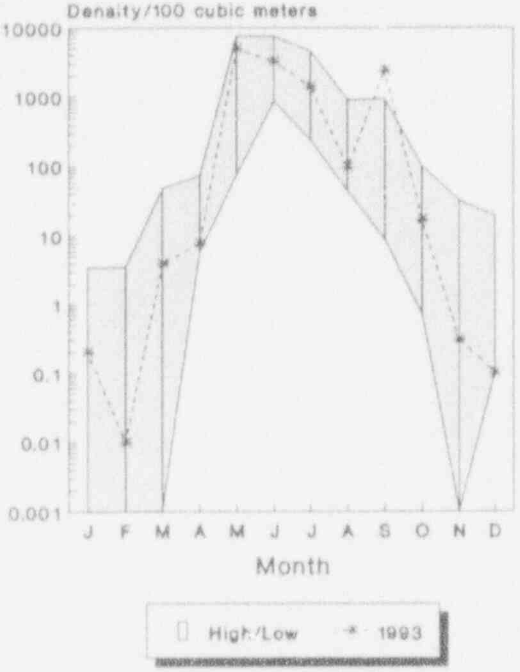
Paralichthys - Scophthalmus
Eggs



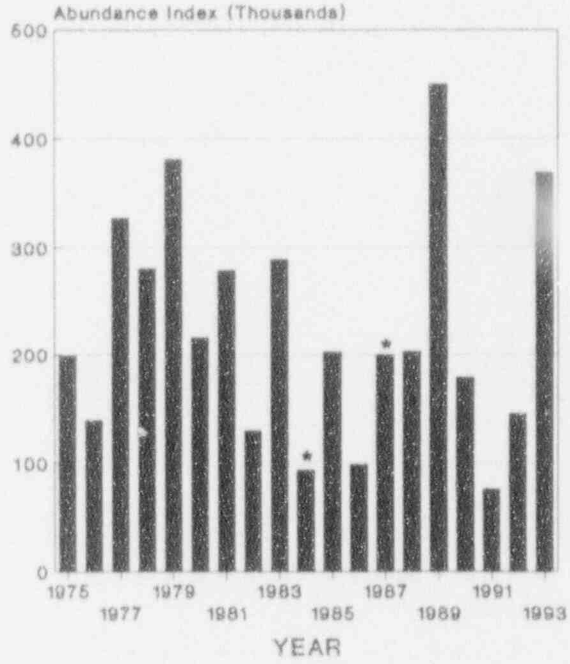
Hippoglossoides platessoides
Eggs



Total Eggs



Density/100 cubic meters
10000
1000
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
Month
High/Low
1993



Abundance Index (Thousands)
500
400
300
200
100
0
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
YEAR

Figure 5. Mean monthly densities per 100 m³ of water in the PNPS discharge canal for the eleven numerically dominant larval species and total larvae, 1993 (dashed line). Solid lines encompassing shaded area show high and low values over the 1975-1992 period.

<u>Brevoortia tyrannus</u>

<u>Clupea harengus</u>

<u>Enchelyopus cimbrius</u>

<u>Myoxocephalus</u> spp.

<u>Liparis</u> spp.

<u>Tautoga onitis</u>

<u>Tautogolabrus adspersus</u>

<u>Ulvaria subbifurcata</u>

<u>Pholis gunnellus</u>

<u>Ammodytes</u> sp.

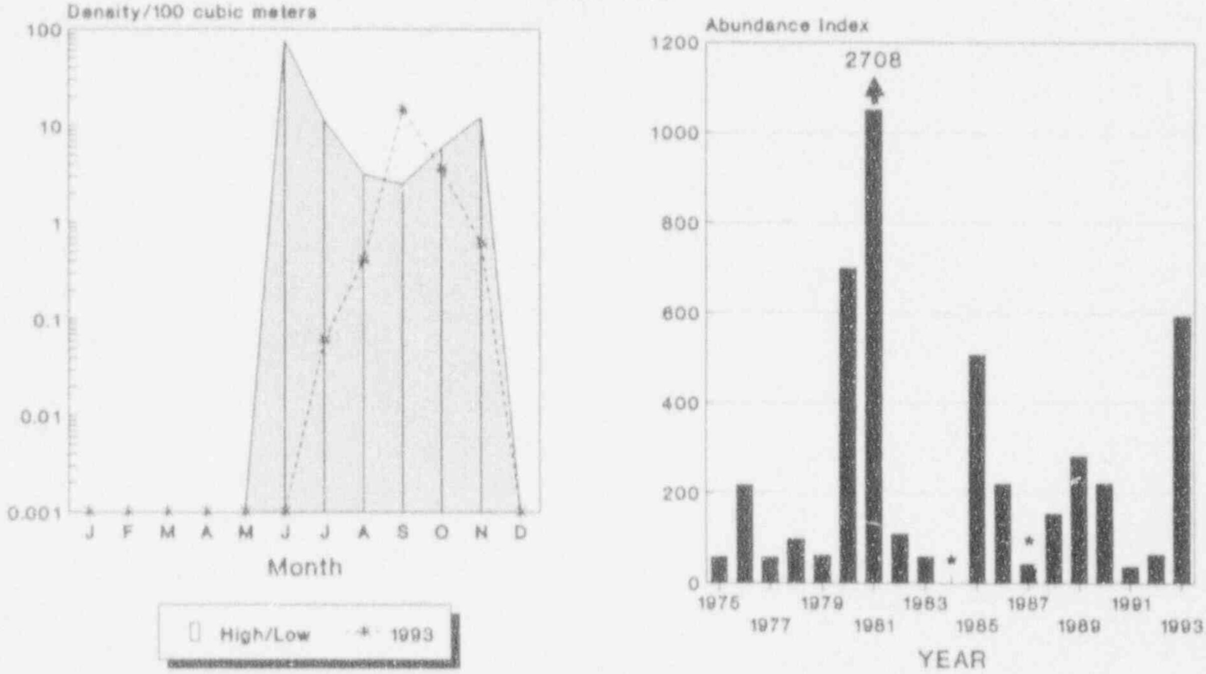
<u>Scomber scombrus</u>

<u>Pleuronectes americanus</u>

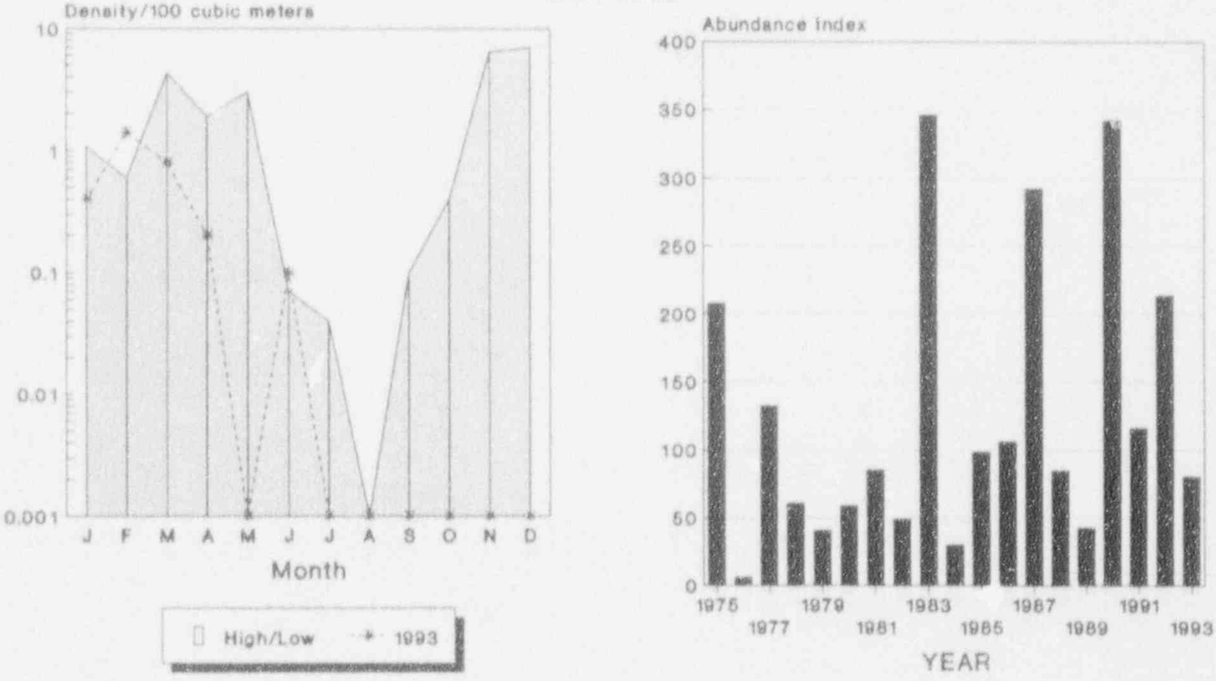
Total larvae

To the right are plotted integrated areas under the annual entrainment abundance curves for 1975-1993. An asterisk above 1984 and 1987 marks the two years when values may have been low due to low through-plant water volumes from April-August; see text for clarification.

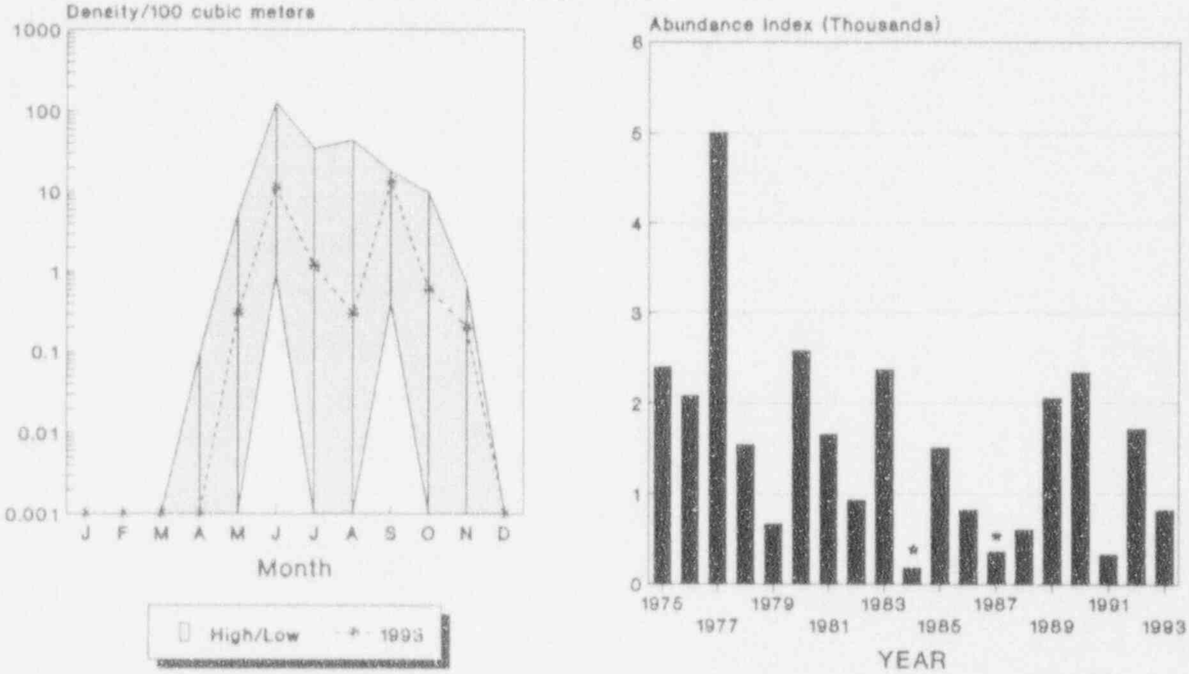
Brevoortia tyrannus
Larvae



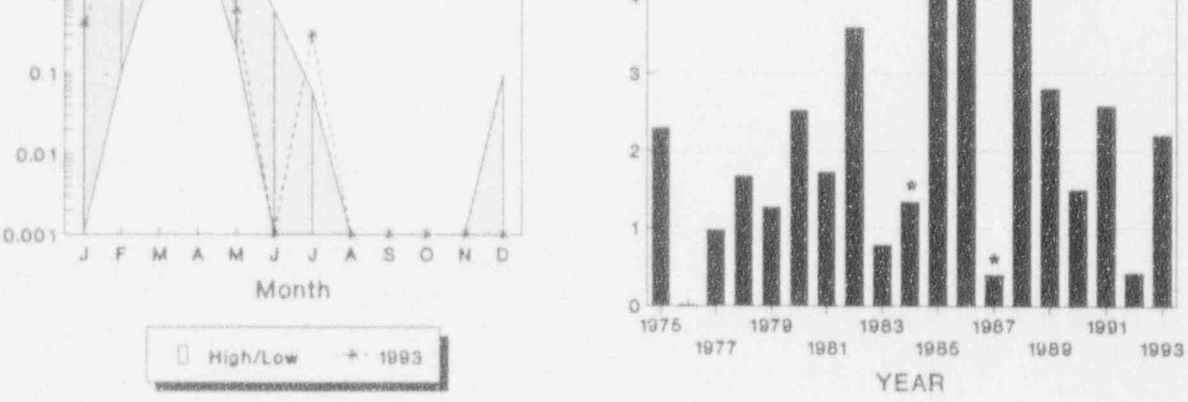
Clupea harengus
Larvae



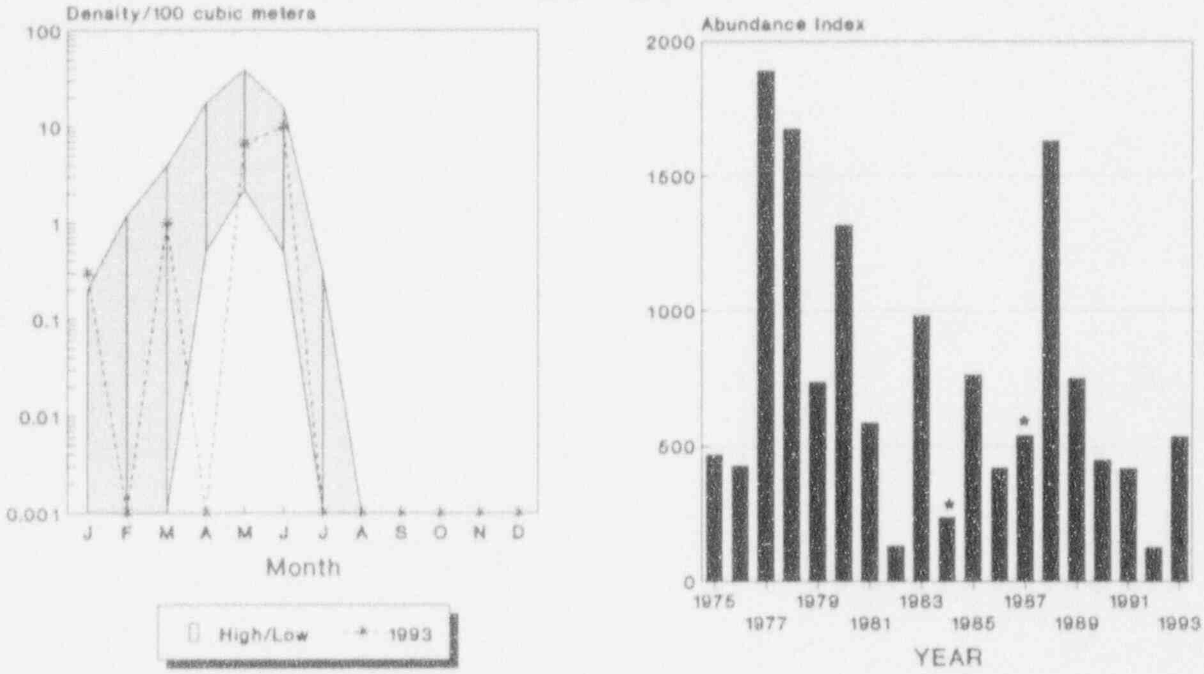
Enchleyopus cimbrius
Larvae



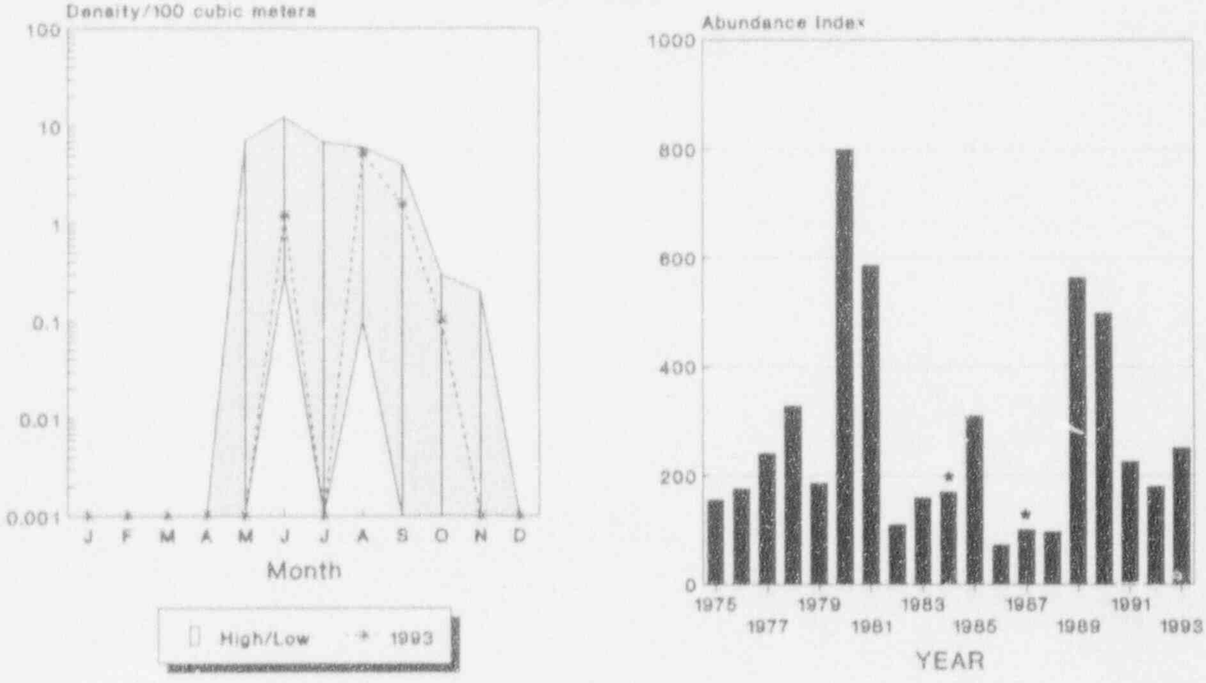
Myoxocephalus spp.
Larvae



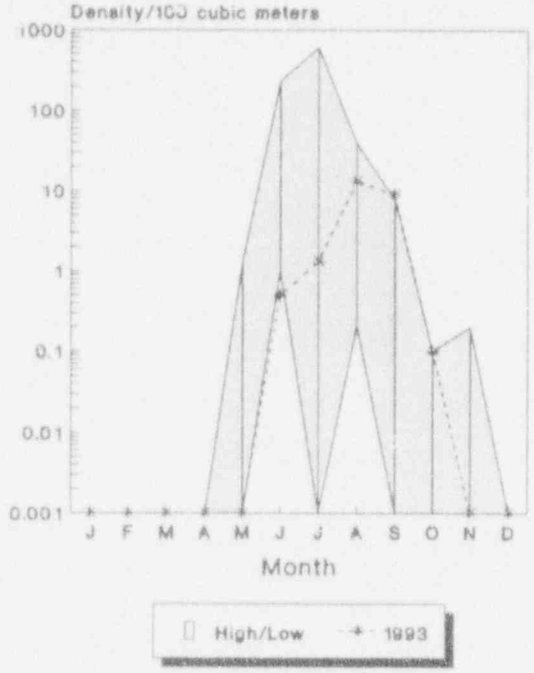
Liparis spp.
Larvae

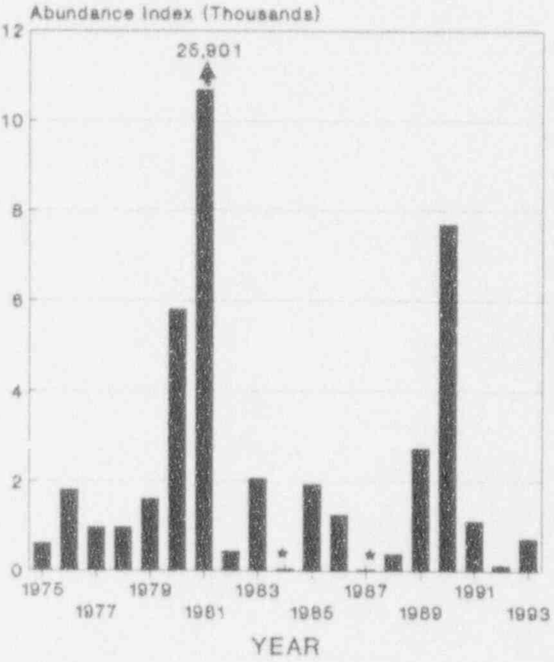


Tautoga onitis
Larvae

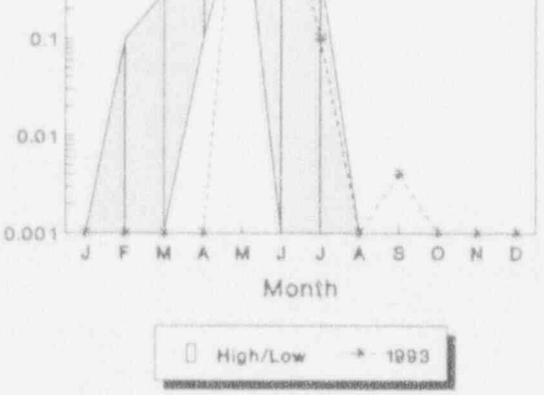


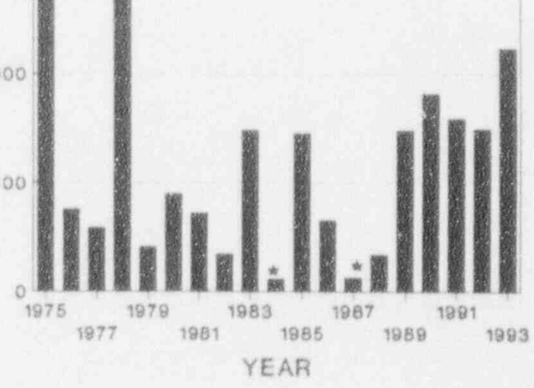
Tautogolabrus adspersus
Larvae



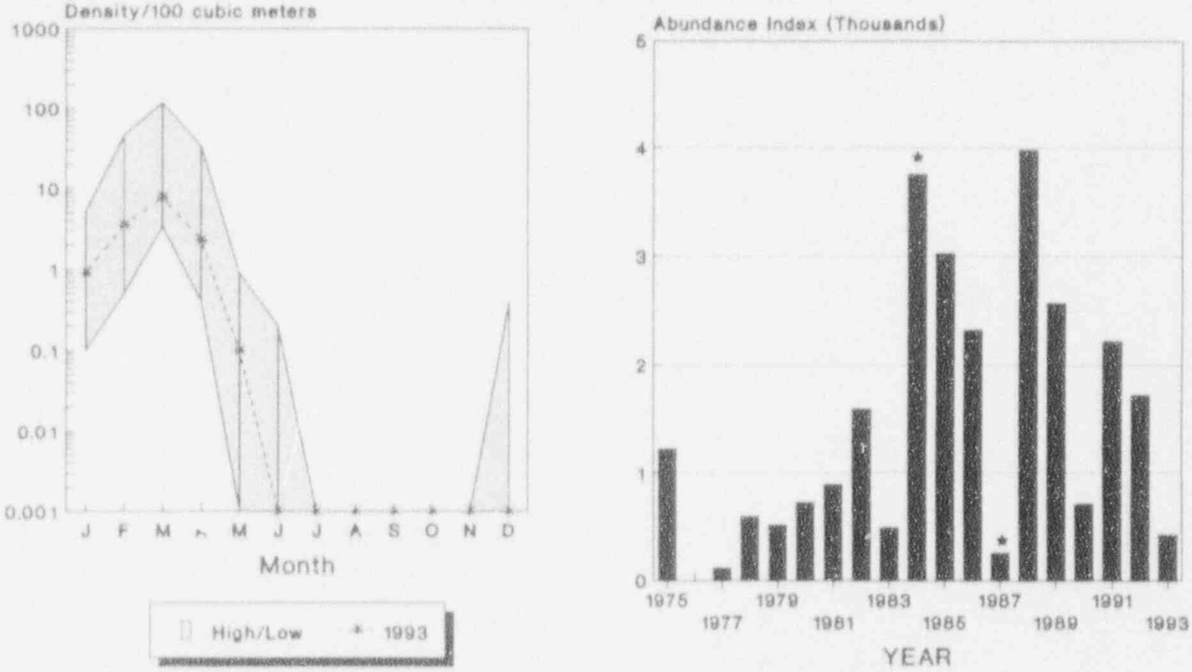


Ulvaria subbifurcata
Larvae

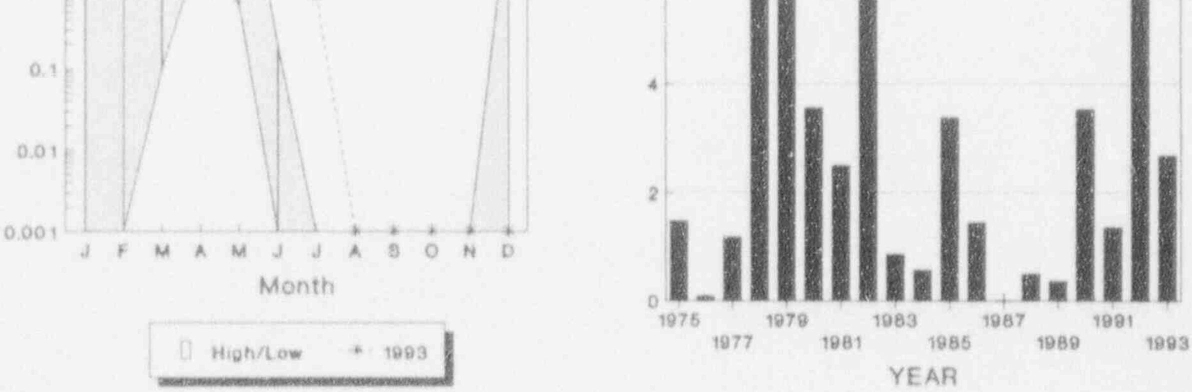




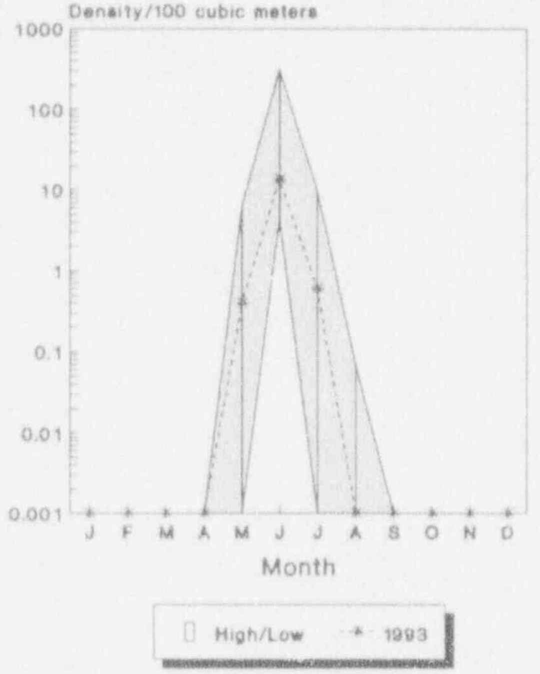
Pholis gunnellus
Larvae

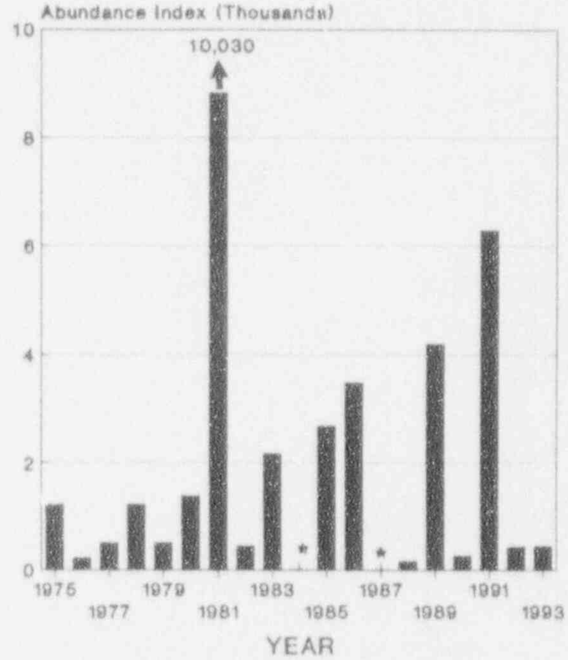


Ammodytes sp.
Larvae

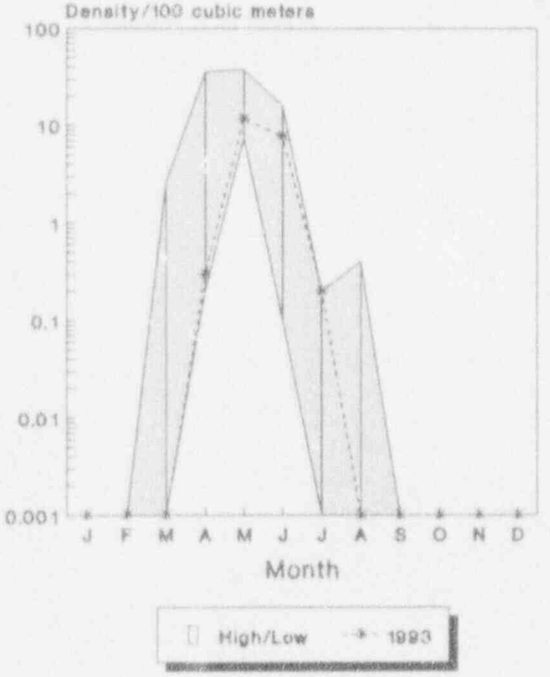


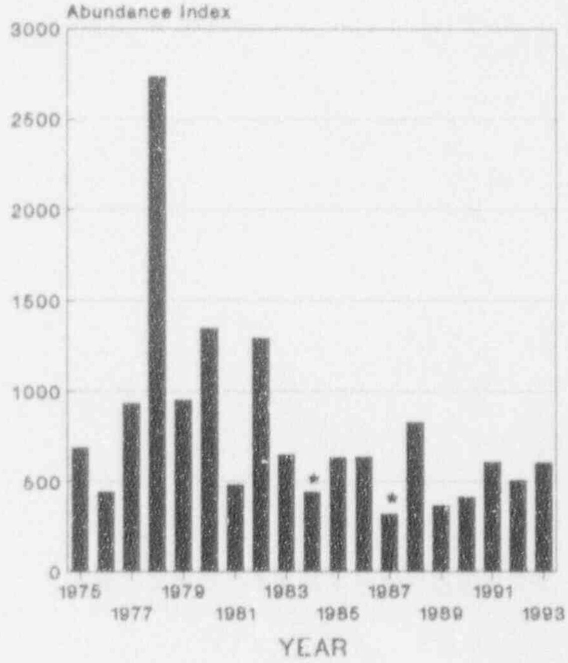
Scomber scombrus
Larvae



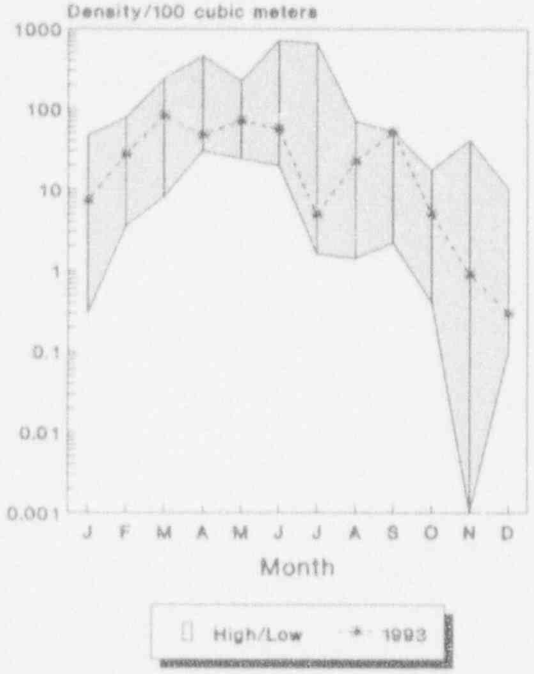


Pleuronectes americanus
Larvae





Total Larvae



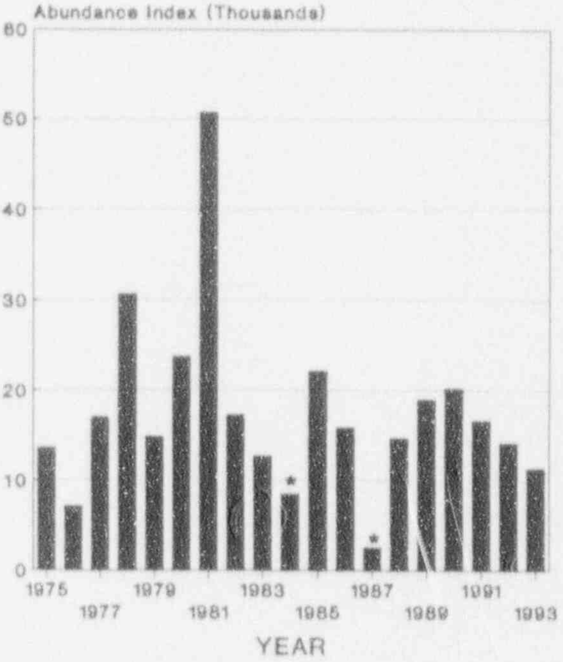


Table 1. Species of fish eggs (E) and larvae (L) obtained in ichthyoplankton collections from the Pilgrim Nuclear Power Station discharge canal, January-December 1993. Lines indicate peak periods for the more abundant species.

Species		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Atlantic menhaden	*Brevoortia tyrannus*						E ——	E/L	E/L	— E/L	L	L	
Atlantic herring	*Clupea harengus*	L	L	L	L	L	L						
Bay anchovy	*Anchoa mitchilli*						E	E				L	
Rainbow smelt	*Osmerus mordax*					L							
Fourbeard rockling	*Enchelyopus cimbrius*				E	E/L ——	E/L ——	E/L ——	E/L	E/L	E/L	L	
Atlantic cod	*Gadus morhua*			E/L	E/L	E	E/L	E/L	E	E		E	E/L
Silver hake	*Merluccius bilinearis*						E	E	E	E/L	E		L
Atlantic tomcod	*Microgadus tomcod*			L	L								
Pollock	*Pollachius virens*					L							
Hake	*Urophycis* spp.						E	E	E/L	E/L	E/L		
Goosefish	*Lophius americanus*						E	E/L	E	E			
Silversides	*Menidia* spp.					L	E/L	L	L				
Northern pipefish	*Syngnathus fuscus*						L	L	L	L			
Searobins	*Prionotus* spp.							E	E/L	E/L			
Grubby	*Myoxocephalus aenaeus*	L	L ——	L ——	L	L		L					
Longhorn sculpin	*M. octodecemspinosus*	L	L	L	L								
Shorthorn sculpin	*M. scorpius*		L	L	L								
Sculpin	*Myoxocephalus* spp.					E							
Lumpfish	*Cyclopterus lumpus*						L						
Seasnail	*Liparis atlanticus*				L ——	L ——	L ——						
Gulf snailfish	*L. coheni*	L		L		L							

Table 1 (continued).

Species		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Black sea bass	*Centropristis striata*									L			
Scup	*Stenotomus chrysops*							L					
Wrasses	Labridae					E —	E —	E —	E	E	E	E	
Tautog	*Tautoga onitis*						L		L	L	L		
Cunner	*Tautogolabrus adspersus*						L —	L	L	L	L		
Radiated shanny	*Ulvaria subbifurcata*					L —	L —	L		L			
Rock gunnel	*Pholis gunnellus*	L	L —	L —	L	L							
Wrymouth	*Cryptacanthodes maculatus*			L									
Sand lance	*Ammodytes* sp.	L	L —	L —	L —	L	L	L					
Atlantic mackerel	*Scomber scombrus*					E —	E/L —	E/L		E			
Butterfish	*Peprilus triacanthus*									L			
Smallmouth flounder	*Etropus microstomus*					E		E		E			
Summer flounder	*Paralichthys dentatus*									L	E		
Fourspot flounder	*P. oblongus*								L	L			
Windowpane	*Scophthalmus aquosus*					E —	E/L —	E —	E/L —	E/L	E		
Witch flounder	*Glyptocephalus cynoglossus*						E/L	E	E	E/L			
American plaice	*Hippoglossoides platessoides*			E	E/L	E/L	E/L	E					
Winter flounder	*Pleuronectes americanus*			E	L —	E/L —	E/L	L					
Yellowtail flounder	*P. ferrugineus*	E	E			E	E/L		E	L			

Table 2. Species of fish eggs (E) and larvae (L) collected in the PNPS discharge canal, 1975-1993. General periods of occurrence for eggs and larvae combined are sho along the right side; for the dominant species, periods of peak abundance are also shown in parentheses.

Species	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Period of Occurrence
Anguilla rostrata	J*	J	J		J	J								J		J				Feb - Jun
Alosa spp.		L	L	J	L						L					J				May - Jul
Brevoortia tyrannus	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Apr(Jun) - (Oct)Dec
Clupea harengus	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	Jan - Dec**
Anchoa spp.	L		L	L	L		L	L	L	L	L	L	L	L	L	L	L	L	L	Jun - Sep
A. mitchilli			E	E	E		E	E/L			E	E			E	E	E	E	E	Jun - Sep
Osmerus mordax	L	L	L	L	L		E/L	L	L		L	L	L	L	E/L			L	L	Apr - Jun
Brosme brosme	E/L	E/L	E/L		E/L	E/L	E	E	E											Apr - Jul
Enchelyopus cimbrius	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Apr(Jun) - (Sep)Dec
Gadus morhua	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Jan(Nov) - (Dec)Dec
Melanogrammus aeglefinus	L	E/L	E/L	E/L	L				L		E			E		E				Apr - Jul
Merluccius bilinearis	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	May(May) - (Jun)Nov
Microgadus tomcod			L	L		L	L	L	L	L	L	L	L	L	L	L		L	L	Jan - May
Pollachius virens	E/L	E/L	E	E/L	E/L	E/L	L			L	E/L	L	E/L	L	L	L	L	E/L	L	Jan-Jun,Nov,Dec
Urophycis spp.	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Apr(Aug) - (Sep)Nov
Ophidiidae-Zoarcidae	L																			Sep
Lophius americanus	E/L	E	E/L	E/L	E/L	L	E/L	E/L	E/L	E/L	E/L	E	E	E	E/L	E/L	E/L	E/L	E/L	May - Oct
Strongylura marina			L																	Jul
Fundulus spp.		E	E																	Jul
F. heteroclitus					E															Jun
F. majalis					J													E		Oct
Menidia spp.		L	L	L	L	E/L	E/L	E	E/L	L	L	L	L	L	L	L	L	L	L	May - Sep
M. menidia	E/L	E/L	E						L								E		[illegible]	May - Sep

*J = juvenile.

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

Table 2 (continued).

Species	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Period of Occurrence
Syngnathus fuscus	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	Apr - Oct
Sebastes norvegicus															L					Jun
Prionotus spp.	E/L	E		E	E	E/L	E/L	E	E/L	E/L	E/L	E/L	E/L	E/L	E	E	E	E	E/L	May(Jun) - (Aug)Sep
Myoxocephalus spp.	L	L	L	L	L	L	L	L	E/L	L	E/L	L	L	L	E/L	L	E/L	L	L	Dec(Mar) - (Apr)Jul
M. aenaeus					L	L	L	L	L	L	L	L	L	L	L	L	E/L	L	L	Jan(Mar) - (Apr)Jul
M. octodecemspinosus						L	L	L	L	L	L	L	L	L	E/L	L	L	L	L	Jan(Mar) - (Apr)May
M. scorpius						L	L	L		L	L	L	L	L	L	L	L	L	L	Feb - Apr
Aspidophoroides monopterygius						L	L	L								L				Mar - Apr
Cyclopterus lumpus		L	L				L	L	E		L		L	L	L	E/L		E/L	L	Apr - Jul
Liparis spp.	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	Jan(Apr) - (Jun)Jul
L. atlanticus							L	L	L	L	L	L	L	L	L	L	L	L	L	Mar(Apr) - (Jun)Jul
L. coheni							L	L	L	L	L	L	L	L	L	L	L	L	L	Jan(Feb) - (Mar)Apr
Centropristis striata	L					L			L	L	L	L	L	L	L	L			L	Jul - Oct
Cynoscion regalis						L					L	L								May - Sep
Stenotomus chrysops	L		L											L	E	L	L	L	L	Jun - Jul
Menticirrhus saxatilis	L				L															Jul - Aug
Labridae	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	Mar(May) - (Aug)Sep
Tautoga onitis	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	May(Jun) - (Aug)Oct
Tautogolabrus adspersus	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	May(Jun) - (Aug)Oct
Lumpenus lumpretaeformis	L						L			L	L	L		L	L	L				Jan - Jun
Ulvaria subbifurcata	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	Feb(Apr) - (Jun)Oct
Pholis gunnellus	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	Jan(Feb) - (Apr)Jun
Cryptacanthodes maculatus				L	L		L	L	L	L	L	L			L	L	L	L	L	Feb - Apr
Ammodytes sp.	L	L	L	L	E/L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	Jan(Mar) - (May)Jun
Gobiosoma ginsburgi	L		L					L						L						Jul - Aug
Scomber scombrus	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Apr(May) - (Jul)Sep
Peprilus triacanthus	E/L	E/L	E/L	E	E	E/L	E/L	L	E/L	E/L	L		E	E/L	E/L	L	E/L		L	May - Oct

Table 2 (continued).

Species	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Period of Occurrence
Etropus microstomus	L								L		E	E/L	E		E		E	E	E	Jul - Oct
Paralichthys dentatus	E/L								E/L		L		E/L	E		L			E/L	Sep - Nov
P. oblongus*		E/L	E/L		E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	L	L	May - Oct
Scophthalmus aquosus*	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Apr(May) - (Sep)Oct
Glyptocephalus cynoglossus	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Mar(May) - (Jun)Nov
Hippoglossoides platessoides	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Jan(Mar) - (Jun)Nov
Pleuronectes americanus	E/L	E/L	L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Jan(Apr) - (Jun)Aug
P. ferrugineus	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	Feb(Apr) - (May)Nov
P. putnami							L	E/L												Mar - Jun
Trinectes maculatus			E	E			E	E				E		E	E/L	E/L	E			May - Sep
Sphoeroides maculatus			L								L									Jul - Aug
Number of Species**	41	36	43	35	37	35	40	38	37	34	42	37	36	41	40	42	34	36	38	

*Although these eggs were not identified specifically, they were assumed to have occurred as shown based on the occurrence of larvae.
**For comparative purposes three species of Myoxocephalus were assumed for 1975-1978 and two species of Liparis for 1975-1980.

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APPENDIX A*

Densities of fish eggs and larvae per 100 m^3 of water recorded in the PNPS discharge canal by species, date, and replicate, January-December 1993.

*This Appendix is available upon request.

APPENDIX B*

Mean monthly densities and range per 100 m^3 of water for the dominant species of fish eggs and larvae entrained at PNPS, January-December, 1975-1993.

*This Appendix is available upon request.

ICHTHYOPLANKTON ENTRAINMENT MONITORING

AT PILGRIM NUCLEAR POWER STATION

JANUARY-DECEMBER 1993

Volume 2 of 2

(Impact Perspective)

Submitted to

Boston Edison Company

Boston, Massachusetts

by

Marine Research, Inc.

Falmouth, Massachusetts

April 1, 1994

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SECTION I

EXECUTIVE SUMMARY

Entrainment sampling at PNPS was completed twice per month during January, February, October-December; weekly during March and June-September. Although scheduled weekly, sampling was possible only twice in April, three times in May due to a refueling outage. On those five occasions sampling occurred with one CWS pump out of service.

Atlantic menhaden egg densities in late September met the unusually abundant criterion established for PNPS, the first such occurrence since 1938. Annual estimated entrainment losses based on full load flow capacity at PNPS totaled 6.4 billion eggs and 197 million larvae. Estimated losses of cunner eggs and larvae were calculated to be equivalent to 60,819 adult fish in 1993, 0.03% of an estimated nearshore adult population. Similar adult equivalent values for winter flounder were 506 or 4820 fish (using two sets of survival values) amounting to 0.02 or 0.2% of the Massachusetts Bay area commercial landings. For Atlantic mackerel 1993 entrainment losses converted to 5475 age 1 fish or 3526 age 3 fish which amounted to 0.3 and 0.8% of the commercial landings.

Declining trends in abundance of cunner, windowpane, yellowtail, and winter flounder in collections around Pilgrim Station appear to be widespread and attributable to overexploitation. The severity of these declines has stimulated a hard look at the role that entrainment might play in rebuilding local stocks.

An analysis of egg and larval entrainment between years with differing pump regimes strongly suggests that larval entrainment densities and perhaps, to a lesser extent, egg entrainment densities are directly related to water withdrawal rates.

One lobster larva was found in PNPS entrainment samples in 1993, bringing the 20-year total to just twelve.

SECTION II

INTRODUCTION

This report addresses results of PNPS ichthyoplankton entrainment sampling in relation to potential impact assessment. Discussions are based on results presented in "Ichthyoplankton Entrainment Monitoring at Pilgrim Nuclear Power Station January-December 1993", Volume 1 - Results. Work was conducted by Marine Research, Inc. (MRI) for Boston Edison Company (BECo) under Purchase Order No. 107011 in compliance with environmental monitoring and reporting requirements of the PNPS NPDES Permit (U.S. Environmental Protection Agency and Massachusetts Division of Water Pollution Control). In a continuing effort to condense the volume of material presented in this and related reports, details of interest to some readers may have been omitted. Any questions or requests for additional information may be directed to Marine Research, Inc., Falmouth, Massachusetts, through BECO.

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

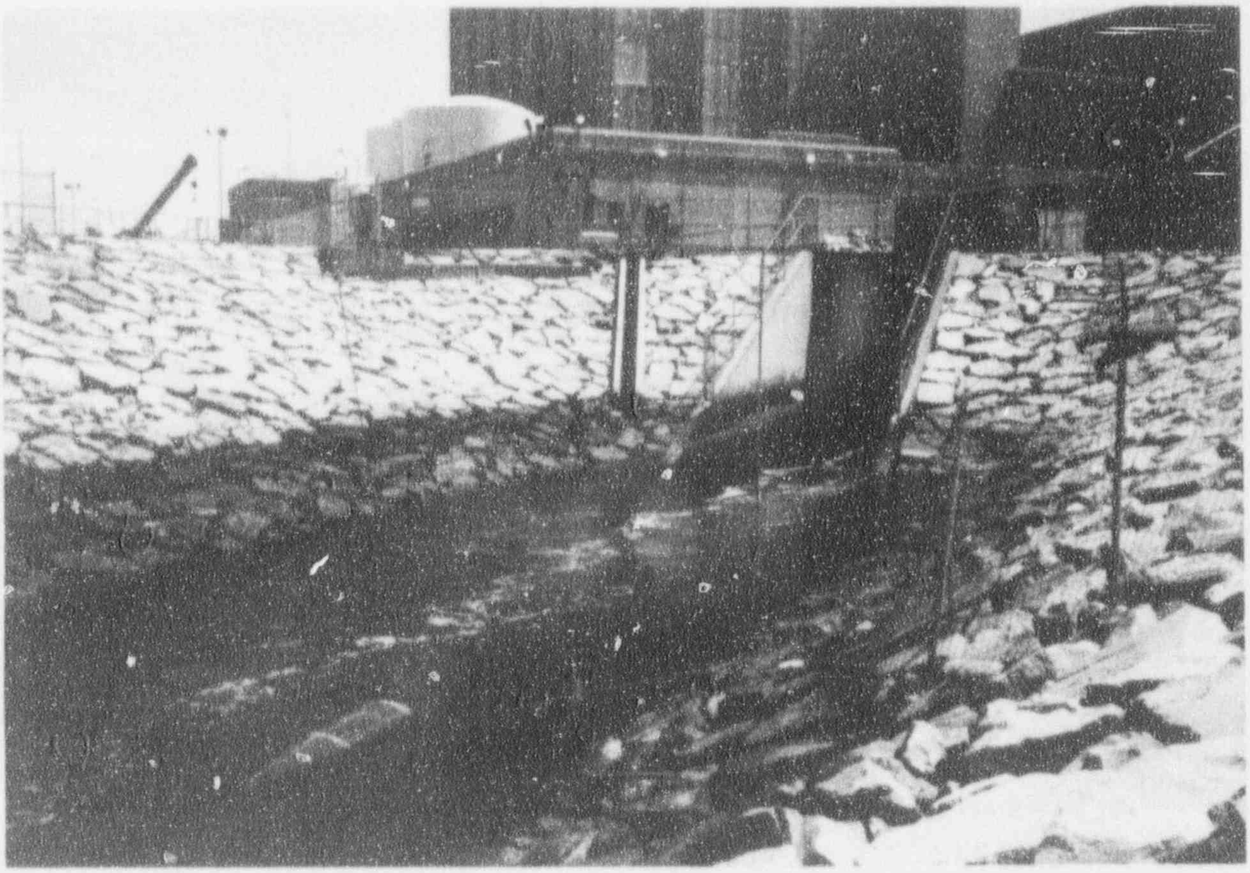

Plate 1. Plankton net streaming in the discharge canal at Pilgrim Station for the collection of fish eggs and larvae (lobster larvae are also recorded). A single, six-minute collection can contain several thousand eggs and larvae representing 20 or more species.

SECTION III

IMPACT PERSPECTIVE

A. Contingency Sampling Plan

Ichthyoplankton densities in the PNPS discharge canal meeting the "unusually abundant" criterion, defined as exceeding by 50% the highest mean density over three replicates recorded during the same month from 1975 through 1992 occurred on one occasion in 1993, the first such occurrence since 1988 (Table 1). On September 21 a mean density for Atlantic menhaden of 11835 eggs per 100 m^3 was obtained, exceeding the previous high value (1962, September 1982) by 603%.

In past years it was standard practice for BECO, in consultation with regulatory personnel, to authorize the collection of an additional set of triplicate entrainment samples following the recording of an unusually large density at PNPS. In most cases the additional sets were taken within two days of the original. In all but three cases when this occurred mean densities dropped back to levels within the range established over previous years, indicating that the "unusual" density probably reflected the occurrence of a high-density ichthyoplankton patch in the Rocky Point area rather than a more widespread phenomenon. In the three cases where high densities persisted (larval Atlantic menhaden, Brevoortia tyrannus, June 1981; larval rock gunnel, Pholis gunnellus, April 1982; larval rock gunnel, February 1985) additional entrainment sampling at about two-day intervals indicated that high densities continued for

Table 1. Ichthyoplankton densities per 100 m³ of water which reached the "unusually abundant"* level in PNPS entrainment samples, 1980-1993.

Species	Month	"Unusually abundant" density (year)	Previous high density (year)
EGGS			
Brevoortia tyrannus	June	74.2 (1980)	6.2 (1978)
	September	1961.9 (1982)	1.4 (1979)
		1065.8 (1982)	" "
		11835.0 (1993)	1961.9 (1982)
	October	37.8 (1980)	0.2 (1978)
Enchelyopus-*Urophycis* *Peprilus*	September	71.3 (1980)	30.1 (1979)
Urophycis spp.	September	152.8 (1980)	22.3 (1978)
Labrid-*Limanda* & labrid	July	12917.0 (1981)	8116.8 (1975)
Scomber scombrus	May	15261.3 (1985)	572.0 (1980)
		1457.6 (1985)	" "
LARVAE			
Brevoortia tyrannus	June	7.1 (1981)**	4.2 (1980)
		495.9 (1981)**	" "
		34.7 (1981)**	" "
	October	11.7 (1980)	1.8 (1976)
	November	24.3 (1980)	3.2 (1978)
Enchelyopus cimbrius	August	204.6 (1983)	36.0 (1980)
Urophycis spp.	September	105.6 (1984)	22.3 (1981)
Tautoga onitis	August	21.6 (1984)	4.1 (1974)
	September	9.2 (1980)	4.8 (1975)
Tautogolabrus adspersus	June	624.5 (1981)	378.8 (1977)
	July	296.5 (1980)	138.5 (1974)
		2162.5 (1981)	296.5 (1980)
	September	20.3 (1980)	1.5 (1975)
Pholis gunnellus	February	19.6 (1984)	7.4 (1975)
		13.8 (1984)	" "
		47.5 (1985)**	19.6 (1984)
	March	70.2 (1980)	36.9 (1975)
		210.5 (1984)	70.2 (1980)
		415.2 (1984)	" "
	April	74.0 (1982)**	12.1 (1977)
		74.7 (1982)**	" "
		34.0 (1982)**	" "
		22.4 (1982)**	" "
		23.5 (1982)**	" "

Table 1 (continued).

Species	Month	"Unusually abundant" density (year)	Previous high density (year)
LARVAE (continued)			
Ammodytes sp.	January	31.1 (1980)	13.5 (1975)
		104.4 (1985)	31.1 (1980)
Scomber scombrus	June	2700.0 (1981)	128.0 (1975)
Myoxocephalus spp.	February	79.2 (1988)	37.4 (1985)
	March	153.6 (1980)	97.0 (1975)
		308.3 (1988)	188.7 (1986)
	April	303.6 (1982)	53.1 (1981)

*"Unusually abundant" was defined as 50% greater than the previous high density observed during the same month 1975-1992. No specific events were recorded prior to 1980 primarily because "unusually abundant" was not yet defined.

**Unusually high densities persisted for up to two weeks.

up to two weeks. Since no changes in PNPS operation occurred such as an increase in circulating water flow, it appeared in those situations that productivity was generally high relative to previous years.

In the current case of menhaden eggs, a follow-up collection was made two days later (the 23rd) with a mean density of 732 eggs per 100 m^3 being recorded. None were taken on September 29, the next regularly scheduled sampling date. As noted in Volume I, it is not uncommon for Atlantic menhaden to demonstrate a bimodal spawning season with peaks in June or July and again in September. Greatest densities over the full time series have been noted in the autumn samples. Production of menhaden eggs in nearshore, western Cape Cod Bay was apparently strong in 1993. It is important to realize however that menhaden eggs hatch in about two to three days at 15-20 C (Reintjes 1968), less than half the one-week sampling interval. Since they travel in dense schools, large numbers of eggs can be spawned and hatch without being detected. Subtle variations in survival (see for example Vaughan and Saila 1976) coupled with larval transport can result in larval densities which do not reflect a short-lived spike in egg densities. In 1993 relatively high larval densities did follow the high egg densities. September's mean density of 15 larvae per 100 m^3 exceeded the previous September high by a factor of five.

As the declining number of "unusual" densities over time suggests (Table 1), each "unusual" density increases the level necessary for future high-density events to be identified within a

given species. In practice each unusual occurrence makes it more unlikely that any subsequent contingency events will be identified. In response to this, beginning in 1994, high densities will be redefined using log-normal curve theory, the delta distribution, and reference distributions.

B. Ichthyoplankton Entrainment - General

Entrainment of ichthyoplankton at PNPS represents a direct, negative environmental impact since fish eggs and larvae pass through the plant in large numbers each day and are subjected to elevated temperatures, mechanical forces, and periodic chlorination. When PNPS is not on line, increased temperature is not a factor but ichthyoplankton may still be subjected to mechanical forces and periodic chlorination when circulating seawater or salt service water pumps operate. Although survival has been demonstrated for some species of fish eggs at PNPS such as the labrids (45%; Marine Research 1978, 1982) and among larvae at other power plants (0-100% initial survival depending on species and size; Ecological Analysts 1981), mortality is conservatively assumed to be 100% for PNPS impact assessment.

To place fish egg and larval densities entrained at PNPS, expressed as numbers per 100 m³ of water, in some perspective in relation to amounts of water utilized by PNPS, they were multiplied by maximum plant flow rates over each respective period of occurrence. This was completed for each of the numerically dominant species as well as total eggs and total larvae. Mean

monthly densities were multiplied by 17,461.44, the full load flow capacity of PNPS in 100 m^3 units per 24-hour day, then by the number of days in each respective month they occurred. Values for each month in which a species or species group occurred were then summed to arrive at a seasonal entrainment value in each case (Figures 1 and 2). Among the eight numerically dominant groups, numbers of eggs entrained ranged from 1,189,000 for the cod/witch flounder group (Gadidae-Glyptocephalus = cod, Gadus morhua, witch flounder, Glyptocephalus cynoglossus) to 2,609,000,000 for the labrid-yellowtail group (tautog, Tautoga onitis, cunner, Tautogolabrus adspersus, yellowtail flounder, Pleuronectes ferrugineus). Corresponding values among the eleven dominant larval species varied from a low of 1,405,000 for Atlantic herring (Clupea harengus) to a high of 46,668,000 for sand lance (Ammodytes sp.). For all eggs and larvae combined, values amounted to 6,442,000,000 and 197,328,000, respectively. These numbers indicate the vast quantities of eggs and larvae which can be entrained by the circulating seawater system at PNPS during a year's time and are assumed lost to local fish stocks.

C. Ichthyoplankton Entrainment - Specific

Estimated numbers of eggs and larvae entrained annually were examined in greater detail for three species using the equivalent adult approach (see Horst 1976, Goodyear 1978, for example). Six years, 1987-1992, were arbitrarily selected for review plus the current year. The adult equivalent procedure involves applying

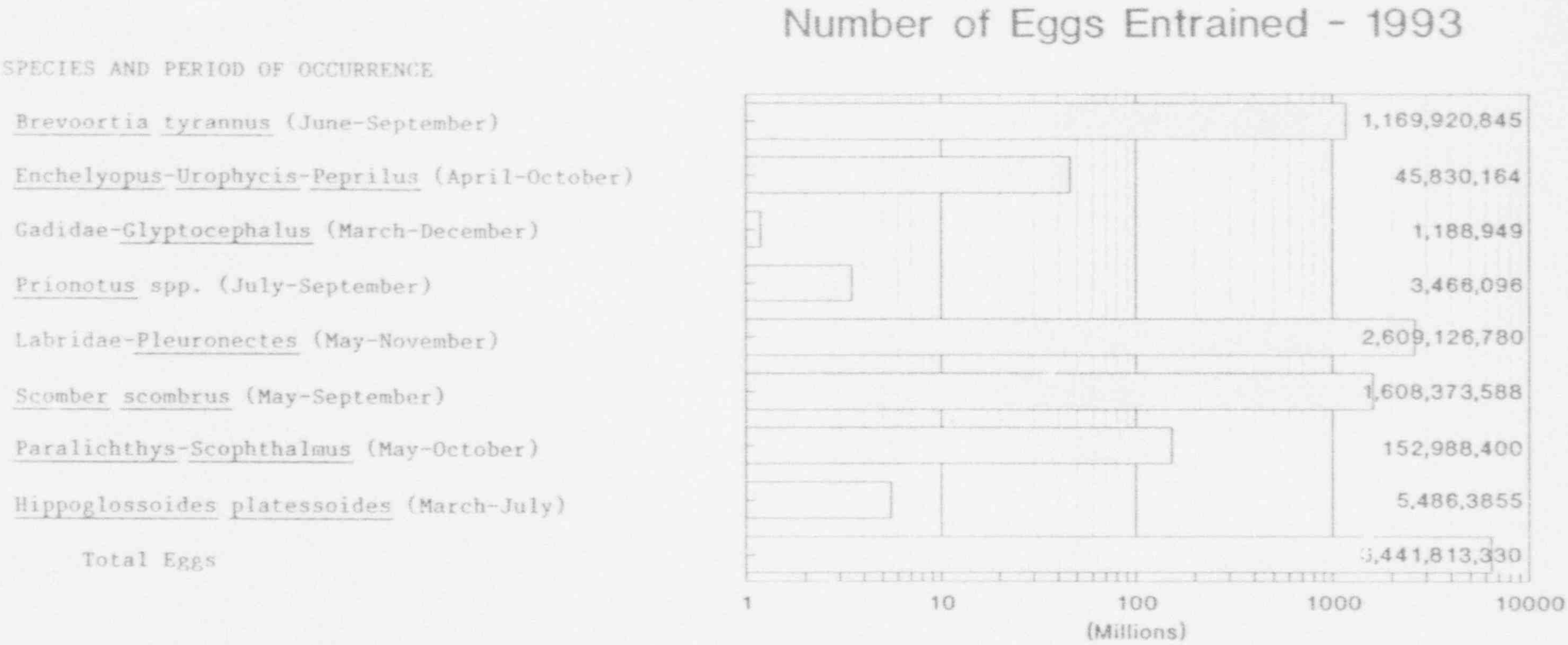

Figure 1. Numbers of eggs estimated to have been entrained by PNPS in 1993 had it operated at full pump flow by species or species group (dominants only) including all egg species combined. The period of occurrence observed in 1993 is also indicated.

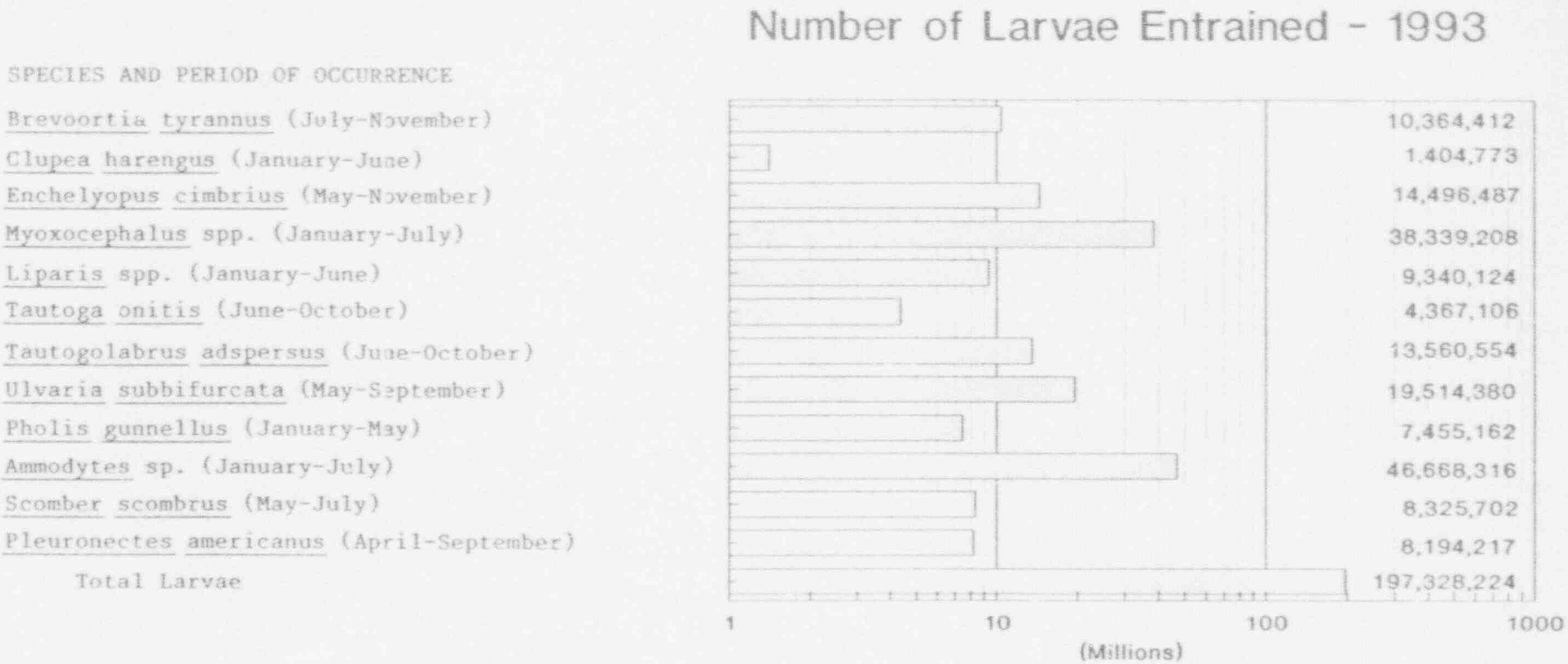

Figure 2. Numbers of larvae estimated to have been entrained by PNPS in 1993 had it operated at full pump flow for each dominant species including all larvae combined. The period of occurrence observed in 1993 is also indicated.

appropriate survival rates to numbers of eggs and larvae lost to entrainment to obtain a number of adult fish which could have been added to the population had entrainment not occurred. Many assumptions are associated with the method. The fish population is assumed to be in equilibrium, therefore in her lifetime each female will replace herself plus one male. It is also assumed that no eggs or larvae survive entrainment and that no density-dependent compensation occurs among surviving individuals. The later two assumptions lend conservatism to the approach. As pointed out earlier, numbers of eggs and larvae entrained were determined using the full load flow capacity of the plant. This value was used even if the station was out of service and less than full capacity was being circulated. In those cases the adult equivalents are conservatively high.

Since plankton densities are notorious for deviating from a normal distribution but do generally follow the lognormal, geometric mean densities more accurately reflect the true population mean. For data which are skewed to the right such as plankton densities, the geometric mean is always less than the arithmetic mean. For PNPS entrainment densities the two means typically varied by 10% or less. In calculating total entrainment values for the adult equivalent methodology we chose to use the larger arithmetic mean to lend additional conservatism to the assessments.

The three species selected were winter flounder (Pleuronectes americanus), cunner and Atlantic mackerel (Scomber scombrus). Flounder were chosen because of their commercial and recreational

value as well as their importance in PNPS ecology studies. Cunner were selected because they are abundant in the area and PNPS finfish studies have been focusing on that species which appears to be in a declining trend begun in 1980 (Lawton et al. 1993). Mackerel were included because they are abundant among the ichthyoplankton entrained, both eggs and larvae being removed from the population, and they are commercially valuable.

Winter flounder. The annual larval entrainment estimates were converted to equivalent numbers of age 3 adults, the age at which flounder become sexually mature (NOAA 1993, Witherell and Burnett 1993). Two sets of survival values were used. The first set followed NEP (1978) using data from Pearcy (1962) and Saila (1976). Briefly, this consisted of dividing the total number of entrained larvae by 0.09 to estimate the number of eggs which hatched to produce that number of larvae. The number of eggs was then multiplied in succession by 0.004536, an estimate of survival from a newly hatched egg to day 26; 0.2995, survival from day 27 to metamorphosis; 0.03546, survival of juveniles from 3 to 12 months; 0.3491, survival from 13 to 24 months; and finally 0.33, survival from 24 to 36 months. The second approach followed larval stage-specific mortality rates derived by NUSCO (1993) as modified by Gibson (1993a). These are as follows:

S (stage 1) = 2.36E-01
S (stage 2) = 1.08E-01
S (stage 3) = 1.54E-01
S (stage 4) = 6.23E-01
S (age 0) = 7.30E-02
S (age 1) = 2.50E-01
S (age 2) = 4.77E-01

In using the stage-specific rates it is recognized that NUSCO employs different morphological stage criteria than those used at PNPS. Corrections, if necessary, should be available following the 1994 larval season when larvae become available from their laboratory. Although small numbers are entrained each year, flounder eggs were ignored because they are demersal and adhesive and not generally impacted by entrainment.

The general, unstaged larval survival values produced an adult equivalent value of 506 age 3 fish for 1993. The stage-specific values produced a value nearly ten times higher at 4820 age 3 individuals. Based on a weight of 0.6 pounds per fish (Gibson 1993b), these values convert to 304 and 2892 pounds, respectively. Comparable values for 1988-1992 ranged from 422 to 1102 fish (mean = 508 fish, 305 pounds) for the general approach and 2412 to 15,479 (mean = 6175 fish, 3705 pounds) for the staged approach. The large differences between the two sets of survival estimates clearly show how relatively small variations in survival values when applied to large numbers of larvae can result in relatively large variations in adult numbers (see Vaughan and Saila 1976 for example).

Over this same period an annual average of 1,677,882 pounds (S.E. = 87,884) of flounder were landed from NOAA statistical area 514 which covers Cape Cod Bay and Massachusetts Bay. Based on a weight of 0.6 pound per fish, the loss of 508 or 6175 fish weighing 305 or 3705 pounds represents 0.02 or 0.2% of those landings.

Cunner. Goodyear's (1978) basic procedures were used to estimate equivalent adult values. This method converts eggs and

Table 2. Numbers of larval winter flounder entrained at PNPS annually by stage, 1987-1993. Number of equivalent age 3 adults calculated by two methods is also shown.

	Number of Larvae Entrained ($x10^6$)					Equivalent Age 3 Adults	
Stage:	I	II	III	IV	Total	General	Staged
1987*	0	0.270	3.088	0	3.359	215*	2625*
1988	1.232	1.022	15.080	0.511	17.845	1102	15479
1989	1.030	3.553	2.225	0.039	6.847	422	2412
1990	0.397	0.713	3.847	0.033	4.990	491	3477
1991	2.143	2.413	5.188	0.038	9.782	604	4776
1992	0.539	0.541	7.035	0.026	8.141	519	6087
1993	0.985	2.186	4.935	0.089	8.195	506	4820
Mean	0.904	1.528	5.914	0.105	8.451	466	5668
w/o 1987	1.054	1.738	6.385	0.123	9.300	508	6175

*No April sampling, estimates therefore biased.

larvae to age at sexual maturity which occurs at about age 2 (R. Lawton, MDMF, personal communication).

Assuming all labrid eggs were cunner eggs in PNPS entrainment samples (Scherer 1984), cunner larvae:egg ratios were determined from PNPS samples to provide an estimate of survival from egg to larva. From 1988-1993 the ratio averaged 0.0318; 1987 was excluded because of plant shutdown. Since fecundity has apparently not been studied for cunner (Auster 1989), a value of 100,000 was assumed for average lifetime fecundity of an age 2 female. These two values provided a larva-to-adult survival rate of 0.00063. Applying the egg-to-larva and larva-to-adult survival rates to the numbers entrained produced an estimated loss of 60,819 adults for 1993. This compares with estimates of 17,663 to 94,686 equivalent adults (mean = 55,627) over the 1987-1992 period (Table 3).

Cunner have no commercial value and little recreational importance (although many may be taken unintentionally by shore fishermen) so that current landing records are not available. To shed some light on their abundance in the PNPS area, calculations were performed to estimate the number of adult cunner which would be necessary to produce the number of eggs found there. The PNPS area was defined by Cape Cod Bay sampling stations 2,3,4,7,8 (MRI 1978), the half-tide volume of which was estimated by planimetry from NOAA chart 1208 at 22,541,000 100 m^3 units. Labrid egg densities were obtained at those stations on a weekly basis in 1975; they were integrated over time (April-December) using the mean density of the five stations. The integrated values were

Table 3. Numbers of cunner eggs and larvae entrained at PNPS annually, 1987-1993. Number of equivalent adult fish is also shown for each year.

Year	Total Number Entrained ($x10^6$) Eggs	Larvae	Equivalent Adults
1987	3601.26	0.75	67,178
1988	1241.20	6.52	26,285
1989	3604.37	44.18	88,950
1990	1077.46	149.40	94,686
1991	544.36	15.13	17,663
1992	1753.76	2.57	33,815
1993	2609.12	13.57	60,819
Mean	1970.40	36.42	54,763

multiplied by 1.6 to account for extrusion through the 0.505-mm mesh used in that survey (MRI unpublished), then by the sector volume. The resulting value was divided by 2.2, the estimated incubation time in days for cunner eggs (Johnsen 1925), then divided by 30,000, an estimate of mean annual fecundity per female. Lastly the resulting value was multiplied by 2 assuming an even sex ratio. These calculations resulted in an estimated production of 6.899E-12 eggs and 9,064,000 adult fish. The mean loss of 54,763 fish represents 0.03% of that value.

Atlantic mackerel. Procedures outlined by Vaughan and Saila (1976) were used to derive a survival rate for mackerel eggs to age 1 fish (2.952E-6). Using the observed ratio of eggs to larvae for PNPS of 0.0338 (1988-1993), a larva-to-age 1 survival rate of 8.734E-5 was calculated. Age-specific fecundity and instantaneous mortality necessary for these calculations was obtained from Griswold and Silverman (1992), Overholtz et al. (1988), and NOAA (1991). According to NOAA (1991) stock biomass consists of fish age 1 and older while fish completely recruit to the spawning stock by age 3. Therefore, adult equivalent values are shown for both age groups (Table 4).

Values for 1993 amounted to 5475 age 1 fish and 3526 age 3. These compare with an average of 6807 and 4384 age 1 and age 3, respectively, over the 1987 through 1992 period.

According to NOAA statistical records, an annual average of 388,266 pounds (S.E. = 157,076) of mackerel were taken commercially from statistical area 514 over the years 1987-1992. Converting the

Table 4. Numbers of Atlantic mackerel eggs and larvae entrained at PNPS annually, 1987-1993. Numbers of equivalent age 1 and 3 fish are also shown for each year.

Year	Total Entrained ($x10^6$) Eggs	Larvae	Equivalent Adults Age 1	Age 3
1987	75.094	0.281	246	159
1988	2378.222	3.401	7318	4713
1989	4173.139	65.562	18045	11621
1990	2065.550	46.273	6502	4187
1991	428.358	66.009	7030	4527
1992	337.152	8.086	1702	1096
1993	1608.374	8.326	5475	3526
Mean	1580.84	28.28	6617	4261

seven-year average equivalent adult values to weight based on 0.2 and 0.7 pounds per individual (Clayton et al. 1978) results in estimated losses of 1323 or 2983 pounds amounting to 0.3% and 0.8% of the commercial landings.

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

If entrainment of ichthyoplankton at PNPS represented a significant source of mortality in western Cape Cod Bay, the losses might be reflected in finfish collections in the PNPS area. A

review of indices of relative abundance for some species based on otter trawl and gill net sampling by Massachusetts Division of Marine Fisheries personnel (Lawton et al. 1990; V.J. Malkoski, personal communication) does not indicate any long-term steady declines among Atlantic herring, pollock, or tautog. Several species, on the other hand, have displayed recent declines in abundance. These include cunner, windowpane (Scophthalmus aquosus), yellowtail flounder, and winter flounder (Lawton et al. 1993).

Cunner in gill net collections have, over the past seven years (1986-1992), declined by 70% from the mean of the previous eight years. Likewise, windowpane catch per unit effort, based on trawl samples, declined 98% from 1986 through 1991 and winter flounder, 93% over the same period. Commercial landings, stock assessment research, and other coastal monitoring studies suggest that these declines, particularly in the case of windowpane and flounder, are widespread, extending all along the Massachusetts coastline (MDMF 1985, Foster 1987, Howe et al. 1992, NOAA 1993, NEP and MRI 1994). Therefore these specific delines appear to be the result of natural population variation coupled with overexploitation. Record low levels of winter flounder and the downward trend in cunner have stimulated renewed examinations of the role that entrainment might play both in the decline of these stocks and the rate at which they can rebuild with reductions in exploitation. For this reason a PNPS-organized workshop was held in early 1994 to discuss revisions

to the ecological monitoring program which might best address these concerns.

D. Relationship Between Entrainment Densities and Circulating Water Volume

During recent years the apparent influence of different PNPS pump regimes on densities of ichthyoplankton have been compared, results strongly suggesting that larvae and to a lesser extent eggs are entrained in direct proportion to incremental changes in plant pumping rates (see MRI 1987-1992).

Mean densities per 100 m^3 of water for total eggs and total larvae, May-July 1983-1992 were examined using a nonparametric, single classification, Kruskal-Wallis test (see below for contribution of 1993 to this analysis). For this test individual sampling dates were used in a balanced design with four pump regimes (both main circulating water system (CWS) pumps = 19.56 m^3 per second, 1 CWS pump = 9.78 m^3 per second, 2 salt service water system (SSWS) pumps = 0.32 m^3 per second, and 1 SSWS pump = 0.16 m^3 per second). Comparisons were restricted to the May-July period because the four pump regimes overlapped only during those months.

No significant difference was apparent among years for eggs ($p > 0.05$) but a very highly significant difference ($p < 0.001$) was found for larvae. Nonparametric multiple comparisons among years for larvae showed years falling into five groups. No significant difference ($p > 0.05$) was apparent among 1990, 1989, 1985, and 1983, the four years when the circulating water system operated at full capacity for all or a good portion of the season. Signifi-

cantly different from this group ($p < 0.05$) was a second composed of 1992, 1991, and 1986. With the exception of 1992 this group consisted of years when one CWS pump was out of service. Data for 1988 (1 CWS pump) fell between those two groups. The last two groups consisted of 1984, the two SSWS year, and 1987, the one SSWS year, both significantly different from the two and one CWS pump groups ($p < 0.05$) and from each other ($p < 0.001$). The summed ranks as well as results of the multiple comparisons (indicated by vertical bars) were as follows:

May-July 1983-1992			
RANK SUM EGGS	PUMPS	RANK SUM LARVAE	PUMPS
1989 - 768	(ALL or 1 CWS O.O.S.)	1990 - 850	(ALL)
1988 - 741	(1 CWS O.O.S.)	1989 - 820	(ALL or 1 CWS O.O.S.)
1985 - 655	(ALL)	1983 - 748	(ALL)
1983 - 639	(ALL)	1985 - 705	(ALL)
1990 - 615	(ALL)	1988 - 638	(1 CWS O.O.S.)
1986 - 556	(1 CWS O.O.S.)	1986 - 537	(1 CWS O.O.S.)
1992 - 550	(ALL)	1992 - 532	(ALL)
1987 - 501	(1 SSWS)	1991 - 520	(1 CWS O.O.S.)
1991 - 442	(1 CWS O.O.S.)	1984 - 395	(2 SSWS)
1984 - 420	(2 SSWS)	1987 - 142	(1 SSWS)
10.09 n.s.	Kruskal-Wallis Coefficient		37.26*** ($p < 0.001$)

O.O.S. = Out Of Service

The fact that 1989 ranked second overall for the May-July period in spite of the six dates when one CWS pump was out of

service, suggests that in general larvae were relatively abundant during that period. In contrast, the relatively low ranking of 1992, an all pump operational year, suggests larval densities were low at that time. The May-July 1991 period ranked low also, lowest among the 1 CWS pump years. A review of monthly densities in Apendix B indicates that larval densities overall were noticeably low in July 1991 and 1992 due to relatively low numbers of rockling, cunner, and mackerel. High densities in 1989 appeared to be due to cunner and mackerel.

Figure 3 presents the monthly means averaged within pump operation categories for the April-August time frame. Data for May-August 1990 were averaged with the corresponding data from 1983 1985, and 1992, the years of full operation. Data for April 1990 when only one CWS pump was in service were averaged with April 1986 and 1988. Similarly April and August 1991 were averaged with 1983, 1985, 1990, and 1992 when all pumps operated; May, June, July were averaged with 1986 and 1988, periods with one CWS pump. Larval densities separated distinctly, particularly when sampling occurred only with one or two salt service water pumps. Data for 1989 with mixed pump usage varied between the all and one CWS pump regimes but in a consistent manner. June and August with all pumps in service during each sampling period ranked above the other years. May and July with two of five and one of four dates with all pumps in service, respectively, showed monthly means which fell between the all and one CWS pump values. April, also having one of four dates with all pumps operating, fell below the one and all CWS pump category but well above the two SSWS pumps mean for that month.

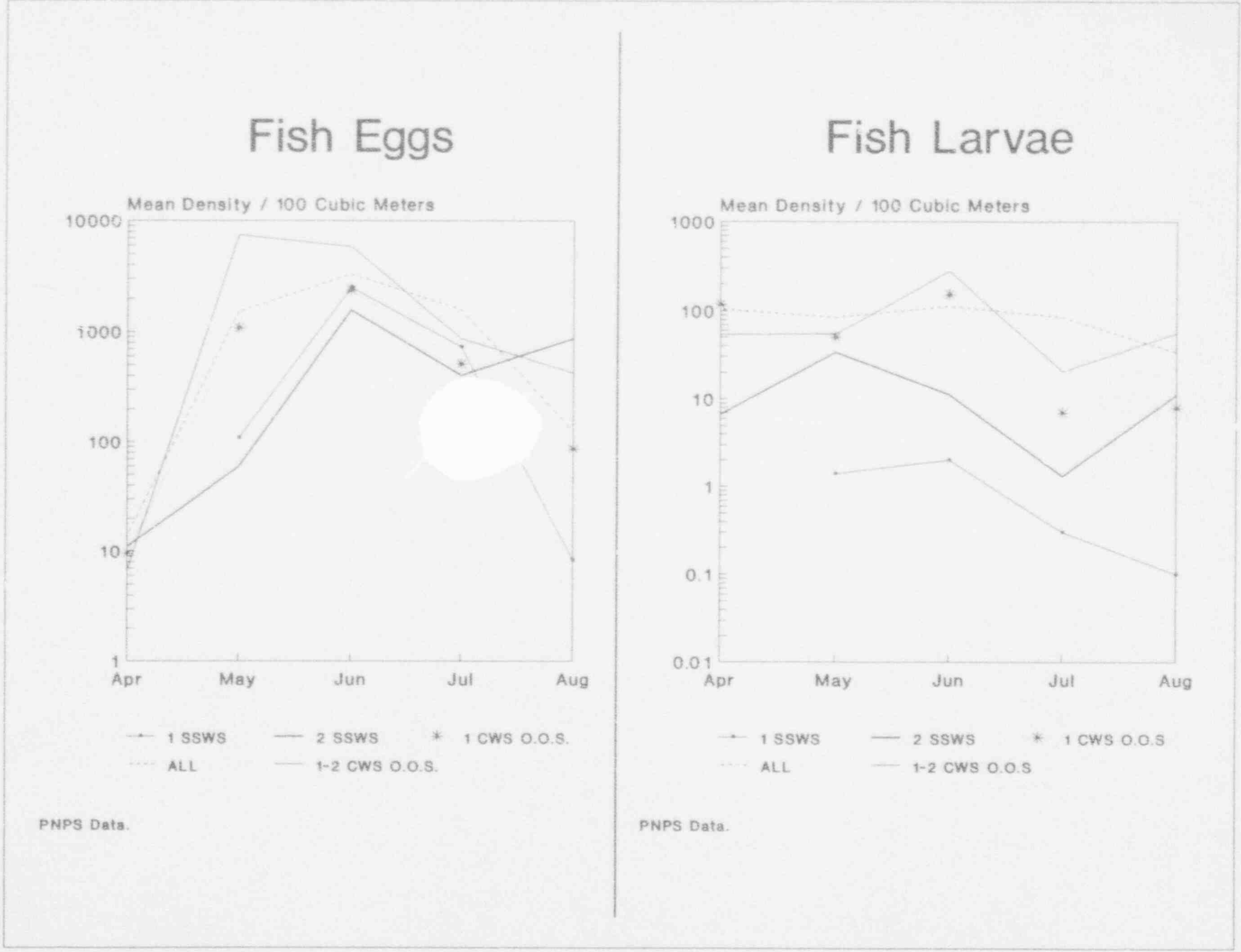

Figure 3. Mean monthly densities per 100 m^3 of water for total eggs and total larvae entrained at PNPS within four pump operation categories during the April-August period of 1983-1992. See text for details.

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

A comparison of the number of ichthyoplankton species recorded from May through July over the 1983-1992 period indicated that 1987, with one SSWS pump operating, was clearly the lowest with 13 overall (22 with inclusion of the three dates when one CWS pump was in use); 1984 (2 SSWS pumps) followed with 25. Numbers of species ranged from 29 (1986) to 34 (1989) during years when at least one CWS pump was in use. The low species count in 1987 was due primarily to a scarcity of larvae (Figure 4). Only six species of larvae were recorded over the May-July period of 1987 compared with 16 (1984) to 30 (1985, 1989) over the other years. Omitting 1984 when both CWS pumps were off, raises the

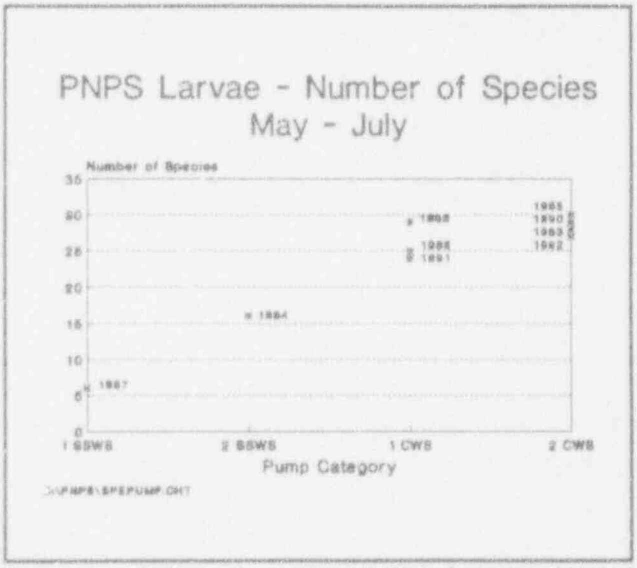

Figure 4. Number of species of fish larvae collected within four pump operation categories at PNPS, May-July 1984-1992.

low end larval species count from 16 to 24 (1991). Numbers of egg species were somewhat more consistent with 12 being taken in 1987 compared with 14 (1988) to 20 (1991) during the other years. Including May 30 and June 25, 1987 when a single CWS pump was in service brought the 1987 totals up to 14 species of eggs and 14 species of larvae.

Collections made in 1993 did not lend themselves to be included in these analyses since any one of the four pump regimes was not maintained over the May-July period. However, a single set of triplicates was taken on May 12, 1993 when only two SSWS pumps were in operation. On May 14 another set was taken with one CWS pump operating. Total larval densities averaged 15 per 100 m^3 over two species on the 12th, 23 per 100 m^3 over seven species on May 14. These data are consistent with results from May 1987.

The low densities of larvae in 1984 and the strikingly low densities in 1987 over the spring and early-summer period strongly suggest that ichthyoplankton populations near PNPS were not impacted in similar proportion by the SSWS pumps as by the main circulating seawater pumps. A sharp decline in larval densities occurred between 1984 (16) and 1987 (6), suggesting that dropping from two to one SSWS pump eliminated entrainment of many larvae.

E. <u>Lobster Larvae</u>

With only 12 individuals being taken in 20 years of entrainment sampling, the scarcity of larval lobsters (<u>Homarus americanus</u>) in PNPS entrainment samples remains a perplexing issue. Neuston sampling conducted in the northwest sector of Cape Cod Bay (Lawton

et al. 1983; Matthiessen and Scherer 1983) also indicated that larvae were not particularly abundant there. According to Massachusetts Division of Marine Fisheries lobster statistics, annual landings in Plymouth County by fishermen working inshore waters have averaged 1368 tons annually from 1985-1992 (see McCarron and Hoopes 1993 for example). Commercial and recreational lobster fishing in the Pilgrim area is considered intense (Lawton et al. 1993). To support such a strong fishery it would appear young lobsters must arrive in the Plymouth area from other regions. Sampling around Rocky Point from 1974 through 1977 showed considerably more late-stage larvae than young larvae (Lawton et al. 1983). That, coupled with the prevailing counterclockwise Cape Cod Bay currents, suggests that larvae may arrive from the north. Sampling at the mouth of the Cape Cod Canal also suggests that large numbers of larvae enter Cape Cod Bay from Buzzards Bay and perhaps the Canal itself (Matthiessen and Scherer 1983; Matthiessen 1984). Regardless of source, larval lobsters appear to be especially uncommon in PNPS entrainment samples. This is supported by Lawton et al. (1983) who caught only eight larvae in twenty neuston tows near shore around Rocky Point in 1975. In addition to their apparent scarcity in near-shore waters, larval lobsters' neustonic habits may reduce the probability of their entrainment since they would contact the PNPS intake skimmer wall which might prevent some from passing to the condensers. Reduced intake flow during the summer of 1984, and the extended outage period covering the 1986-1989 larval seasons no doubt lowered the probability of lobster entrainment even further at least during those periods.

SECTION IV

HIGHLIGHTS

1) Atlantic menhaden eggs meeting the unusually abundant criteria established for PNPS occurred in late September. Production of menhaden eggs in nearshore western Cape Cod Bay was apparently strong in the fall of 1993.
2) Total number of eggs and larvae which may have been entrained by PNPS in 1993 were estimated to range from 1,189,000 for the cod/witch flounder egg group to 2,609,000,000 for tautog/cunner eggs and from 1,405,000 for Atlantic herring to 46,668,000 for sand lance larvae.
3) Annual adult equivalent estimates for potential PNPS ichthyoplankton entrainment losses to cunner and Atlantic mackerel populations from 1987 to 1993 averaged 54,763 and 6617 fish, respectively. Similar calculations for winter flounder using two sets of survival values produced estimates of 508 and 6175 fish.
4) Analysis of entrainment data collected from April through August 1983-1992 strongly suggests that larvae and to a lesser extent eggs are entrained in direct proportion to incremental changes in plant pumping rates. Very limited comparable data available from 1993 support these results.
5) A single lobster larva collected in 1993 brought the total number collected at PNPS to 12 over a 20-year period. Available data suggest that young lobster arrive in the PNPS area from the north.

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IMPINGEMENT OF ORGANISMS AT
PILGRIM NUCLEAR POWER STATION
(January - December 1993)

Prepared by: [signature]

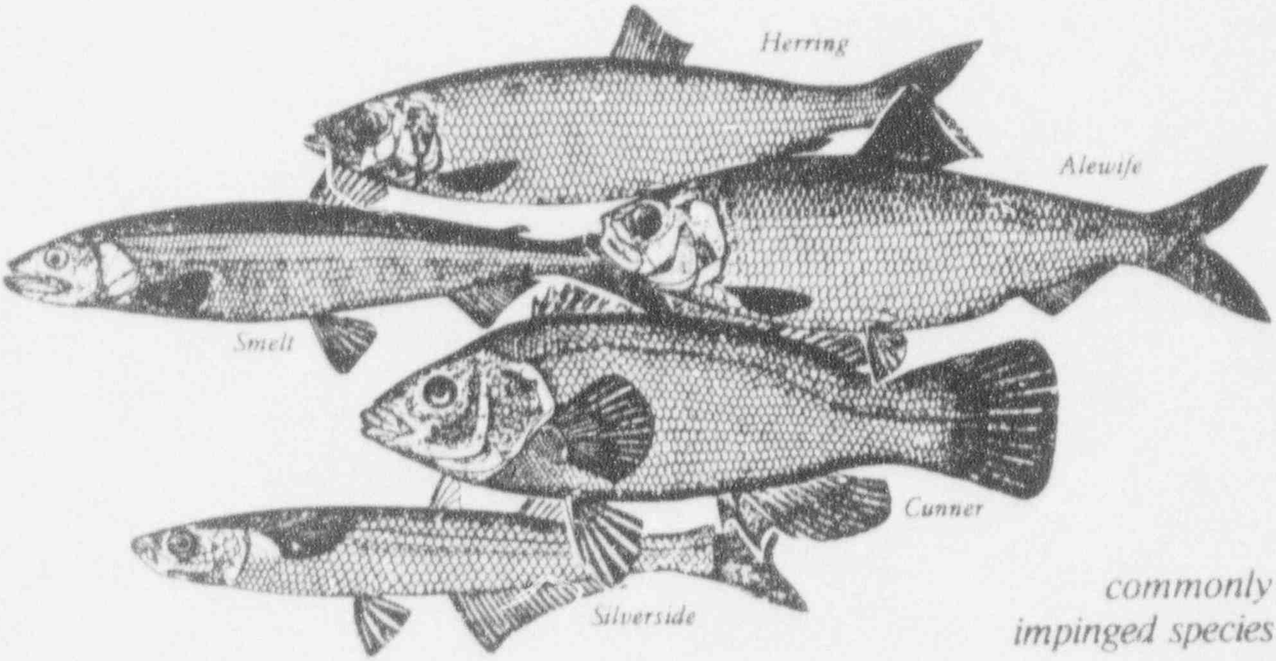
Robert D. Anderson

Principal Marine Biologist

Licensing Division

Boston Edison Company

April 1994



commonly impinged species

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SECTION I

SUMMARY

Fish impingement rate averaged 2.78 fish/hour during the period January-December 1993, which is several times higher than 1992 because of a large impingement incident. Rainbow smelt (Osmerus mordax) accounted for 39.2% of the fishes collected followed closely by Atlantic silverside (Menidia menidia) at 38.4%. Winter flounder (Pleuronectes americanus), Alewife (Alosa pseudoharengus) and grubby (Myoxocephalus aeneus) accounted for 4.8, 2.8 and 2.7%, respectively, of the fishes impinged. The peak period was December 15-28 when a large fish impingement incident was dominated by an estimated 5,100 rainbow smelt on the intake screens. Initial impingement survival for all fishes from static screen wash collections was approximately 57%, and from continuous screen washes 88%.

At 100% yearly (January-December) operation of Pilgrim Nuclear Power Station (PNPS) the estimated annual impingement was 24,375 fishes (512 lbs.). The PNPS capacity factor was 74.0% during 1993.

The collection rate (no./hr.) for all invertebrates captured from January-December 1993 was 0.97+. Ctenophores were most numerous. Sevenspine bay shrimp (Crangon septemspinosa), rock crab (Cancer irroratus) and American lobster (Homarus americanus) accounted for 19.9+, 17.1 and 13.9%, respectively, of the invertebrates impinged. Mixed species of algae collected on intake screens amounted to 8,029 pounds.

SECTION 2

INTRODUCTION

Pilgrim Nuclear Power Station (lat. 41°56′ N, long. 70°34′ W) is located on the northwestern shore of Cape Cod Bay (Figure 1) with a licensed capacity of 670 MWe. The unit has two circulating water pumps with a capacity of approximately 345 cfs each and five service water pumps with a combined capacity of 23 cfs. Water is drawn under a skimmer wall, through vertical bar racks spaced approximately 3 inches on center, and finally through vertical travelling water screens of 3/8 inch wire mesh (Figure 2). There are two travelling water screens for each circulating water pump.

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

This report is based on data collected from screen wash samples during January-December 1993.

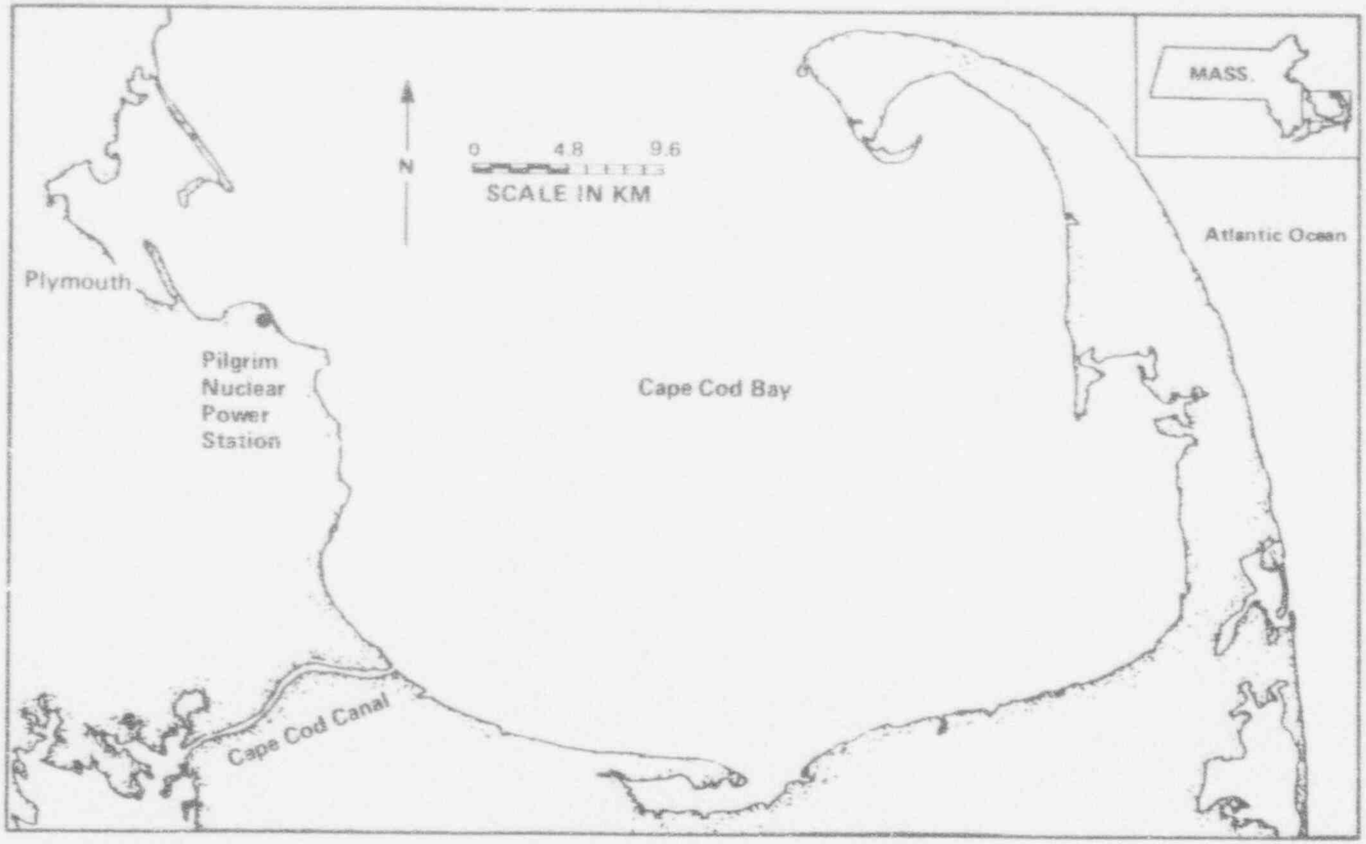

Figure 1. Location of Pilgrim Nuclear Power Station.

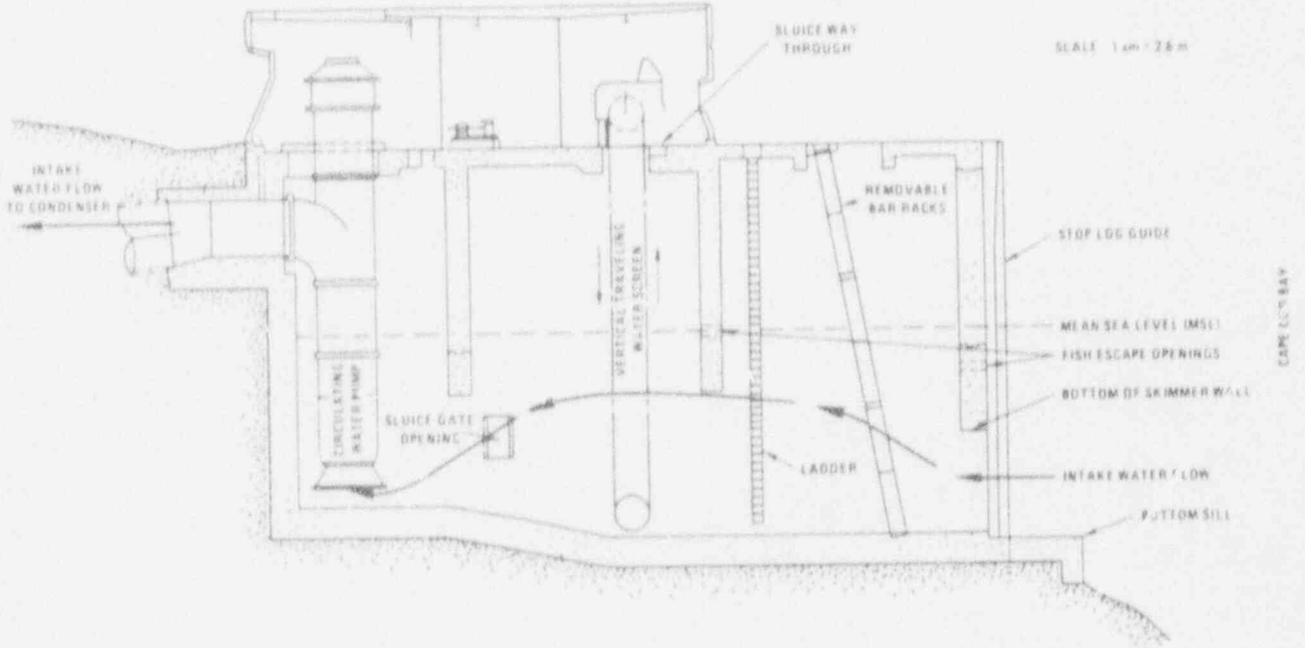

Figure 2: Cross-section of intake structure of Pilgrim Nuclear Power Station.

SECTION 3

METHODS AND MATERIALS

Three screen washings each week were performed from January-December 1993 to provide data for evaluating the magnitude of marine biota impingement. The total weekly collection time was 24 hours (three separate 8-hour periods: morning, afternoon and night). Two collections represented dark period sampling and one represented light period sampling. At the beginning of each collection period, all four travelling screens were washed. Eight hours later, the screens were again washed (minimum of 30 minutes each) and all organisms collected. When screens were being washed continuously, one hour collections were made at the end of the regular sampling periods, and they represented two light periods and one dark period on a weekly basis.

Water nozzles directed at the screens washed impinged organisms and debris into a sluiceway that flowed into a trap. The original trap was made of galvanized screen (3/8-inch mesh) attached to a removable steel frame and it collected impinged biota shortly after being washed off the screens. A second trap was designed and used for sampling 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. Initial fish survival was determined for static (8-hour) and continuous screenwash cycles. Plates 1 and 2 provide views of the beginning and end of the sluiceway structure which was constructed in 1979.

Variables recorded for organisms were total numbers, and individual total lengths (mm) and weights (gms) for up to 20 specimens of each species. A

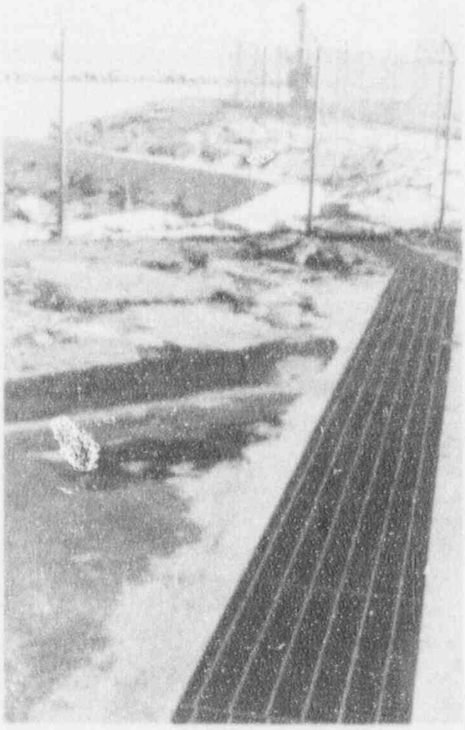

Plate 1. The 300 foot long Pilgrim Station, concrete screenwash sluiceway is molded from 18" corrugated metal pipe, and meanders over breakwater rip rap.

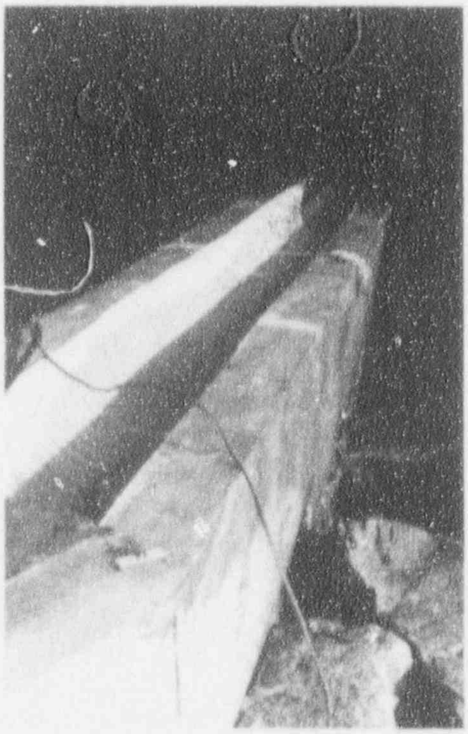

Plate 2. Fish survival testing is done at the end of the sluiceway where it discharges to ambient temperature intake waters.

random sample of 20 fish or invertebrates was taken whenever the total number for a species exceeded 20; if the total collection for a species was less than 20, all were measured and weighed. Field work was conducted by Marine Research, Inc.

Intake seawater temperature, power level output, tidal stage, number of circulating water pumps in operation, time of day and date were recorded at the time of collections. The collection rate (#/hour) was calculated as number of organisms impinged per collecting period divided by the total number of hours in that collecting period. Beginning in 1990, if all four intake screens are not washed for a collecting period then the number of fishes collected is increased by a proportional factor to account for the unwashed screens, as requested by the Pilgrim Administrative-Technical Committee. Common and scientific names in this report follow the American Fisheries Society (1988, 1989, 1991a and 1991b) or other accepted authority when appropriate.

SECTION 4

RESULTS AND DISCUSSION

4.1 Fishes

In 673.5 collection hours, 1,874 fishes of 38 species (Table 1) were collected from Pilgrim Nuclear Power Station intake screens during January - December 1993. The collection rate was 2.78 fish/hour. This annual impingement rate is several times higher than last year, primarily because of a large impingement incident of an estimated 7,900 fishes, primarily rainbow smelt (Osmerus mordax), from December 15-28, 1993. Rainbow smelt was the most abundant species in 1993, accounting for 39.2% of all fishes collected, followed closely by Atlantic silverside (Menidia menidia) at 38.4% (Table 2). Winter flounder (Pleuronectes americanus), alewife (Alosa pseudoharengus) and grubby (Myoxocephalus aeneus) accounted for 4.8, 2.8 and 2.7% of the total number of fishes collected and identified to lowest taxon.

Rainbow smelt occurred most predominantly in monthly samples from December. Hourly collection rates per month for them ranged from 0 to 9.9. Rainbow smelt impinged in December accounted for 91% of all this species captured in impingement collections from January-December 1993. They averaged 124 mm total length and 12 grams in weight. Their impingement indicated no relationship to tidal stage or diel factors. It is somewhat unusual for them to be the dominant fish in the annual impingement catch, the only other years in which they dominated were 1987 and 1978 when there was also a large smelt December impingement incident. A review of historical data shows them to be impinged in greatest numbers during late fall/early winter when they were well represented in 1993. Some other relatively abundant species impinged at Pilgrim Station over the past 10 years are also documented in Table 3.

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

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IMAGE EVALUATION
TEST TARGET (MT-3)

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IMAGE EVALUATION TEST TARGET (MT-3)

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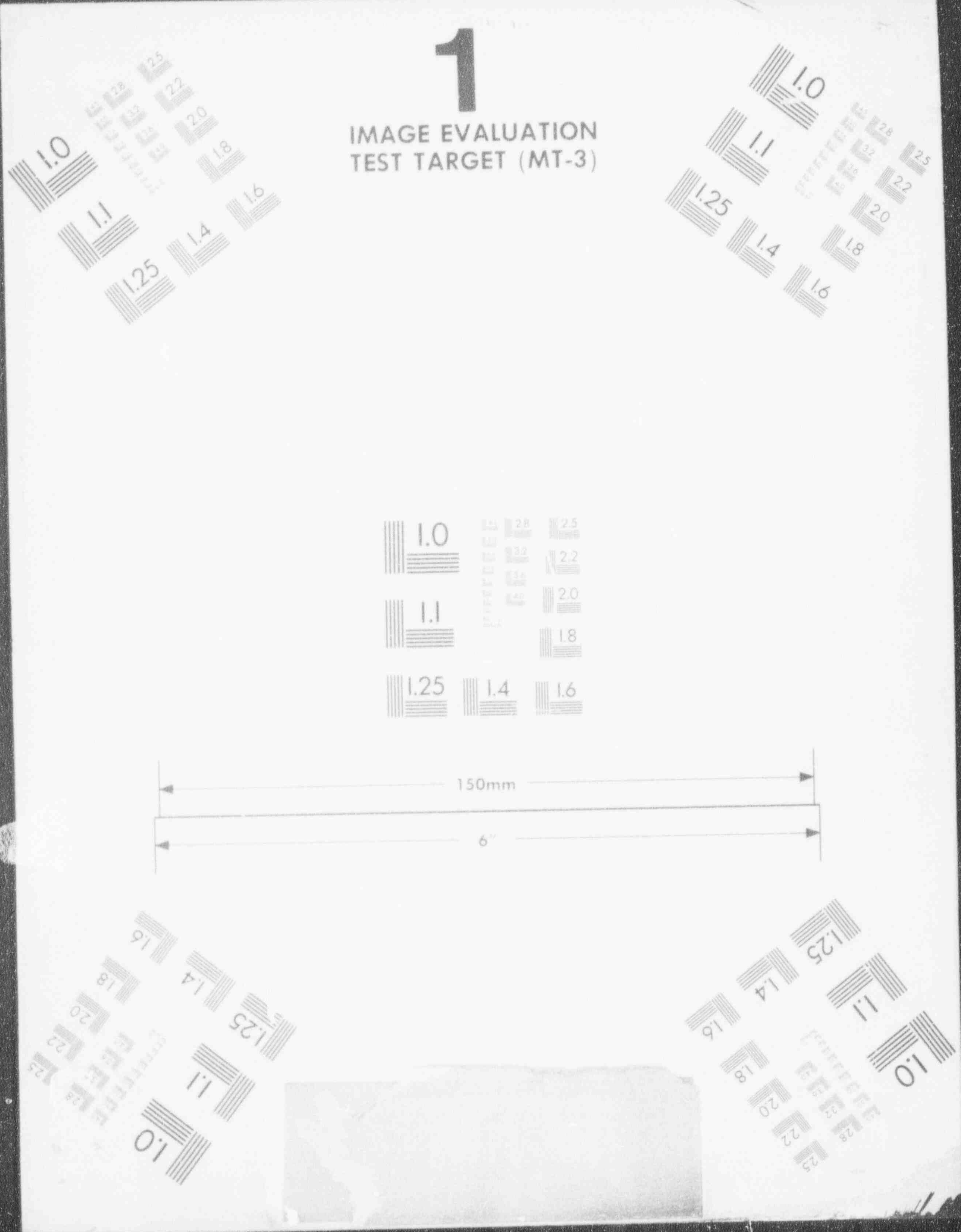
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2.8
3.2
150mm
6"

Table 1. Monthly Impingement For All Fishes Collected From Pilgrim Station Intake Screens, January-December 1993

Species	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals
Rainbow smelt	23	11	16	7		1			1		6	670	735
Atlantic silverside	58	7	381	55						5	2	212	720
Winter flounder	6	14	20	5				5		2	4	34	90
Alewife	1	1	2	22	4	2		4	3		10	3	52
Grubby	5	6	9	2				1		1	2	25	51
Lumpfish	4			7	2						1	22	36
Atlantic tomcod	1				2				2	1	10	10	26
Blueback herring			1	1						1	6	16	25
Tautog				1							10	12	23
Atlantic herring					3	1					2	4	10
Little skate					2			2	3	3			10
Windowpane					1	1		1	1			6	10
Northern pipefish				1				1		1	3	3	9
Rock gunnel				7			1					1	9
Cunner			3						1	2	2		8
Hake spp.						4	2	1		1			8
Pollock					2	3					1		6
Red hake								1			5		6
Atlantic cod							1				2	1	4
Atlantic menhaden	1								2			1	4
Northern searobin						4							4
Radiated shanny		1	1	1								1	4
Threespine stickleback			1								1	2	4
Silver hake										1	2		3
Blackspotted stickleback	1		1										2
Pearlside	2												2
Striped killifish									1		1		2
Butterfish									1				1
Fourspot flounder						1							1
Mummichog												1	1
Northern puffer									1				1
Scup										1			1
Shorthorn sculpin												1	1
Spiny dogfish										1			1
Spot										1			1

(cont)...

Table 1. Monthly Impingement For All Fishes Collected From Pilgrim Station Intake Screens, January-December 1993

Species	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct	Nov.	Dec.	Totals
Strined cusk-eel				1									1
Striped searobin											1		1
Yellowtail flounder				1									1
TOTALS	102	40	435	111	16	17	4	16	16	21	71	1,025	1,874
Collection Time (hrs.)	66	47	54	27	25	60	59	55	61	89	62	67.5	673.5
Collection Rate (#/hr.)	1.55	0.85	8.05	4.11	0.64	0.28	0.07	0.29	0.26	0.24	1.15	15.19	2.78

Table 2. Species, Number, Total Length(mm), Weight(gms) and Percentage For All Fishes Collected From Pilgrim Station Impingement Sampling, January-December 1993

Species	Number	Length Range	Mean Length	Weight Range	Mean Weight	Percent of Total Fish
Rainbow smelt	735	70-291	124	2-75	12	39.2
Atlantic silverside	720	67-137	99	2-12	4	38.4
Winter flounder	90	43-322	97	1-219	13	4.8
Alewife	52	62-265	111	2-199	16	2.8
Grubby	51	38-130	71	1-30	6	2.7
Lumpfish	36	36-101	52	2-48	8	1.9
Atlantic tomcod	26	51-207	133	1-76	22	1.4
Blueback herring	25	65-108	85	2-9	4	1.3
Tautog	23	48-97	66	2-14	5	1.2
Atlantic herring	10	37-272	125	0.2-100	25	0.5
Little skate	10	330-507	464	-	-	0.5
Windowpane	10	58-301	148	2-112	31	0.5
Northern pipefish	9	106-188	145	0.4-3	1	0.5
Rock gunnel	9	68-110	87	1-3	2	0.5
Cunner	8	48-165	92	2-75	17	0.4
Hake spp.	8	62-188	84	2-43	7	0.4
Pollock	6	67-390	128	2-621	107	0.3
Red hake	6	80-197	136	4-60	23	0.3
Atlantic cod	4	87-150	124	5-27	16	0.2
Atlantic menhaden	4	95-328	213	8-488	209	0.2
Northern searobin	4	210-223	215	74-100	81	0.2
Radiated shanny	4	67-112	84	2-11	5	0.2
Threespine stickleback	4	37-60	54	1-2	2	0.2
Silver hake	3	210-285	254	58-110	75	0.2
Blackspotted stickleback	2	42-43	43	1	1	0.1
Pearlside	2	49-50	50	1	1	0.1
Striped killifish	2	68-92	80	3-9	6	0.1
Butterfish	1	94	94	7	7	0.1
Fourspot flounder	1	321	321	253	253	0.1
Mummichog	1	98	98	12	12	0.1
Northern puffer	1	80	80	24	24	0.1
Scup	1	90	90	13	13	0.1
Shorthorn sculpin	1	220	220	190	190	0.1
Spiny dogfish	1	910	910	-	-	0.1
Spot	1	101	101	13	13	0.1
Striped cusk-eel	1	130	130	11	11	0.1
Striped searobin	1	52	52	2	2	0.1
Yellowtail flounder	1	58	58	2	2	0.1

Atlantic silverside were very abundant in the March and December impingement collections and have been most prevalent in the early spring period in the past, ranking first in 9 out of the last 13 years in total numbers impinged. It has been common for them to rank highly in impingement (Table 3).

Winter flounder were relatively prevalent in December-March samples, possibly indicative of this species seasonal inshore spawning movements. It has been one of the more commonly impinged fish over the years.

Alewife occurred predominantly in April when 38% of them were sampled, not reflecting this species historical nature of maximum impingement in the summertime. It has been one of the most impinged fish, although not dominating the annual catch.

Grubby were impinged most in the winter and have historically been collected in relatively low numbers, although its year-round presence in the Pilgrim Station area is apparent. Monthly intake water temperatures and impingement rates for the five dominant species in 1993 are illustrated in Figure 3.

There were a couple of small, fish impingement incidents (20 fish or greater/hr.) at Pilgrim Station in 1993 (March 27 and April 3) when mostly Atlantic silversides were recorded, but their impingement rate rapidly decreased upon subsequent sampling, indicating minimal impact. There was a large, fish impingement incident (1,000 fish or greater) from December 15-28 when a rate of 25.38 fishes (16.78 smelt)/hour was recorded. Approximately 5,100 rainbow smelt, mostly juveniles (mean length 116 mm), were estimated impinged and killed during this incident. A total of 7,900 fishes were

Table 3. Annual Impingement collections (1984 -1993) For the 10 Most Abundant Fishes From Pilgrim Station Intake Screens During January - December 1993

Number of Impinged Fishes Collected From January - December

Species	1984*	1985	1986	1987**	1988***	1989	1990	1991	1992	1993	Totals
Rainbow smelt	5	8	278	41	11	39	38	41	25	735	1,221
Atlantic silverside	22	174	44	27	35	120	457	275	232	720	2,106
Winter flounder	5	39	76	10	11	42	31	67	72	90	443
Alewife	12	37	25	4	8	8	131	24	22	52	323
Grubby	15	36	30	5	5	29	59	46	43	51	319
Lumpfish	13	5	5	10	8	3	8	5	10	36	103
Atlantic tomcod	12	18	16	5	31	17	26	16	11	26	178
Blueback herring	5	17	5	1	2	15	103	31	11	25	215
Tautog	2	2	2	5	2	12	6	18	9	23	81
Atlantic herring	0	2	346	1	2	16	35	2,370	3	10	2,785
Totals	91	338	827	109	115	301	894	2,893	438	1,768	7,774
Collection Time (hrs)	1,042	465	806	527	525	618	919.5	501.25+	774	673.5	6,851.25+
Collection Rate (#/hr)	0.09	0.73	1.03	0.21	0.22	0.49	0.97	5.77	0.57	2.63	1.13

*No CWS pumps were in operation 29 March - August 1984.
**No CWS pumps were in operation 18 February - 8 September 1987.
***No CWS pumps were in operation 14 April - 5 June 1988.

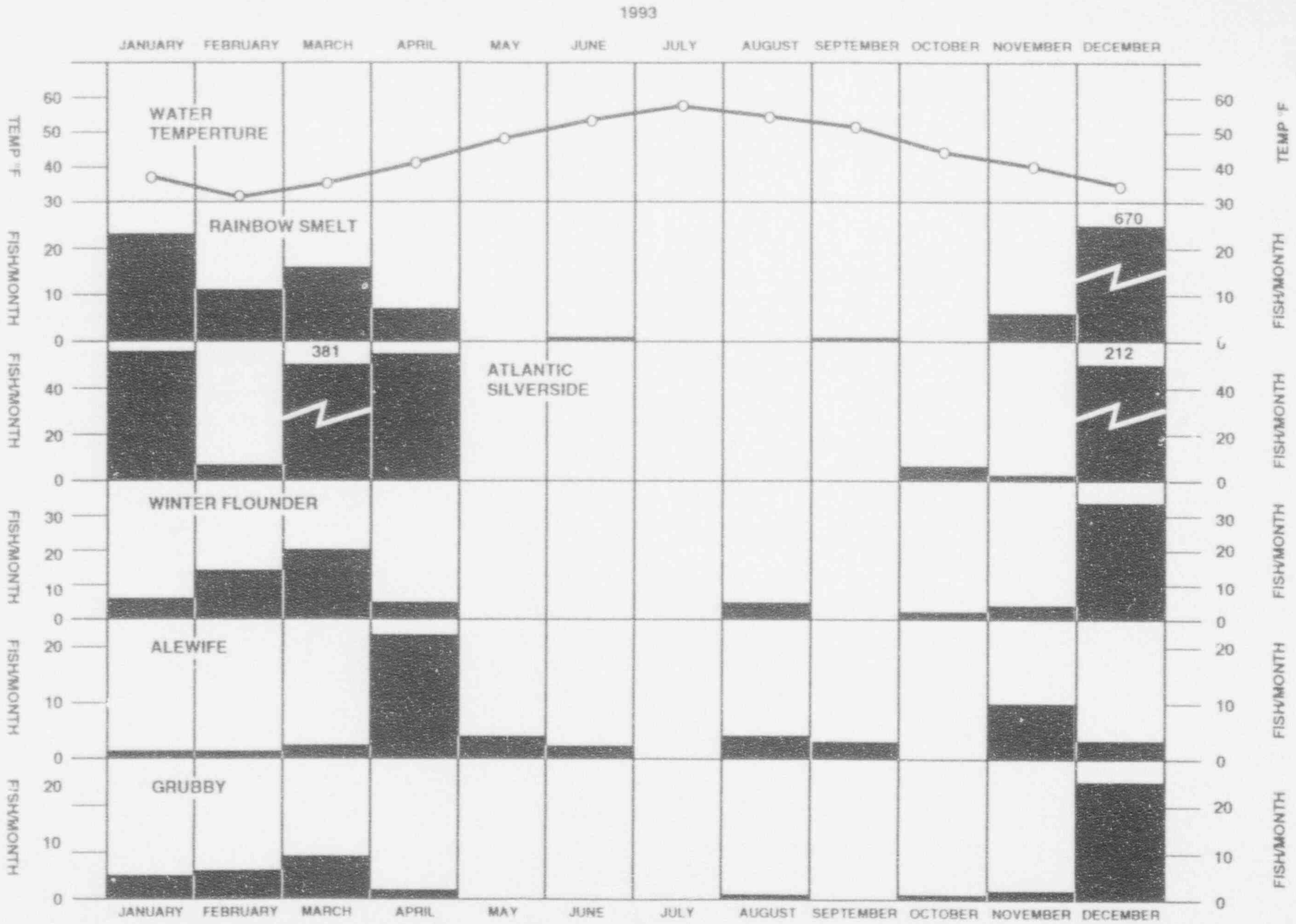

Figure 3. Trends of Intake Water Temperature, and Number of Fish Captured by Month from Pilgrim Station Intake Screens for the Five Most Abundant Species Collected, January-December 1993.

projected to be caught on intake screens with Atlantic silverside being a distant second to smelt in numbers impinged. Most large fish impingement mortalities have occurred while both circulating water pumps were operating, as in this case.

Twelve large fish incidents have been documented since Pilgrim operation commenced in 1973, and most (8) have involved impingement as the causative agent (Table 4). However, at least in two of these the possibility of pathological influence was implicated as indirectly contributing to the mortalities. They were the Atlantic herring (tubular necrosis) and rainbow smelt (piscine erythrocytic necrosis) impingement incidents in 1976 and 1978, respectively.

Fish impingement rate at Pilgrim Station has been shown to be significantly related to the number of circulating water pumps operating (Lawton, Anderson et al, 1984b). Reduced water pumping capacity has lowered total impingement, particularly during the April-mid-August 1984 and portions of the mid-February-August 1987 periods when no circulating water pumps were operating for extended time frames. The significance of this relationship is supported by the fact that total fish impingement and rate of fish impingement were several times lower in 1984 and 1988 (low-pump year) than in 1985, 1986 and 1989 - 1992, despite a greater number of collecting hours in 1984 and an average number of hours in 1988. In 1987, far fewer collecting hours were possib. hen both circulating pumps were off than in these other years which limits comparisons to them. However, total fish impingement rates in 1984, 1987 and 1988 were several times lower than in 1985, 1986 and 1989 - 1992 when at least one circulating pump was always in operation.

Table 4. Approximate Number and Cause for Dominant Species of Most Notable Fish Mortalities at Pilgrim Nuclear Power Station, 1973-1993

Date	Species	Number	Cause
April 9-19, 1973	Atlantic menhaden	43,000	Gas Bubble Disease
August/September, 1973	Clupeids	1,600	Impingement
April 2-15, 1975	Atlantic menhaden	5,000	Gas Bubble Disease
August 2 1975	Atlantic menhaden	3,000	Thermal Stress
August 5 19[illegible]	Alewife	1,900	Impingement
November 23-28, 1976	Atlantic herring	10,200	Impingement
August 21-25, 1978	Clupeids	2,300	Thermal Stress
December 11-29, 1978	Rainbow smelt	6,200	Impingement
March/April, 1979	Atlantic silverside	1,100	Impingement
September 23-24, 1981	Atlantic silverside	6,000	Impingement
July 22-25, 1991	Atlantic herring	4,200	Impingement
December 15-28, 1993	Rainbow smelt	5,100	Impingement

Projected fish impingement rates were calculated assuming 100% operation of Pilgrim Nuclear Power Station, under conditions at the times of impingement, during the period January-December 1993. Table 5 presents hourly, daily and yearly impingement rates for each species captured (rates are rounded to significant figures). For all fishes combined the respective rates were 2.78, 66.78 and 24,375. The yearly rate of 24,375 fishes impinged is 128% of the last 20-year (1974-1993) mean annual projection of 18,996 fishes (Table 6). This is the second highest, yearly fish impingement rate since 1981, and greatly exceeds the historical annual average as have other years in which large impingement incidents inflated yearly projections. Relatively high impingement rate years offset low impingement years, and they may be attributed to population variances of the dominant species and/or extreme meteorological conditions influencing species' behavior and vulnerability.

Over the past 20-year period (1974-1993), Pilgrim Station has had a mean impingement rate of 2.17 fishes/hr., ranging from 0.13 (1984) to 10.02 (1981) (Table 6). Anderson et al. (1975) documented higher annual impingements at seven other northeast power plants in the early 1970's. Maine Yankee Atomic Power Company (1978), at their Nuclear Generating Station, had a mean impingement rate of approximately 58 fishes/hr. from late 1972 - late 1977. Stupka and Sharma (1977) showed annual impingement rates at numerous power plant locations for dominant species and compared to these, rates at Pilgrim Station were lower than at most other sites. However, in terms of the number of fish species impinged, Pilgrim Station displays a far greater variety than other power plants in the Gulf of Maine area (Bridges and Anderson, 1984a), perhaps because of its proximity to the boreal-temperate zoogeographical zone presented to marine biota by Cape Cod.

Table 5. Impingement Rates Per Hour, Day and Year For All Fishes Collected From Pilgrim Station Intake Screens During January - December 1993. Assuming 100% Operation of Pilgrim Unit 1*

Species	Rate/Hr.	Rate/Day	Rate/January-December 1992*	Dominant Months Of Occurrence
Rainbow smelt	1.09	26.19	9,560	December
Atlantic silverside	1.07	25.66	9,365	March & December
Winter flounder	0.13	3.21	1,171	December & March
Alewife	0.08	1.85	676	April
Grubby	0.08	1.82	663	December
Lumpfish	0.05	1.28	468	December
Atlantic tomcod	0.04	0.93	338	November & December
Blueback herring	0.04	0.89	325	December
Tautog	0.03	0.82	299	November & December
Atlantic herring	0.01	0.36	130	May & December
Little skate	0.01	0.36	130	September & October
Windowpane	0.01	0.36	130	December
Northern pipefish	0.01	0.32	117	November & December
Rock gunnel	0.01	0.32	117	April
Cunner	0.01	0.28	104	March
Hake sp.	0.01	0.28	104	June
Pollock	0.009	0.21	78	May & June
Red hake	0.009	0.21	78	November
Atlantic cod	0.006	0.14	52	November
Atlantic menhaden	0.006	0.14	52	September
Northern searobin	0.006	0.14	52	June
Radiated shanny	0.006	0.14	52	March
Threespine stickleback	0.006	0.14	52	December
Silver hake	0.004	0.11	39	November
Blackspotted stickleback	0.003	0.07	26	January & March
Pearlside	0.003	0.07	26	January
Striped killifish	0.003	0.07	26	September & November
Butterfish	0.001	0.04	13	September
Fourspot flounder	0.001	0.04	13	June
Mummichog	0.001	0.04	13	December
Northern puffer	0.001	0.04	13	September
Scup	0.001	0.04	13	October
Shorthorn sculpin	0.001	0.04	13	December
Spiny dogfish	0.001	0.04	13	October
Spot	0.001	0.04	13	October
Striped cusk-eel	0.001	0.04	13	April
Striped searobin	0.001	0.04	13	November
Yellowtail flounder	0.001	0.04	13	April
Totals	2.78	66.78	24,375	

* Rates have been rounded to significant figures.

Table 6. Impingement Rates Per Hour, Day and Year For All Fishes Collected From Pilgrim Station Intake Screens During 1974-1993, Assuming 100% Operation of Pilgrim Unit I*

Year	Rate/Hr.	Rate/Day	Rate/Year	Dominant Species (Rate/Year)
1974	0.58	13.85	5,056	Clupeids** (4,542)
1975	0.19	4.54	1,659	Atlantic silverside (702)
1976	6.67	160.17	58,461	Atlantic herring (45,065)
1977	1.06	25.44	9,286	Atlantic silverside (2,735)
1978	4.04	97.03	35,416	Rainbow smelt (29,357)
1979	3.24	77.69	28,280	Atlantic silverside (20,733)
1980	0.66	15.78	5,769	Cunner (1,683)
1981	10.02	240.42	87,752	Atlantic silverside (83,346)
1982	0.93	22.39	8,173	Atlantic silverside (1,696)
1983	0.57	13.65	4,983	Atlantic silverside (1,114)
1984+	0.13	3.13	1,143	Atlantic silverside (185)
1985	1.14	27.46	10,022	Atlantic silverside (3,278)
1986	1.26	30.34	11,075	Atlantic herring (3,760)
1987+	0.28	6.74	2,460	Rainbow smelt (682)
1988+	0.27	6.48	2,372	Atlantic silverside (586)
1989	0.80	19.30	7,045	Atlantic silverside (1,701)
1990	1.70	40.74	14,872	Atlantic silverside (4,354)
1991	6.27	150.48	54,925	Atlantic herring (41,419)
1992	0.63	15.22	5,572	Atlantic silverside (2,633)
1993	2.78	66.78	24,375	Rainbow smelt (9,560)
Means	2.17	52.04	18,996	

*Rates have been rounded to significant figures.

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

+No CWS pumps were in operation 29 March - 13 August 1984, 18 February - 8 September 1987 and 14 April - 5 June 1988.

Monthly intake water temperatures recorded during impingement collections at Pilgrim Station were mostly colder during 1993 compared to the mean monthly temperatures for the 10-year interval 1984-1993 (Table 7). Only January water temperatures were higher than this 10-year period's monthly means.

Overall, 1983/1985/1986/1990 displayed relatively warm water temperatures, 1984/1987/1989/1991 were average years, and 1988/1992/1993 were cold water years. Pilgrim Station intake temperatures approximate ambient water temperatures. A dominance of cold water species (i.e., winter flounder, grubby and rainbow smelt) appeared at the top of impingement collections during 1993.

4.2 Invertebrates

In 673.5 collection hours, 654 invertebrates of 17 species (Table 8) were recorded from Pilgrim Station intake screens during January-December 1993. The annual collection rate was 0.97+ invertebrates/hour. Ctenophores and sevenspine bay shrimp (*Crangon septemspinosa*) dominated, being captured in greatest numbers in March and April, respectively. Sevenspine bay shrimp, rock crabs (*Cancer irroratus*) and American lobster (*Homarus americanus*) represented 19.9+, 17.1% and 13.9%, respectively, of the total invertebrates enumerated. Unlike the fishes, the 1987 and 1988 invertebrate impingement rates were comparable to 1985, 1986, and 1989 - 1993 despite relatively low circulating water pump capacity available in 1987 and 1988.

A noteworthy occurrence was the collection of so many blue mussels during 1986-1989. This could be an effect of the Pilgrim Station outage during the late 1980s (reduced power level in 1989) which precluded the use of regular thermal backwashes for macrofouling control, and the migratory/adhesive

Table 7. Monthly Means of Intake Temperature (°F) Recorded During Impingement Collections at Pilgrim Nuclear Power Station, 1984-1993

Month	Year										(X̄)
	1993	1992	1991	1990	1989	1988	1987	1986	1985	1984	1984-1993
January	37.36	36.34	37.56	38.45	38.42	36.80	38.42	35.97	35.61	33.55	36.81
February	32.21	34.32	36.70	38.15	42.97	36.00	38.71	34.98	33.40	36.08	36.36
March	35.24	36.53	39.72	37.87	38.43	36.20	40.70	37.18	37.84	37.62	37.77
April	41.16	43.42	44.46	46.63	41.37	41.30	*	44.98	41.85	*	43.96
May	48.33	51.56	53.79	50.86	48.70	48.79	*	48.84	50.55	*	50.17
June	52.70	54.21	60.09	53.63	57.38	50.21	56.68	56.11	56.31	*	55.25
July	56.78	55.94	61.67	61.24	61.57	52.83	63.00	61.51	58.96	67.00	60.05
August	53.66	60.40	58.49	64.71	59.80	58.75	*	63.29	63.44	64.62	60.79
September	50.55	57.42	58.63	63.35	58.62	56.86	58.21	58.26	63.74	60.91	58.67
October	43.96	53.83	52.00	55.13	53.92	52.31	52.73	58.58	57.75	55.88	53.61
November	39.97	50.85	47.88	47.88	45.60	47.17	47.49	52.23	52.01	45.71	47.67
December	34.53	43.06	41.74	42.86	35.58	38.90	41.30	44.00	42.44	42.30	40.66
Mean											48.48

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

Table 8. Monthly Impingement For All Invertebrates Collected From Pilgrim Station Intake Screens, January-December 1993

Species	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals
Ctenophore			*										*
Sevenspine bay shrimp	19	28	57	*	1							25	130+
Rock crab	4	1			2	2	2	1	4	36	27	33	112
American lobster	1		1	2	26	11	7	11	8	11	9	4	91
Horseshoe crab					39	21	11	4	1				76
Green crab	7	1	1	3	7	7	9	7	4	5	11	10	72
Common starfish		1	1		1	1				2	25	24	56
Nereis spp.	10	10	5	3							1	21	50
Longfin squid					2	6	5	4	5	5	1		28
Nemertea	9			2									11
Polychaeta		7											7
Green seau chin										2	1	3	6
Lady crab						1				3	1		5
Isopoda				1			1					1	3
Nematoda	3												3
Arctic lyre crab												2	2
Asterias temera												2	2
TOTALS	53	48	65+	11+	78	49	35	27	22	64	77	125	654+
Collection Time (hrs.)	66	47	54	27	25	60	59	56	61	89	62	67.5	673.5
Collection Rate (#/hr.)	0.80	1.02	1.20+	0.41+	3.12	0.82	0.59	0.48	0.36	0.72	1.24	1.85	0.97+

* Undetermined numbers

abilities of mussels. In 1990 - 1993 several thermal backwashes were performed and blue mussel impingement was minor for those years. During 1993 aggressive biofouling control activities included three effective thermal backwashes during the months of April, June and November.

Rock crabs were the third most abundant invertebrate impinged, peaking in October-December. Ninety-one specimens of the commercially important American lobster were captured in 1993, ranking them fourth. This equals 1,184 lobsters impinged on an annual basis at 100% operation of Pilgrim Station, under conditions at the times of impingement. This is comparable to 1991 and 1992, and is a much larger number of lobsters impinged than in most previous years. The lobsters ranged in size from 25-77 mm carapace length.

Approximately 8,029 pounds of mixed algae species were collected during 1993 impingement sampling for a rate of 11.9 pounds/hr. This equates to 51 tons of algae annually on Pilgrim intake screens. This rate is considerably higher than the low flow 1984, 1987 and 1988 outage years, and higher than 1989-1992 possibly because of very adverse meterological conditions of high winds and coastal storms, particularly in December.

4.3 Fish Survival

Fish survival data collected in 1993 while impingement monitoring was conducted are shown in Table 9. Static screen wash collections provided the greatest numbers of fishes and revealed an overall survival rate of approximately 57%. Fishes collected during continuous screen washes fared much better showing a survival rate of 88%. The relatively high initial survival rate for static screen washes, compared with most years previous to 1991, was influenced by the high initial survival of Atlantic silverside which

Table 9. Survival Summary for the Fishes Collected During Pilgrim Station Impingement Sampling, January-December 1993. Initial Survival Numbers Are Shown Under Static (8-Hour) and Continuous Wash Cycles

Species	Number Collected		Number Surviving (Initial)		Total Length (mm)	
	Static Washes	Cont. Washes	Static	Cont.	Mean	Range
Rainbow smelt	205	530	40	490	124	70-291
Atlantic silverside	506	214	370	181	99	67-137
Winter flounder	59	31	51	28	97	43-322
Alewife	30	22	4	9	111	62-265
Grubby	27	24	25	23	71	38-130
Lumpfish	18	18	9	18	52	36-101
Atlantic tomcod	19	7	7	7	133	51-207
Blueback herring	23	2	3	2	85	65-108
Tautog	10	13	8	12	66	48-97
Atlantic herring	6	4	2	3	125	37-272
Little skate	10	0	10	-	464	330-507
Windowpane	5	5	3	5	148	58-301
Northern pipefish	2	7	2	3	145	106-188
Rock gunnel	1	8	0	5	87	68-110
Cunner	8	0	4	-	92	48-165
Hake spp.	8	0	3	-	84	62-188
Pollock	5	1	1	0	128	67-390
Red hake	5	1	0	0	136	80-197
Atlantic cod	3	1	0	1	124	87-150
Atlantic menhaden	3	1	2	1	213	95-328
Northern searobin	4	0	4	-	215	210-223
Radiated shanny	1	3	1	2	84	67-112
Threespine stickleback	2	2	0	2	54	37-60
Silver hake	3	0	1	-	254	210-285
Blackspotted stickleback	2	0	2	-	43	42-43
Pearlside	2	0	0	-	50	49-50
Striped killifish	2	0	1	-	80	68-92
Butterfish	1	0	0	-	94	94
Fourspot flounder	1	0	1	-	321	321
Mummichog	0	1	-	1	98	98
Northern puffer	1	0	1	-	80	80
Scup	1	0	0	-	90	90
Shorthorn sculpin	1	0	0	-	220	220
Spiny dogfish	1	0	1	-	910	910
Spot	1	0	1	-	101	101
Striped cusk-eel	0	1	-	0	130	130
Striped searobin	0	1	-	0	52	52
Yellowtail flounder	0	1	-	1	58	58
All Species:						
Number	976	898	557	794		
(% Surviving)			(57.1)	(88.4)		

were impinged in abundant numbers. As illustrated in 1993, fishes have a noticeably higher survival rate during continuous screen washes because of reduced exposure time to the effects of impingement. However, reduced intake currents in 1984, associated with limited circulating water pump operation, may have been a factor in higher static wash survival then because of less stress on impinged individuals; although this wasn't apparent from 1987 and 1988 limited pump operation results.

Among the ten numerically dominant species impinged in 1993, eight demonstrated initial survival rates of 50% or greater. Grubby showed 94% survival, winter flounder 88%, tautog 87%, Atlantic silverside 77%, lumpfish 75%, rainbow smelt 72%, Atlantic tomcod 54%, Atlantic herring 50%, alewife 25%, and blueback herring 20%. Some of these relatively high survial percentages may be explained by the large proportion of fish that were sampled during continuous screenwashes at the time of the large fish impingement incident in December.

SECTION 5

CONCLUSIONS

1. The average Pilgrim collection rate for tne period January-December 1993 was 2.78 fish/hour. The impingement rates for fish in 1984, 1987 and 1988 were several times lower than in 1985, 1986 and 1989 - 1993 because of much reduced circulating water pump capacity during the former years.

2. Thirty-eight species of fish were recorded in 673.5 impingement collection hours during 1993. In 1985, 1986 and 1989 - 1993 several times the number of fishes were sampled as compared to 1984 and 1988, despite more collection hours in 1984 and an average number of hours in 1988. This illustrates the importance that the number of circulating pumps operating has on the quantity of impinged organisms. Substantially less collecting hours for portions of 1987 precluded its comparison with other years.

3. At 100% yearly operation the estimated maximum January-December 1993 impingement rate was 24,375 fishes (512 lbs.). This projected annual fish impingement rate was several times higher than 1992 at Pilgrim Station because of a large impingement incident of primarily rainbow smelt in December.

4. The major species collected and their relative percentages of the total collections were rainbow smelt, 39.2%; Atlantic silverside, 38.4%; winter flounder, 4.8%; alewife, 2.8%; and grubby, 2.7%.

5. The peak in impingement collections for rainbow smelt occurred during the December 15-28 fish impingement incident. Rainbow smelt hourly impingement rate per month varied from 0 to 9.9.

6. Monthly intake water temperatures, which generally reflect ambient water temperatures, were mostly colder during 1993 than the ten-year monthly averages for the period 1984-1993. The only exception to this was January when mean water temperatures were higher than the ten-year average.

7. The hourly collection rate for invertebrates was 0.97+. Ctenophores and sevenspine bay shrimp dominated because of large March and April collections, respectively. Rock crabs and American lobsters were 17.1 and 13.9% of the catch. Ninety-one American lobsters were collected which equates to a potential 1993 impingement of 1,184 lobsters.

8. Impinged fish initial survival was approximately 57% during static screen washes and 88% during continuous washes for pooled species. Of the ten fishes impinged in greatest numbers during 1993, eight showed initial survival rates of 50% or greater.

SECTION 6

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SUMMARY REPORT:
FISH SPOTTING OVERFLIGHTS
IN WESTERN CAPE COD BAY
IN 1993

Prepared by: ________________________
Robert D. Anderson
Principal Marine Biologist

Licensing Division
Boston Edison Company

April 1994

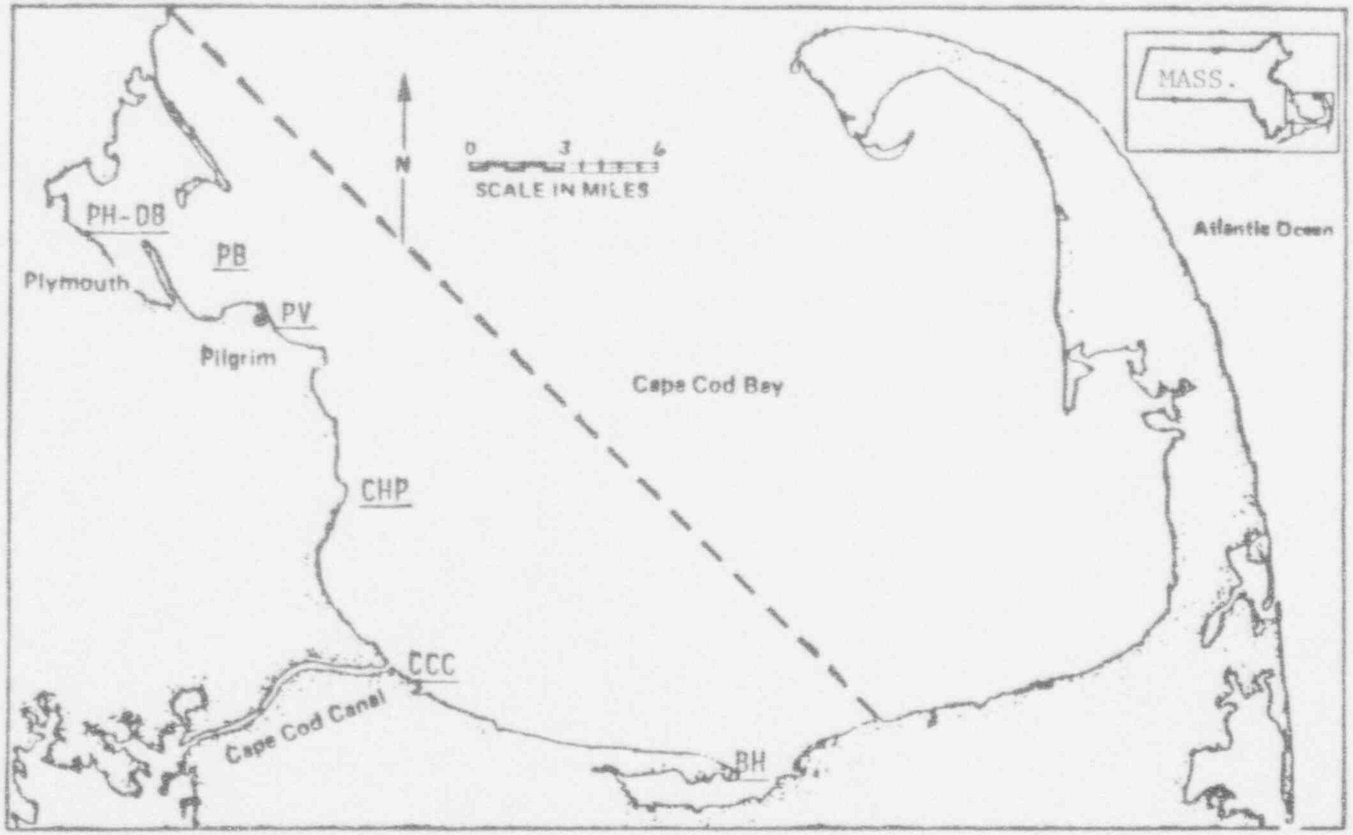
SUMMARY REPORT:
FISH SPOTTING OVERFLIGHTS IN
WESTERN CAPE COD BAY IN 1993

Weekly fish spotting overflights were made north, south and in the vicinity of Pilgrim Nuclear Power Station (PNPS) from March-November 1993. Four main groupings of fish were noted by the overflight pilot who was trained to spot fish for commercial fishing operations. The four groupings are: 1) herring, consisting primarily of Atlantic herring (Clupea harengus), alewife (Alosa pseudoharengus) and/or blueback herring (Alosa aestivalis); 2) Atlantic menhaden (Brevoortia tyrannus); 3) Atlantic mackerel (Scomber scombrus); and 4) baitfish, consisting primarily of any species too small to identify but most likely being composed of Atlantic silverside (Menidia menidia), rainbow smelt (Osmerus mordax), sand lance (Ammodytes spp.) or the juveniles of other species. In addition, sightings of other marine species, such as bluefish (Pomatomus saltarix) or whales (Cetacea), are occasionally reported.

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

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

Figure 1. FISH SURVEILLANCE OVERFLIGHTS
(Critical Area)



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

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

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

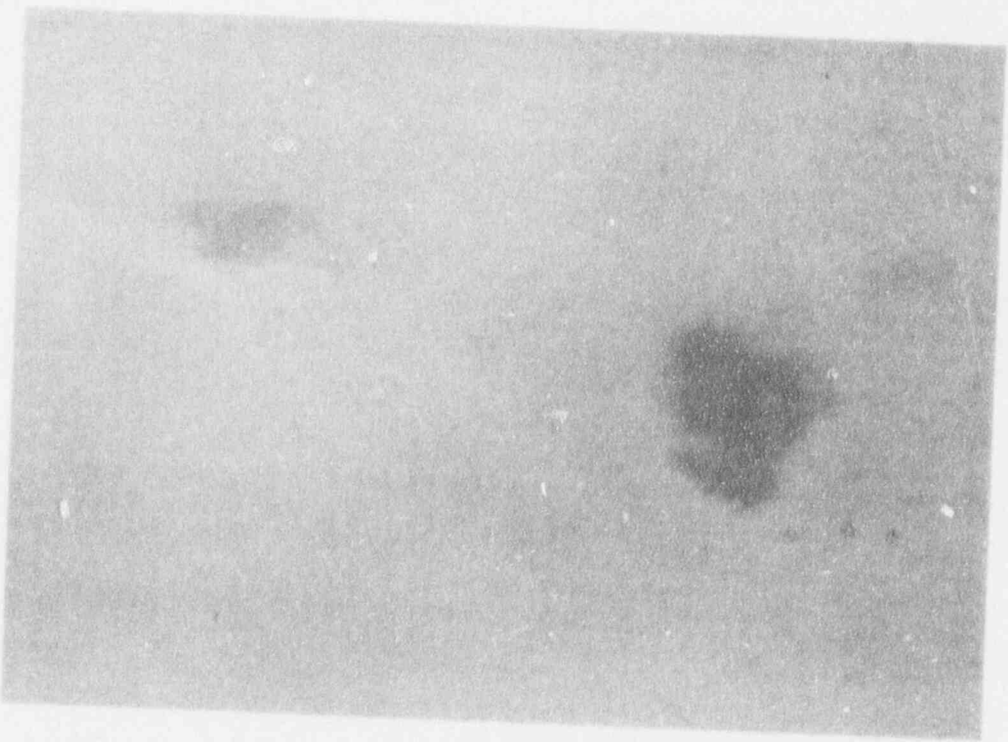


Plate 2. A fish school appears as a dark shadow from the airplane, and it takes an experienced pilot to distinguish its composition from submerged objects.

Boston Edison Company and regulatory personnel of the potential for a discharge-related fish mortality.

Table 1 summarizes location, approximate poundage and seasonal information for the four groupings of fishes defined above. Below are some interpretive comments based on general trends illustrated by fish observation data for the four predominant fish groups from March-November 1993:

1. Herring - This is a mixed species category, but the majority of pounds of herring observed by fish overflights represents Atlantic herring as borne out by commercial catch statistics. This species was in the Cape Cod Bay region during most of the observation period, primarily north and south of PNPS. The alewife and blueback herring were not spotted throughout Cape Cod Bay; late April - mid May they are normally on spawning migrations. All of the herring observed were Atlantic herring with a number of sightings of them during 1993 in the vicinity of PNPS. Four observations of Atlantic herring within a few miles of PNPS were made during 1993, including 185,000 pounds on August 22. No fish mortalities occurred, although in November 1976 over 10,000 Atlantic herring were killed by impingement on PNPS intake traveling water screens.

2. Atlantic Menhaden - This species is of concern at Pilgrim because of past gas bubble disease mortalities in the discharge canal and thermal plume. As can be seen from Table 1, menhaden may occur over the entire Cape Cod Bay region in millions of pounds from spring through early fall. Overflight pilots are particularly adept at

TABLE 1. Approximate Location, Relative Species Poundage and Seasonality from Fish Observation Overflights in the Western Cape Cod Bay Area in 1993

LOCATION	SPECIES	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER
North of Pilgrim	Herring		20,000		200,000	170,000			55,000	
	Menhaden			3,090,000	535,000	458,000	567,000	582,000	47,000	
	Baitfish									
	Mackerel			20,000		3,000			65,000	2,000
Pilgrim Vicinity	Herring						275,000		105,000	
	Menhaden			60,000	40,000					
	Baitfish									
	Mackerel									
South of Pilgrim	Herring			10,000	60,000	30,000			30,000	300,000
	Menhaden			1,975,000	830,000					
	Baitfish					20,000	20,000			
	Mackerel		50,000	20,000				3,000,000	30,000	
Totals	Herring		20,000	10,000	260,000	200,000	275,000	582,000	190,000	300,000
	Menhaden			5,125,000	1,405,000	458,000	567,000		47,000	
	Baitfish					20,000	20,000			
	Mackeral		50,000	40,000		3,000		3,000,000	95,000	2,000

* Regulators notified (EPA/DWPC).
\+ Unestimated poundage.

identifying this species as commercial ventures depend heavily on accurate observations for success. The first menhaden north of Cape Cod in 1993 were observed on May 8 between Duxbury Beach and the Cape Cod Canal. The great majority of menhaden were sighted north of PNPS from May through October. Menhaden were spotted in the PNPS vicinity on May 8 (60,000 pounds) and June 8 (40,000 pounds). Regulatory agencies (EPA and Mass. DWPC/DMF) are notified when fish are within 1/2 mile of the point of thermal discharge into Cape Cod Bay. The last menhaden observed in 1993 were 47,000 pounds in the Duxbury Bay/Plymouth Harbor area on October 6.

3. Atlantic Mackerel - These fish support a valuable commercial fishery and were reported frequently both north and south of PNPS. In 1993, there were several observations made of Atlantic mackerel schools from May - November with largest quantities seen in September. There were no sighting dates close to PNPS.

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

4. Baitfish - This category is a catchall and may include large numbers of small unidentified fish. On July 16 and August 22 several thousand pounds of sand lance were seen a few miles north of the Cape Cod Canal. Sand lance, as well as most species in this grouping,

regularly inhabit the PNPS intake area in numbers too small to be seen by overflights but recorded during past seine net sampling from the intake beach.

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

5. Other - There were several other spottings made in 1993 which fall outside the above categories. Included were bluefish, finback whales, striped bass, bluefin tuna, ocean sunfish, seals and basking sharks. Those species seen in the proximity of PNPS included striped bass in June; ocean sunfish in July; and bluefish in July and August.

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

PHILIP G. COATES
DIRECTOR

MEMORANDUM

888-1155

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 80th meeting of the Pilgrim Administrative-Technical Committee

DATE: October 6, 1993

The 80th meeting of the Pilgrim Administrative-Technical (A-T) Committee was called to order by Chairman Szal (DWPC) on September 28, 1993 at 10:10 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 79th Meeting

There were no additional comments on the previous A-T meeting minutes. The minutes were accepted unanimously.

II. Pilgrim Station Status Update

Bob Anderson mentioned that Pilgrim Station operated at about 66% capacity through August 1993, even with the April/May refueling outage. Pilgrim Station will plan the next mid-cycle outage for April, which will fortuitously lessen potential entrainment impact of winter flounder larvae. BECo is attempting to eventually phase out these mid-cycle outages. Hydraulic dredging of the plant's Intake embayment is possible for spring 1994, with all permits obtained. Repair of the Intake breakwater and Discharge jetty is budgeted and may occur by September 1994 so that the planned thermal plume study can be undertaken. The discharge barrier net is still intact and functioning despite the proximity of boulders from the damaged jetty. A discussion of thermal backwashes then ensued.

III. 1994 Benthic Monitoring Program

Don Miller stated that the Benthic subcommittee recommends (1) the continuation of the quarterly qualitative SCUBA surveys at Pilgrim and (2) the six-week special discharge plume bottom contact study for September 1994. The latter will be rebid, assuming the planned discharge jetty repairs occur. After the plume data are analyzed, the A-T Committee then can consider monitoring efforts, if any, beyond the SCUBA observations. A motion to accept these recommendations passed unanimously.

IV. 1994 Marine Fisheries Monitoring

Bob Lawton mentioned that the upcoming workshop to evaluate the fisheries monitoring efforts will be held in Narragansett in January 1994, with all Committee members welcome. The review panel will consist of UMASS Amherst Professors Jack Finn, John Boreman, and Frances Juanes, along with Linda Birely of Northeast Utilities and Saul Saila of URI. Money has been budgeted for two days per panelist, a day for data/report review and a day for the meeting. The Fisheries subcommittee will ask the panelists to evaluate the monitoring efforts at Pilgrim Station - are efforts directed at pertinent questions? - are the right methodologies being utilized? - are further studies necessary?

The lobster study will terminate this year unless some measurable impact is found. Bob Lawton and Martha Mather distributed copies of the DMF fisheries proposal and the adjunct preliminary draft of the UMASS cunner reproduction/recruitment proposal.

DMF studies will concentrate on cunner and winter flounder, which may be adversely impacted by entrainment. The main questions that will be investigated for cunner in the Pilgrim area are: (1) their age-specific fecundity, (2) size estimate of the population, and (3) what are the sources/fates of cunner eggs and larvae? Martha explained what UMASS proposed to do with a graduate student to accomplish these objectives, mainly through a fecundity study and mapping of habitat types/larval recruitment. Leigh Bridges thought the scope of the UMASS proposal needed to be redefined; Martha and Bob Lawton agreed to rethink what is achievable in a two-year study period for cunner. Don mentioned fishing mortality on cunner at Pilgrim should be considered in the overall picture.

For winter flounder, DMF will estimate population size through both an area swept approach and a tag-recapture method. Bob Lawton noted that MRI will do the Adult Equivalency Analyses again for winter flounder and cunner. DMF personnel then left the room while the Committee discussed the proposals. A motion was made to accept (1) running the January fisheries panel workshop, (2) proposals of both DMF and UMASS, to which, subject to A-T approval, modest changes in the scope of work may occur based on input from the workshop review. The motion passed unanimously.

V. 1994 Impingement/Overflight Monitoring

Bob Anderson touched on impingement/overflight monitoring at Pilgrim. The motion was made to continue the present impingement sampling schedule of three times per week, which passed unanimously. A discussion ensued concerning the utility of the overflights. A motion was made that BECo can do the overflights at their disgression, but that the A-T Committee did not recommend continuation of this effort; the motion passed.

VI. 1994 Entrainment Monitoring

Bob Anderson commented on entrainment monitoring at Pilgrim. The Fisheries subcommittee had recommended continuing the present entrainment sampling scheme but changing the entrainment notification levels to the mean $\pm$ 2 standard deviations for species of concern (their eggs and larvae) and $\pm$ 2.5 standard deviations for other species and to modify the contingency sampling plan. Carolyn Griswold made a motion to accept these recommendations, which passed unanimously.

VII. Other Business

Nick Prodoni may replace Ted Landry on the TAC after Ted retires; Gerry Szal will confirm this. A motion was made that the Committee recommend the same NPDES Marine Ecology Program contractors for next year's work in order to maintain the integrity of the Pilgrim historical database; this motion passed unanimously.

The Committee pursued the idea of a multi-year/final report being published in book form to update and expand the original western Cape Cod Bay monograph. Bob Anderson will look into sources of funding from the utility industry to aid in publishing costs. A monograph subcommittee was formed of Bob Lawton (chair), Bob Anderson, Leigh Bridges, Martha Mather, Carolyn Griswold, and Jack Parr.

Jack Parr initiated a discussion on the shortcomings of present regional power plant monitoring efforts. Jack proposed a future brainstorming meeting to prioritize objectives. New England regulators could discuss the future of 316a & b permitting programs. He suggested that regulators evaluate resources being consumed by utilities and the possibility of leveling a pooled assessment fee for all dischargers to be used for environmental studies. This is done presently in North Carolina. Bob Anderson suggested such a meeting include utility biologists.

VIII. Adjournment

The meeting adjourned at 2:15 PM.

Pilgrim Administrative-Technical Committee Meeting Attendance

September 28, 1993

Gerald Szal, Chairman	Mass. DEP, Grafton
Don Miller	EPA, Narragansett
Carolyn Griswold	NMFS, Narragansett
Robert Anderson	BECo, Braintree
Robert Lawton	Mass. DMF, Sandwich
Leigh Bridges	Mass. DMF, Boston
Jack Parr	EPA, Lexington
Martha Mather	Mass. Coop. Fish Unit, UMASS, Amherst
Brian Kelly	Mass. DMF, Sandwich (recording secretary)

Pilgrim Advisory_Technical Committee
October 5, 1993

Gerald Szal, Chair 508-792-7470
Robert Maietta
Office of Watershed Management
P.O. Box 116, 40 Institute Road,
No. Grafton, MA 01536-0116

Robert D. Anderson 617-849-8935
Boston Edison Company
25 Braintree Hill Office Park
Braintree, MA 02184

Robert Lawton 508-888-1155
Brian Kelly (recording secretary)
Mass. Div. Marine Fisheries
18 Route 6A
Sandwich, MA 02563

W. Leigh Bridges 617-727-3194
Mass. Div. Marine Fisheries
State Office Building
100 Cambridge Street
Boston, MA 02202

Rick Zeroka 617-727-9530
Mass. CZM
20th Floor
100 Cambridge Street
Boston, MA 02202

Jack Parr 617-860-4604
U.S. EPA
New England Regional Lab
Surveillance and Analysis
60 West View Street
Lexington, MA 02173

Dr. Michael Scherer
Marine Research Inc.
141 Falmouth Heights R[illegible]
Falmouth, MA 02540

Dr. Don Miller 401-78[illegible]-3090
Environmental Protection Agency
Environmental Research Lab
27 Tarzwell Drive
Narragansett, RI 02882

Dr. Jan Prager 401-782-3090
Environmental Protection Agency
Environmental Research Lab
27 Tarzwell Drive
Narragansett, RI 02882

Carolyn Griswold 401-782-3273
Natl. Marine Fisheries Service
28 Tarzwell Drive
Narragansett, RI 02882

Ted Landry 617-565-3508
EPA Region 1
Industrial Permits Section
J. F. Kennedy Building
Boston, MA 02203

Dr. Martha E. Mather, Assistant
Unit Leader 413-545-4895
Mass. Coop. Fish & Wld Unit
Holdsworth Hall
U. Mass, Amherst, MA 01003

Other Contacts

Derek McDonald, Marine Biofouling Control Corp. 508-888-4431
Dr. James Blake, SAIC, 89 Water St., Woods Hole 02543 508-540-7882